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Modelling disaster risk reduction: decoding social-ecological interactions to foster transformative adaptation

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“To learn and innovate,
systems must be open and tolerant of failure.”
(Lance H. Gunderson et al., 2006)

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Abstract

The present research intends to contribute to the discussion concerning disaster risk reduction, especially applied to the question of how to assist the adjustment and renovation of the development path of local communities in relation to the surrounding pressures and threats.

In particular, a first part was devoted to exploring the adaptation of the panarchy heuristics to the factors and dynamics of risk. In particular, it was possible to draw a theoretical model, the Social-Ecological Panarchy, that could describe the conditions of risk and allow to identify the two *cores* of disaster risk reduction, that are disaster resilience and environmental sustainability. Then, the model served as a base for the development of a methodology for a Combined Assessment of Resilience and Sustainability. The applications focused on flood risk, a rising concern at an international level also as a consequence of the ongoing environmental changes. Hence, the second part of the research envisaged a quantitative investigation through numerical indicators that allowed to identify the levels of resilience and of sustainability, as well as of their combination. In this case, the conditions of two case studies, the Marche Region (Italy) and Hokkaidō (Japan) could be evaluated at a Municipal scale. Following, the third part of the research mirrored the quantitative analysis employing qualitative tools, namely questionnaires, in order to gather the thoughts of local communities on the dynamics of risk occurring in their Municipalities. In this case, the methodology was applied to six case studies within the Esino river basin of the Marche Region (Italy).

Results evidenced the significant role performed by the impact of extreme flood events in determining the resilience capacities of local communities, and by the anthropic alterations of the ecosystems for defining their sustainability. At the same time, elements related to social welfare and protection appeared pivotal in building local resilience, as much as the presence and extension of vegetation, both natural and cultivated, shape sustainability. In any case, most critical issues were found to lie in the mountainous and hill areas. From the standpoint of local populations, it emerged a substantial mismatch between assessed and perceived conditions of resilience and sustainability, with a general trend towards more pessimistic perspectives.

In general, it appeared that further efforts should be tailored to the innermost areas, although the overall region might benefit from strategies to raise awareness and consolidate resilience capacities. At the same time, local populations seemed highly responsive to environmental issues, suggesting a potential endorsement of the enhancement of sustainability capacities. Eventually, insights of this kind might be integrated into risk reduction strategies, in the perspective of an urgent transformative adaptation of local communities urged by exacerbating disruptive threats.

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i. Introduction

The world we inhabit is complicated, from a multitude of viewpoints. From the very beginning of human history, men have strived to satisfy their basic needs, in the face of threating menaces. The more efficient they got in collecting resources and coping with threats, the more development paths that could be explored. Indeed, when the basic needs are satisfied, there is space for the luxury of curiosity and of triviality. Thence, unessential desires could arise, as well as could be satisfied. Either more attention was dedicated to abstract concepts or material trifles, the consequence was still a humankind becoming estranged from the natural environment, often positioning itself on a different, usually superior level compared to nature. At the same time, at the very core, a fundamental challenge persisted unaltered until these days: the strife to survive. In particular, the survivability of humankind is still inevitably bound to the interrelation of humankind with the natural environment. Indeed, human life is sustained by the fundamental resources that natural ecosystems provide: although they might be easily taken for granted, basic services such as air, water, food, they are all delivered by natural processes (Millennium Ecosystem Assessment, 2003b) and they still do not find an equivalent in human capacities. At the same time, human assets might be overwhelmed by the formidable energy that natural phenomena express. Floods, droughts, storms have been affecting the widest portion of global population in the last two decades (CRED & UNDRR, 2020), thus representing a significant element of concern for humankind, along with the other threats, known and unknown, that might occur. As a consequence, when discussing the path that should be undertaken in order to project the survivability of humankind in the long term, it is not sufficient to either focus on the benefits or on the menaces posed by occurring phenomena: it is necessary to identify a path that fosters both resilience to disasters and sustainability of processes, at the same time and with the same magnitude. As we progress through potentially unpredicted environmental changes and the evolution of human communities is still uncertain, it urges an integrated perspective on the possible strategies to enact in order to enhance an effective coexistence between humankind and the natural environment. Indeed, the awareness of the inextricable interplay between maintaining human communities and valuing ecosystem services is consistently growing (Collier et al., 2013). Nevertheless, those two domains of research and advancement are still often maintained separated if not in contrast, especially during the designing processes of urban settlements, thus precluding an integrated planning as well as the ignition of positive synergies (Cariolet et al., 2016). Against this background, a fundamental year was marked by 2015, when the United Nations endorsed two epitomising frameworks of intentions. Few months apart, the “*Sendai Framework for Disaster Risk Reduction 2015-2030*” (UNDRR, 2015) and the “*Transforming Our World: The 2030 Agenda for Sustainable Development*” (UN, 2015) were made public and stated the strategies that the international endeavours fostering human development should be harmonised to. In particular, the Sendai Framework came as a renovation and advancement of the resolves of the Hyogo Framework of Action (UNDRR, 2005), leading international efforts towards reducing disaster risk through the understanding of disaster dynamics and the implementation of appropriate measures to cope with and respond to adverse events. The focus is on inhibiting the conditions that induce disasters, either addressing existing critical issues or preventing the creation of new ones, broadening the range of engaged stakeholders as well as the domains of concerns. At the same time, the Agenda 2030 built on the previous international discussions and agreements to identify a series of thematic objectives to be achieved, that together compose a multifaceted path to promote human wellbeing in terms economic, social and technological capacities, along with the preservation of natural assets. It is remarkable that in both documents a consistent cross-reference emerges evidently, delineating a common goal of sound coexistence between humankind and the natural environment, a common acknowledgment that achieving one is inherently dependent with the other. This standpoint underpins a fundamental concept: humans and nature are not separated entities, but rather form an interconnected, complex system, that might be addressed as a Social-Ecological System (Berkes & Folke, 1998). This terminology was introduced with the intention to emphasise the idea of "*humans-in-nature*", evidencing that the interrelation is so deep rooted that the boundary between what is "human" and what is "natural" is essentially volatile, if not artificial and arbitrary (Folke, 2006; Folke et al., 2010). Indeed, Social-Ecological Systems are not just social systems, nor just ecological systems, nor a simple juxtaposition of a social and of an ecological system. These complex systems envision a multitude of driving forces: apart from the powerful determinant exerted by human intend and foresight (L. Gunderson, 2010), controlling variables might have different scales and timing of action on the two sides (B. Walker et al., 2006), translating in significant nonlinearity of response as well as potential surprise effects where the inner dynamics are not thoroughly understood (Jianguo et al., 2007). Indeed, when coming to the management of complex systems, optimising the efforts to strengthen one side of the complex system easily triggers detrimental effects for the other side (Folke, 2006). In other words, when the evolution of a system is moulded by the unceasing interplay and constant feedback loops unravelling between human and natural components, the resulting Social-Ecological System must be necessarily considered as a whole, without disregarding either component, otherwise the probability to fail in accounting for fundamental traits and behaviours might become guiltily high.

The *objective* of the present research lies in this central nucleus, that is to contribute to the understanding of human-nature interactions and to support a sounder coexistence, through the enhancement of disaster resilience and environmental sustainability, towards the adaptation and the transformation of human communities to the natural environment. This aim assumes a fundamental tenet, that is embracing change in order to maintain a system (Folke et al., 2010). Although this might appear counter-intuitive, it has already been acknowledged that the persistence of a Social-Ecological System necessarily entails adapting and transforming in response to the surrounding drivers of change (B. Walker et al., 2004). These two approaches refer to different strategies that a system might adopt. Indeed, "*adaptation*" implies shaping the present system and accommodating it to external or internal pressures, whereas "*transformation*" implies a fundamental reframing of the system in order to better cope with those drivers (B. Walker et al., 2004). In other words, a system might either introduce some adjustments within the existing development trajectory or reorganise itself in order to cross into a new development trajectory (Lovell & Taylor, 2013). Nevertheless, as it is not possible to identify a solution that might fit any potential scenario, the persistence of a Social-Ecological System appears contingent to the possibility to rearrange either superficially or deeply as necessary, that is the ability to foster a transformative adaptation to external and internal drivers of change.

In a nutshell, the present discussion explores the theme of reducing the risk of disasters, wandering through the possible ways of strengthening the inner structure of the complex system defined by human and natural components and of inhibiting the possible paths of mutual destruction. Indeed, such a comprehensive approach is suggested from the very definition of disaster risk reduction as strategies and plans "*aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development*" (UNDRR, n.d.-c). As a consequence, the present research embraces the disaster risk reduction approach to the widest extension, that is as an effective holistic standpoint to comprehend and foster the interaction of humans and nature within complex Social-Ecological Systems.

ii. Research overview

Before delving in the exploration of the concepts and questions surrounding the matter of reducing disaster risk, it might be significant to begin from the core of this matter, that is disasters. In other words, before investigating how to reduce their occurrence, it might be beneficial to address their actual essence. The leading authority in this field is recognised as the United Nations Office for Disaster Risk Reduction (UNDRR). The definition that it provides states a disaster as a "*serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts*" (UNDRR, n.d.-a). In this definition a multifaceted problem is presented, where not only both human and natural elements interact, but they also can constitute either triggering or susceptible components. When disaster risk is considered as the potential occurrence of such jeopardising disruption (UNDRR, n.d.-b), it becomes fundamental to trace the basic factors of risk, and thence of disaster. The facets envisioned in the above mentioned definition were indeed effectively summarised in the commonly accepted formula of risk (Eq. 1):

$$\mathrm{R} = \mathrm{H} * \mathrm{E} * \mathrm{V} \tag{1}$$

where risk (R) is identified as the combination of hazard (H) and of exposed (E) as well as vulnerable (V) entities (Varnes, 1984). In spite of being a simplification, the formula well shows how the only place where a risk might be manifested is at the interface between threatening forces and susceptible elements. In particular, an hazard represents the process that by unravelling might negatively impact a system, whereas exposed is that system located in an area prone that impact, vulnerable is that same system when it might be suffer damages (UNDRR, n.d.-d).

In general terms, the comprehension and management of multidimensional matters significantly rely on the possibility to simplification. Discussions concerning disaster make no exception to this general paradigm. Consequently, a manifold of models were developed (Elkin, 2014). For instance, in the 1980s, the Comprehensive Emergency Management (CEM) model was proposed. It rapidly gained a sound approval and it continues to constitute a funding paradigm, as it envisions four pillars of emergency management, that are: mitigation, preparedness, response and recovery. In other words, within the CEM model the focus revolves around the strike of a hazard. Hence the aim is to prepare resources and perform procedures in all the phases surrounding a disaster. A particular and operative consequence of an effective CEM could be considered the activation of the Incident Command System (ICS): when a risk materialises, exerting dire costs on a community, the ICS provides a standardised set of procedures and hierarchies to manage the ongoing emergency, intended to favour the integration of different actors within a common framework, promoting the optimisation of resources and efforts. Evidently, this kind of organisation requires to be prepared and tested in advance in order to prove successful in times of need, though the systems is designed to be in function from the onset to the resolution of the crisis. Given its operative essence, it might be significant to notice that its origins date back to 1970s, even before the CEM model, when its nucleus formed in military context (Elkin, 2014). Indeed, one of the characterising traits resides in its reliance on a command-and-control system, designed to pursue a specific objective and to be adaptable to different operational situations. Nevertheless, critiques are still rising, especially on the applicability of this practice. Indeed, it has been suggested that ICS might be underestimating the relevant of local conditions and especially the involvement of local communities in the application of the envisioned processes (Buck et al., 2006). A further critique that might be advanced is that both CEM and ICS are focus on the operations dealing with disaster emergency: how to deal with and to overcome it. Nevertheless, the perspective that is currently being internationally endorsed is broader: the essence of disaster risk reduction is indeed to avoid disasters.

A broader conceptualisation was provided by the Pressure And Release (PAR) model (Blaikie et al., 1994), that received prompt appreciation and diffusion. Within this framework, the factors of risk are directly addressed, especially distinguishing between hazards and vulnerability. In particular, attention is devoted to the social, economic and cultural drivers of vulnerability, whose progress is identified into three main components: root causes, dynamic pressures and unsafe conditions. In general terms, the PAR model suggests tackling the side of risk pertaining to the community domain, thus acting on behavioural attitudes of populations. Although this represents a significant integration to the above mentioned CEM and ICS models, it might still be possible to identify some critical points. Indeed, it has been noticed that the PAR model does not adequately consider the issues recognised by the sustainability discourses: for instance, it does not actually provide a comprehensive representation of complex human-natural systems, it does not include an extensive representation of the hazard dynamics as well as it does not envisages the effects of external feedbacks (Turner et al., 2003).

Although the above mentioned models represent a very limited range of the available conceptualisations dealing with disaster risk, it is still possible to evidence how one of the most substantial difficulties, that lead to significant weaknesses on the models, is the adoption of a real comprehensive perspective on the complex relations among humans and nature. Indeed, the reference point when discussing the reduction of disaster risk is undeniably the Sendai Framework for Disaster Risk Reduction (SFDRR), that sets priorities and goals in an international setting for the time perspective of 2015-2030 (UNDRR, 2015). In this case, there is an explicit call for the "*substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries*." (UNDRR, 2015). As a consequence, this, that is the perspective currently finding shared agreement worldwide when investigating the concepts and practices dealing with disaster risk, should be necessarily funded on broad and comprehensive approaches.

In this case, a peculiar though potentially beneficial viewpoint might be provided by ecological models. As, by definition, ecological models are developed in order to portray complex systems, they provide a reliable base for considerations concerning the complex relation of humankind with the natural environment, and the duality of resources and hazard that nature provide and that can be affected by human processes (Burton, 1993). In general terms, ecological models either adopt two major approaches: equilibrium or non-equilibrium. Equilibrium models would tend to avoid disasters at all costs, whereas non-equilibrium models assumes disasters as an integral part of the evolution and development system (Elkin, 2014). In light of this consideration, equilibrium models might still be unable to capture the complex dynamics of change that characterise human-natural systems, alternatively called social-ecological systems. Nevertheless, non-equilibrium models appear to hold a significant potential to contribute to the disaster discourse. Against this background, it seems especially promising and meaningful to explore in depth one of the most appreciated ecological models, that is the *panarchy*.

The panarchy model

Through the adoption of a systems approach, the panarchy model (L. H. Gunderson & Holling, 2002; Holling, 2001) exposes the multidimensional structure and the nonlinear dynamics across space and time that identify a complex system, declined either as an ecological or a social or a coupled social-ecological system (Allen et al., 2014). Nevertheless, the hierarchy that emerges through this application of the systems approach is far from rigid: control is not exclusively exerted by larger components and transformations are not inhibited. Rather, the interactions among sub-systems allow for a continuous mutual influence, hence changes happen at all levels and at any time (Allen et al., 2014). In other words, a panarchy is a complex system constantly evolving due to the exchanges of information and resources within and outside the system. Indeed, this is suggested by the very denomination of the model. Although the term "panarchy" holds a distinctive history, dating back to the mid-19th century (OED, n.d.), Holling and Gunderson renewed the term in its significance through re-evaluating its two halves. Actually, where the first part echoes the Greek god Pan and its creative yet destructive power, the second part sets the actions within a hierarchy that sustains the system in order to allow for experiments and restructuring (L. H. Gunderson & Holling, 2002). As a matter of facts, a panarchy assists in containing and controlling complexity by means of two main features: *adaptive cycles*, that describe the components of the system, and the *interactions*, taking place among such components. It has been observed that within this framework, a complex system might be reduced to a handful of key components, reasonably three to five, while still maintaining the functions and the peculiar response of each component to both internal and external pressures, thence preserving the dynamics that shape the system as a whole (Resilience Alliance, 2010). Similarly to the *adaptive cycles*, also the *interactions* can be reduced to a restricted range of possibilities and still maintain the ability to represent how deeply the components are interlaced throughout the multi-dimensional structure. Hence, a panarchy indeed requires a low number of variables to see through a tangle of deep interdependencies. It might be interesting to draw attention to the potential of this model to provide a solid foundation for both abstract and operational investigations. Even though at a first glance the powerful visualisation of a complex issue that the panarchy provides might lead to limit its application to a mere descriptive function, the panarchy indeed is able to provide a versatile heuristic that might sustain conceptualisations as well as the formulation of operational hypothesis to be empirically verified when studying the dynamics of complex systems (Allen et al., 2014). In other words, even though the first appearance might enthral for the qualitative power of visual representation, also quantitative approaches might extensively benefit from the application of this model (Angeler et al., 2016). In light of the above brief discussion, the panarchy model appears to effectively address the issues and perspectives of this present study. Therefore, before moving on to the discussion about the implications and limits of this model, it might be relevant to spend some more words on the peculiarities of such characterising features.

Adaptive cycle

One of the most apparent features of the panarchy model resides in the expressed intention of embracing change and unpredictability. A further underlying assumption concerns the possible equilibrium of the system: no set singularities of stability, but rather multi-stable states that accept surrounding domains of stability and non-linear responses (Folke, 2006). The intrinsic transformability of a complex system is expressed not only as an overarching characteristic of the system per se, but also as each component of a panarchy is allowed to experiment and change.

That is, the state of each component is not rigidly static: rather, each *adaptive cycle* envisions a series of possible *phases* that succeed and trace the constant occurring renovation. A nested set of *adaptive cycles* forms a panarchy: each *adaptive cycle* represents a specific spatial scale, while the inner *phases* take into account the temporal scale of change. In this way, the *adaptive cycles* mirror the description of a multi-scale and multi-dimensional hierarchy on their own. Furthermore, as well as different *adaptive cycles* address components of different dimensions, they also reproduce different rates of change, where larger components hold a higher inertia towards change, whereas smaller components are more prompt to experiment new states (Holling, 2001).

Regardless of their scale, though, the *adaptive cycles* share a similar dynamic of change. As previously mentioned, in this case transformability is interpreted through four main *phases*: reorganisation – exploitation – conservation – release (Fig. 1.1).

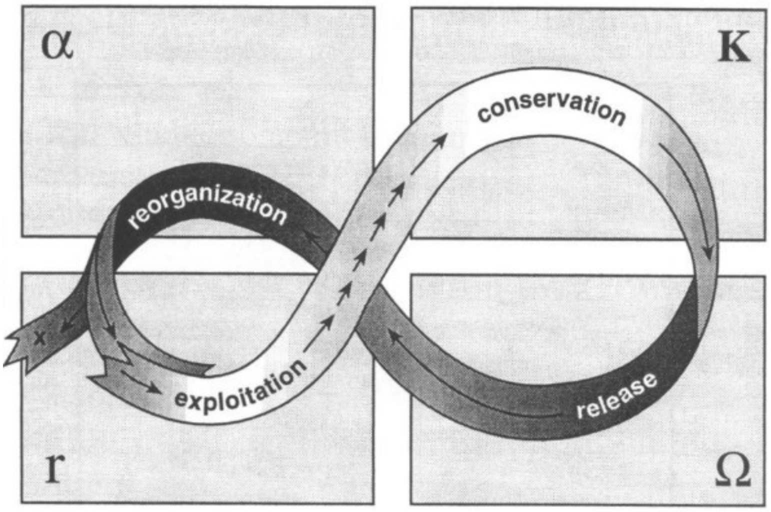


Figure ii.1 — The adaptive cycle and its four main phases: reorganisation, exploitation, conservation, release (Holling, 2001).

These *phases* depict the growth, crisis and recovery of the potential and availability of a component of the system (that might be considered as a *sub-unit* of the complex system) towards change. The same shape of the *adaptive cycle*, that resembles the mathematical symbol for infinite, suggests the idea that the cycle is never-ending. A *phase* always follows an other, with slower processes that build up the conditions for abrupt turns to eventually take place: the *sub-unit* might come back to a structure similar to the previous one or, on the contrary, take advantage of the incurred condition of "*creative destruction*" (Holling, 2001, p. 395) to experiment and craft anew its architecture. That is, the internal dynamics of a *sub-unit* eventually open some "windows of opportunity" for novelty. In any case, either those windows are explored or not, the *sub-unit* will eventually undertake a path of development, moving from the previous condition of collapse. The meaning of the *phases* is epitomised by the symbols that represent each of them (Fig. 1.1). The reorganisation and the release *phase* take inspiration from the Greek alphabet: they are α and Ω, the beginning and the ending, the rise and the fall. The development path commences when the *sub-unit* reorganises (α) the structure and copes with the crisis of the fundamental functions induced by the previous collapse. A collapse that eventually will happen again, when the path approaches once more the point that triggers the release (Ω) of the accumulated weight in terms of rigidities and constrains. What happens to the development path between these two extremes is then described by the two other *phases*: r and K. In this case, the roots of the model find their echo. As a matter of facts, the symbols recall a heuristic that sparked discussion in the field of Evolutionary Ecology, concerning the development behaviour of population and providing a predictive paradigm (Reznick et al., 2002). According to this heuristic, populations might belong only to one of these opposing and complementing typologies. In particular, the r-strategists focus on abundance: offspring are numerous, resources are widely consumed, growth is rapid. In contrast, K-strategists focus on efficiency: offspring is limited and attentively cared, resources are preserved, growth is slow (Reznick et al., 2002). Similarly, the *sub-unit* that undertakes a new beginning, at first exploits (r) the available resources to explore and test new development paths, interlacing interconnections and accumulating capacities. Eventually, the condition grows in stability and the interest shifts towards a sounder conservation (K) of the achieved status, accumulating also rigidities. Here the cycle would eventually disperse such restrains and start anew. In a few words, the *adaptive cycle* describes the succession of the precariousness of a re-start (α), through the restlessness of trying new possibilities (r), towards the stabilisation over a precarious equilibrium (K) that eventually breaks into a crisis that comprises the seeds for a renovation (Ω). The impulse from r to K is also called *fore-loop*, whereas the transition from Ω to α takes the name of *back-loop*. Overall, the dynamics of an *adaptive cycle* are indeed complex: they are not only subject to the inner variability and unpredictability, but a *sub-unit* is also inextricably exposed to the oscillations of the other *sub-units*. As previously mentioned, this further agent of change are the *interactions*.

The interactions

A complex system is simplified by decomposing it into the fundamental *sub-units* that constitute it and then by designing the *adaptive cycles* that follow the development of each *sub-unit*. Nevertheless, a complex system is not merely the juxtaposition of its *sub-units*: the changes that occur within a complex system are not just the summation of what happens to an *adaptive cycle*. Rather, the development of a complex system is driven by the synergies that sparkle between the *adaptive cycles*. Such synergies might assume several different shapes, but in general two main typologies have been recognised: the *remember* interaction and the *revolt* interaction (Fig. 1.2).

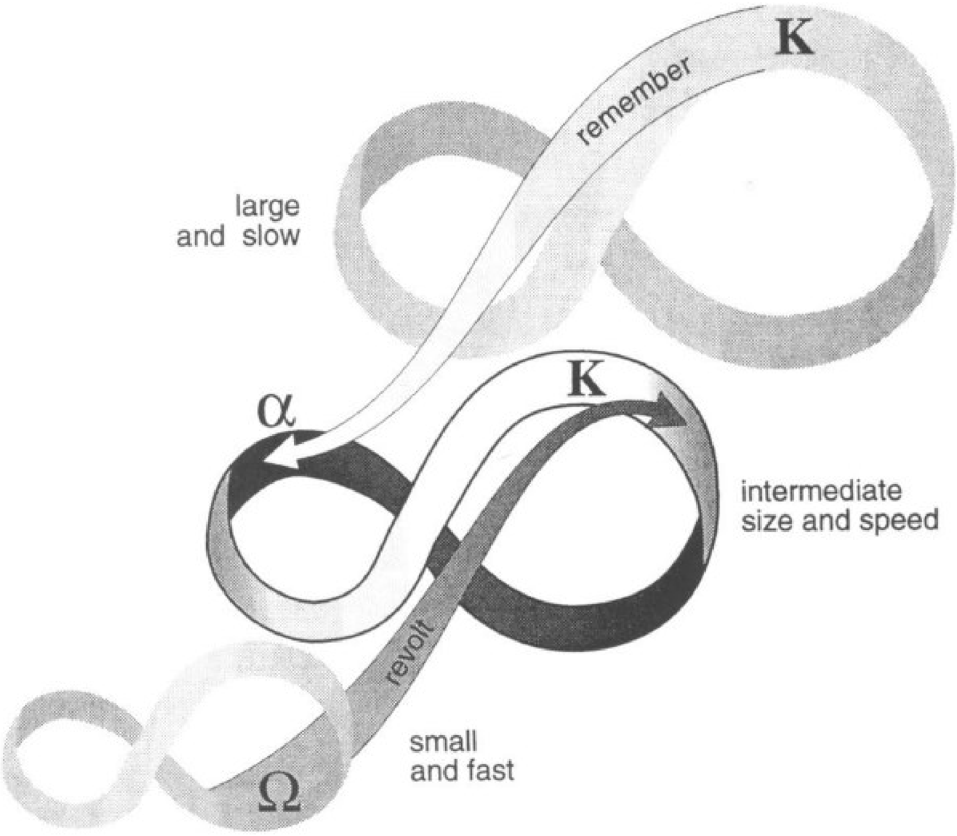


Figure ii.2 — The nested adaptive cycles that form a panarchy and the two main interactions that may occur: remember and revolt (Holling, 2001).

This duality emerges in the moment when two *sub-units* interact. In fact, the consequences might point towards two major, opposite domains: either the interaction contributes to enrichen and stabilise the system or the interaction triggers the spread of an unstable and destabilising condition (Angeler et al., 2016). In the first case, a *remember* interaction takes place, whereas in the second case the *revolt* interaction comes into play. At the same time, the difference relies not only on the effects, but also on the origins of the interactions: they are either a cascading or an escalating among the levels of the panarchy (Holling, 2001). In a few words, the *remember* interaction describes a situation where a larger and stable *sub-unit* (conservation *phase* (K) of the *adaptive cycle*), provides its accumulated knowledge and experiences in order to support a smaller *sub-unit* that has undergone a recent collapse, in order to definitely exit the *back-loop* and move towards the reorganisation of a new development path (α-*phase*). From this derives the name of "remember", as if the system would implement the cultivated wisdom to foster stability (Holling, 2001). On the contrary, the *revolt* interaction occurs when a smaller *sub-unit* is experiencing a status of deep destabilisation (Ω-*phase*) and ignites the collapse of a larger *sub-unit* that is fatally building up rigidities (K-*phase*). In this sense it is a "revolt", because smaller and rapid levels compel and overwhelm larger and slower levels of a system, shaking the inner unstable equilibrium (Holling, 2001). In light of these considerations, it emerges a peculiar facet of the interactions: they appear only when there is a proper "alignment of the stars" (Holling, 2001, p. 404). Only when the *sub-systems* occupy the susceptible positions of their respective *adaptive cycles* at the same time, the interactions might follow the delineated path and thence influence the development of the system as a whole (Allen et al., 2014). This is especially relevant with regards to the disruptive potential of the revolt interaction: only when the vulnerabilities align within a system, it is possible for the destabilising forces to propagate throughout the levels. This results in a threating power of escalating disastrous events (Pescaroli & Alexander, 2016), but it also means that radical transformations are reasonably rare (Holling, 2001). Nevertheless, this conclusion should not obfuscate the primary assumption of the panarchy model: change is inherent to complex systems and the equilibrium is continuously adjusted to cross-scale relations. In Holling's words, "The whole panarchy is therefore both creative and conserving. The interactions between cycles in a panarchy combine learning with continuity" (2001, p. 399).

Critical issues

Since the panarchy theory and model play a central role in establishing the foundations of the present research, it might be significant to explore a bit further some peculiar and possibly tricky aspects.

Until this point, the *adaptive cycle* was presented as a two-dimensional object, dominated by the variation of potential and of connectedness, that would occupy the ordinate and the abscissa, respectively. According to the original theory, a third axis is missing: it would represent the adapting capacity of the *sub-unit*, assumed as its resilience. Although these considerations enrich and add insight to the conceptualisation, in the present case they were not explicitly included as they might perturb the discussion. This limitation was especially addressed to the third axis, where the name itself might contrast with the present speculations. Furthermore, it frequently happens that the *adaptive cycle* is treated as a 2D object (e.g. Angeler et al., 2016; Baker & Refsgaard, 2007; O'Connell et al., 2015; Resilience Alliance, 2010), hence it seems appropriate to adopt this approach here. An additional facet to bear in mind is that even though it is a "cycle", it has been observed that the *phases* might not be universally valid and in particular they might not necessarily come into a strict succession (Gotts, 2007). Although there are evidences for intrinsic cyclicity, there should also be cautiousness in attributing an unquestionable predictive potential to the *adaptive cycle* (Abel et al., 2006). In particular, an *adaptive cycle* might experience a peculiar status where variability is firmly limited: this might happen because it has fallen in a *poverty trap* or in a *rigidity trap*, that are identified as conditions of maladaptation (Holling, 2001). An *adaptive cycle* might plummet into a *poverty trap* when its resources and diversity are either internally dilapidated or externally extinguished. This condition of low availability of assets, capacities and interconnections inhibits positive renovation and force the cycle to linger in the *back-loop*, threating a similar fall to the other levels of the panarchy (Holling, 2001). The *rigidity trap* might materialise in opposite conditions and yet cause a similar outcome. When a *sub-unit* has maximised the use of available resources and process are tightly controlled, it might also have developed a high capacity to resist adverse events, but here is the point: this kind of maladaptive system might be unable to embrace positive change and to escape from this perverse optimisation (Holling, 2001). Also in this case, such unfortunate stable point of equilibrium might stiffen the overall panarchy and thence discourage the overall variability (L. Gunderson et al., 2017). Coming more precisely to the interactions, the major typologies were identified and described as *remember* and *revolt* ones. Even though their dynamics have been recognised in several systems (Holling, 2001), it has also been suggested that other form might appear. In particular, it might happen that the same effects are manifested although the interactions follow a reversed direction (Redman & Kinzig, 2003). This holds true for both interactions, but it might be especially threatening when considering the *revolt* interaction: it means that instabilities have the potential to move both upwards and downwards the panarchy levels, that is both escalating and cascading disastrous events should be expected (L. Gunderson et al., 2017).

iii. Overarching hypothesis and sub-hypotheses

Humans and nature compose a complex system, where their interactions mould an inextricable net of feedback loops, both positive and negative. Indeed, both sides have the potential to nurture or to jeopardise the other. In particular, humans necessarily rely on natural processes to meet their fundamental needs, although natural phenomena might represent a serious threat to the survivability of human communities. At the same time, nature might benefit from strategies devoted to the preservation of ecosystems, although the detrimental effects of human activities on natural equilibria is evident and undeniable nowadays. In other words, this inherent interdependence of humans and nature determine the evolution of the multifaceted system that is commonly addressed as a Social-Ecological System. The foundations of this study lie in the acknowledgement of those complex dynamics that occur within and that represent the essence of a coupled Social-Ecological System. In particular, the main focus resides on the inappropriate interactions among the components of a Social-Ecological System leading to disasters, that are disruptive and destabilising events, potentially underpinning the stability of the Social-Ecological System as a whole.

As a consequence, the overarching *objective* of this research is to contribute to the exploration of the issues related to disaster risk reduction, in order to draw relevant insights to the moulding of the development path of human communities and of the Social-Ecological System. In particular, in order to enhance the comprehension of those multifaceted phenomena, the panarchy heuristics was explored as a promising model to be implemented in the domain of disaster science. Indeed, the panarchy is able to address the multi-faceted and multi-scalar essence of Social-Ecological Systems, as well as to model the continuous interactions among their components.

In light of the above observations, it was possible to formulate an overarching hypothesis:

Disaster risk reduction may be effectively modelled using the panarchy theory.

Accordingly, two sub-hypotheses follow:

> *Hazard and susceptibility (vulnerability and exposure) can be modelled by two separated adaptive cycles composing the hierarchy of the disaster risk reduction panarchy.*
>
> *Risk can be modelled by a destabilising interaction (revolt interaction) between adaptive cycles.*

In other words, the aim of the present research is to verify the possibility to describe the factors and dynamics of risk through the heuristics offered by the panarchy model. In particular, this investigation is intended to identify strong points, critical issues, informative lessons within the complex Social-Ecological System, in order to foster a sounder and more comprehensive development path that could preserve the survivability of its components in the long-term.

Although the above statements represent the fundamental cornerstone of the research, further exploration is required. In particular, it appears necessary to delve more deeply into the theoretical consequences of the application of the panarchy model in the disaster risk reduction domain, as well as the related potential to provide a base for an operative methodology to be developed.

As a consequence, the discussion that prompts from these lines is intended to preliminary provide an ***interpretivist paradigm*** to assist in the comprehension of the inherent dynamics of a Social-Ecological System, especially in the case of a disaster. Then, a ***positivist paradigm*** will take advantage of the achieved outcome to further unravel. In particular, it seemed significant to develop first a *quantitative methodology* to investigate through numerical indicators the conditions of resilience and related capacities of local communities. Then, a second line of investigation will be developed, in order to integrate the previous endeavour with perspectives and perceptions of the communities on the local conditions through a *qualitative methodology*.

In a few words, it appeared significant to structure the present research as follows: the *first part* will envision the exploration of the theoretical application of the panarchy heuristics to the disaster risk reduction domain, in order to develop a relevant tool to assist the comprehension of the dynamics occurring within a Social-Ecological System; then, the *second part* will be devoted to the development and application of a methodological framework to quantify the *core* features related to the long-term survivability of the Social-Ecological System, in order to identify the actual conditions of the System; eventually, the *third part* will explore those same *cores* from the perspective of local communities through the development and application of a qualitative methodology, in order to account for the unique and advantaged standpoint of those experiencing the events unravelling within a local Social-Ecological System. The final *conclusions* will aim to recompose the multifaceted picture, fragmented in the previous discussions, possibly identifying some common lessons and insights to inform the moulding of a Social-Ecological System in a long-term perspective.

iv. PART 1 – *from theory…*

1. Literature review: interpretivist paradigm

The complexity of Social-Ecological Systems pose a profound epistemological hindrance of challenging solution. The interrelations might become overwhelming and the manifold of components might turn ineffable. In this perspective, conceptual models might provide substantial assistance. Their potential resides in the capacity to simplify the surrounding reality, by unravelling the underlying fundamental structure and thence untangling the knots of mutual and interrelated feedbacks that determine the evolution of a Social-Ecological System. In other words, conceptual models identify the essential elements of a complex system, reducing the range of variables to consider and consequently making the system more manageable, also for further developments. As previously suggested, in the present case an interpretivist model would be beneficial to better comprehend the dynamics of Social-Ecological Systems, while whittling some basis for a possible more positivist investigation. In order to be operative, such a conceptual model would likely present some major facets. For instance, it should be flexible enough to be applied to both human and natural components, as they are deeply interlaced within a Social-Ecological System. At the same time, flexibility should be exhibited also in the possibility to apply this model to different temporal and spatial contexts, in order to include a variety of systems under the same interpretative frame, hence promoting a generalisation of local observations. Nonetheless, the model should not overly favour simplicity to complexity, in the sense that the drive towards a manageable structure should not discard the typifying features. Additionally, when Social-Ecological Systems are constantly mutating, it might be significant to envisage a temporal dimension, in order to place such alterations downstream of observed interactions within the Social-Ecological System. Among the theoretical frameworks that aim to deepen the common understanding about Social-Ecological Systems, a conceptual model that responds to these requirements is the panarchy model (Anderies et al., 2006; B. Walker et al., 2006).

1.1 Panarchies of complex systems

In spite of these aspects that require some thoughtful attention, the panarchy effectively supports a deeper comprehension of the human, natural and coupled human-natural systems. Indeed, this heuristics has been fruitfully employed in several endeavours aiming at the explanation of observed dynamics, either focusing on the *adaptive cycle* itself or rather developing a broader panarchy (Garmestani et al., 2009). For instance, some traces of such operative applications can be found in the first explanatory works of the panarchy model: forests, coral reefs as well as societal changes and renewals are narrated by Holling (2001) to ground the description of the *adaptive cycles* and of the dynamics of the hierarchies.

Throughout the broader literature, it is possible to identify some relevant efforts to interpret the dynamics of natural systems through such peculiar lenses. In particular, it has been suggested that environmental issues might be modelled through panarchies, in order to comprehend the complex structure of natural ecosystems, that is interconnected and develops across multiple scales of space and time (Angeler et al., 2016). In this way, environmental management might rely on an integrated model to guide the enhancement of comprehensive strategies: indeed, panarchy recognises interdependencies, feedback loops and nonlinearities, as well as their double-fold potential to destabilise or maintain the architecture of the system. Nonetheless, some knowledge and data constraints prevent from an extensive application of the panarchy model in this domain, hence it is suggested that field experiments should sustain a further understanding of the complex dynamics of natural systems, as well as they should help identify the critical variables and processes that are pivotal for the persistence, promoting a special endeavour to apply quantitative strategies of investigation (Angeler et al., 2016).

Actually, a quantification effort has been carried on and applied to marine systems. In particular, the phytoplankton communities of the Baltic Sea were employed as a testing field to assess whether the *adaptive cycle* might fit the paradigms already well established to model their annual cycle (Angeler et al., 2015). In this case, quantitative data concerning water and phytoplankton characteristics could fit the four main *phases* of the *cycle*. It was observed that the *adaptive cycle* properly describes the recognised ecological patterns and it efficiently complements the other theories, enriching the representation of the ecological dynamics though a comprehensive perspective on the blooms and development of phytoplankton communities throughout the seasons. Consequently, it is suggested that the *adaptive cycle* might hold the potential to shift from a mere interpretative paradigm to an heuristics suitable for empirical validation and, furthermore, for informing environmental policies and management (Angeler et al., 2015).

At the same time, other attempts aimed at identifying panarchies within the social domain. A peculiar study concerned the development of port areas: the aim was to identify a tool to guide a sounder and more resilient progress of these human settings (Vonck & Notteboom, 2016). Thus, rather than as an explanatory tool, the panarchy theory was adopted to benefit from its potential to raise questions on the critical facets of the complex dynamics occurring when several different stakeholders interact. Consequently, different processes were analysed and the panarchy framework revealed examples of multi-stable states within a port development or the occurrence of the confinement in a *rigidity trap* when some highly focused development strategies are enacted. In other words, the panarchy framework appeared to hold the potential to be beneficial in assisting the interpretation of some processes and at the same time in informing future management strategies (Vonck & Notteboom, 2016).

Similarly, some other research efforts were directed towards societal dynamics, but in this case the context was set on climate change adaptation (Park et al., 2012). The objective aimed at developing a comprehensive framework to support local authorities when taking action against environmental changes. Hence, different conceptual models dealing with transition, transformation and adaptation processes were examined and integrated, including *adaptive cycles* and related interacting hierarchies. In particular, the panarchy model resulted highly complementary to the other discourses, supporting the description of adaptive management as a series of decisions and actions that inevitably crosses scales and time, influencing the development path of the overall complex system (Park et al., 2012).

Since the panarchy framework inherently acknowledges the interrelations within a complex system, it might be expected that the application of this model that best exploits its potential occurs in settings where the natural components are decisive in the development and not just the background of human actions. This kind of situation is especially evident when considering agricultural systems. Even though such systems might be dominated by human activities, ecological processes play a fundamental role in supporting those same activities. In this perspective, a study concerning Dutch dairy farm system employed ecological parameters (such as nitrogen and soil organic matter) adopted as a reference to interpret ongoing transformations and processes (van Apeldoorn et al., 2011). Among the other conceptual frameworks, *adaptive cycles* and panarchy contributed to the modelling effort. In particular, it was found that dairy farming management tends to simplify the *adaptive cycle*, disturbing and altering the commonly observed sequence of *phases* in natural settings. Human interventions allow to optimise the productive rate by artificially supplying nitrogen when natural processes would tend towards a stabilisation and then the minimum content of nitrogen. That is, human components are able to influence the natural components to the point of compromising their "naturalness". The analysis also suggested that the concept of resilience might be a matter of scales: this kind of dairy farms are highly adaptable to external pressures because of their massive intervention on natural processes, although this same characteristic reverses such a local resilience into a completely un-sustainable and un-resilient system on a higher scale. On the other hand, the discussion focusing on soil organic matter concerned a multi-scale and multi-temporal Social-Ecological System. In particular, the panarchy framework allowed to investigate how traditional management might be more influenced by societal expectations of rapidly achieved results rather than natural constraints, while innovative management strategies tend to reconnect with the slower ecological pace of transformation. In this perspective, agroecosystem governance approaches are expression of two opposite timeframes: short-term when dominated by socio-political pressures, long-term when aligned to natural processes (van Apeldoorn et al., 2011).

Along this line, a deeper interconnection between humans and nature is manifested when an agro-pastoral system settles within a riverine area: in a similar case identified in Australia, the Social-Ecological System (SES) would encompass different components (social, economic, biophysical), as well as different scales (local, regional, national) (B. H. Walker et al., 2009). In order to trace the transformations that such a complex system has undergone through time and to identify a pattern of change in the resilience of all its components, the *adaptive cycle* metaphor was applied. Indeed, the metaphor effectively assisted in the interpretation of the feedbacks that crossed multiple scales and affected the development of the overall Social-Ecological System (SES) in the long term. Loops interlacing agricultural techniques, consequent alterations of natural processes (of both ecological and water ecosystems), thence the reorganisation of productive activities could be traced and identified. In particular, resilience was discussed both at a single-component level and at a general level. This appeared significant when it had already been highlighted that systems highly resilient to a specific typology of threat might sensibly reduce its ability to cope with other threats: for instance, complex systems that are highly efficient in dealing with frequent disturbances necessarily find much more difficulty in responding to rare events. Overall, this examination guided by the *adaptive cycle* resulted to be beneficial in designing suggestions for future management strategies that would foster a compromise between social demands, economic viability and biophysical equilibria, learning from the critical issues and crisis arose along the years (B. H. Walker et al., 2009).

As mentioned, a fundamental moment when humans and ecosystems come into contact is when agricultural activities develop throughout a territory. In these conditions, the mutual influence becomes more evident and especially how the changes at a certain scale of the Social-Ecological System (SES) might significantly impact an other scale. An investigation of this kind was performed focusing on the quinoa farming activities carried on in the Bolivian mountains, interlacing the local social habits, the evolving economic demands and the natural processes that support the quinoa production (Winkel et al., 2016). The panarchy model was implemented to mould a simplified architecture of the inner complex feedbacks, thus revealing how economic pressures and political resolutions have impacted the social domain, with escalating consequences on the biophysical processes, to the point of moving them towards critical thresholds. In particular, it is suggested how in agroecosystems, that is systems where the human activities and natural processes are strongly interlaced, human endeavours and engagement play a pivotal role in determining the development path of the overall Social-Ecological System (SES). Hence, in similar cases, the overall prosperity of the Social-Ecological Systems lies in the hands of human actors. At the same time, the panarchy model helped to gain insights to design future management strategies, in order the promote a renewed equilibrium between anthropic processes and natural landscapes. Observed critical alignments within the different *adaptive cycles* might become critical early-warnings for the future, and even though a measure fitting for all situations might not exist, it is advised to support adaptive and integrated governance efforts in order to prevent the Social-Ecological Systems from crossing compromising no-return thresholds (Winkel et al., 2016).

In line with this perspective, a further example was recognised in the Italian Alpine grasslands (Soane et al., 2012). A traditional pastoral system was examined: this farming activity is centred on a household that live in close contact with the peculiar natural landscapes of the area, although the recent decades have witnessed profound changes in this structure. Panarchy was thence employed to assist in identifying the major drivers of change, attempt to associate a quantitative dimension to the alternation of *adaptive phases* and thus guide the investigation on the overall vulnerability of the Social-Ecological System. Natural, social, political and economic drivers were comprised, covering an extensive range of spatial and temporal scales. The examination of different farming regimes allowed also to draw attention on the different shapes that an *adaptive cycle* might assume, depending whether the focus would be primarily on nature conservation or agricultural management. Even though panarchy was essentially adopted as a qualitative metaphor to sustain the comprehension of complex interdependencies, the model allowed to identify some significant quantitative parameters. These variables could be further refined through integrated approaches, that is engaging local stakeholders and involved social actors, in order to develop informative thresholds on the alternation of on the alternation of *cycle* shifts (Soane et al., 2012).

When studying coupled Social-Ecological Systems, the investigation around resilience might further be enriched by introducing the themes of the sustainability discourse, although only recently this multi-disciplinary approach has gained attention. Nonetheless, this perspective might benefit from the application of the panarchy framework: that is the starting point of an investigation that considered complex social-ecological systems, settling on a community level and questioning the escalating and cascading consequences of policies, community cohesion, economic drivers and their meaning for the sustainability of the overall system (Berkes & Ross, 2016). In particular, the model supports a multi-level visualisation of the occurring interactions, that results especially significant in highlighting the limitations of single-discipline or single-level discussions concerning sustainability. In other words, it is possible to comprehend how in some cases detrimental drivers of change (for instance economic demands) might underestimated if the analysis is too narrow. At the same time it might also reveal that those drivers act at a level too high for smaller components of the system to influence them, thus suggesting that a different development path should be prompted at lower scales, for example enhancing solutions viable for local-level application. In this perspective, it is also possible to interpret the shift from mitigation to adaptation: when climate drivers operate at a global level, local communities might not be able to endorse activities to mitigate their occurrence, but they might tailor adaptation efforts for their specific territories. Eventually, this complex hierarchy reminds that policies, directed towards both resilience and sustainability objectives, should not be considered as external pressures to the system, but rather as operating at a specific level of that system: their design and consequences are an integral part of the complex Social-Ecological System, that is their development should be influenced by the characteristics of the Social-Ecological System and at the same time the impact of their enactment should be envisaged (Berkes & Ross, 2016).

The close contact and unavoidable interdependence with nature becomes even more evident when the analysed social system is settled on an island, especially in the case of Small Islands Developing States (SIDS). Here, it more clearly emerges the dominant role of the mutual interactions in determining the development path of a Social-Ecological System (SES). Consequently, this context might be a peculiar stage to further the discussion on environmental sustainability and to introduce an additional theme, that is disaster resilience. The panarchy framework was applied to the Bahamas (Holdschlag & Ratter, 2013, 2016) to shed some light on the environmental management of the island. It was possible to evidence how the current policies and economic drivers are inducing profound changes to the local environment, potentially leading to critical thresholds. On the other hand, citizens, especially younger generations, appear aware and sensible to such alterations and are promoting the adoption of different habits, from everyday activities to higher-level innovations. That is, internal drivers of change that have degraded the surrounding environment might become advocates of a sounder coexistence with nature, reversing the crucial impacts that triggered this change of perspective. In this context, it was possible to evidence that without the active engagement of local communities in sustainability efforts as well as in building local resilience, top-down management strategies are doomed to fail, especially when dealing with threatening hazards (Holdschlag & Ratter, 2013). Similarly, local management comes under the spotlight of the other case study, set in the Island State of Grenada (Holdschlag & Ratter, 2016). In this case, an overwhelming driver of change was a hurricane that destroyed social, economic and natural assets, thus exposing the lack of preparation of the local community to face such extreme adverse events that led to the collapse of the Social-Ecological System. In spite of notable internal efforts, this condition could be effectively reversed only thanks to external (hierarchically higher-level) assistance. Nonetheless, the local community did not just passively accept external aid, but rather it seized the chance to learn from the disaster and innovate its structure, adapting local assets to the surrounding pressures. Actually, this renovation allowed more efficiently to absorb the impact another hurricane (coming shortly after the previous) and thence to limit the potential detrimental consequences. Overall, the panarchy metaphor allowed to better comprehend the development path of these peculiar Social-Ecological System, although even more important might be the evidence of how cross-scale interactions might disrupt as well as stabilise a system, in these cases where the inherent components cannot be considered in isolation from the others. That is, when the components of a Social-Ecological System are constantly influenced by each other, a fruitful coexistence might be based on mutual learning and adjusting to respective equilibria, thus inspiring innovative and transformative local management strategies that comprehensively involve multi-dimensional approaches (Holdschlag & Ratter, 2013, 2016).

In a similar vein, the investigation concerning the development of a small island might take a look backwards, towards past events. In particular, when studying disasters two major *phases* might especially draw attention: the moment of collapse and that of restoring previous functions (that are, in the *adaptive cycle* metaphor, the *release* and the *reorganisation phases*). The historical development of the Rodrigues islands (Mauritius) were examined under these assumptions, combining official records and data with interviews and surveys of local communities (Bunce et al., 2009). Through the lens of the panarchy framework, it was possible to identify the devastating effects of natural hazards on human assets, the potentially missed chances of renewal and how limited resources prompted an adaptive behaviour in terms of integrated economic activities. At the same time, it was possible to recognise a certain point when a cyclone triggered a peculiar cascade of events that evolved in a spiral of subsequent collapses. Even though attempts of rebuilding the fundamental activities and functions were recorded, they seemed not sufficient to move past the condition of collapse. In particular, the analysis allowed to identify some variables operating at multiple levels that potentially determined the lingering in that critical state, such as mismanagement of natural resources, societal marginalisation or economic demands. In conclusion, this investigation supported the hypothesis that, after a disaster, complex systems might get stuck in an asphyxiating state that prevents renovation and innovation. In these conditions, the system appears extremely vulnerable to external pressures. Here, connectedness and cross-level interactions might turn either detrimental, if further obstructing the development path, or pivotal, if supporting a renewal. It consequently derived that when designing and implementing management policies, it is fundamental to carefully evaluate the most beneficial level of application, to include the feedbacks from external pressures and to take into account their multi-dimensional consequences (Bunce et al., 2009).

Although every component of a Social-Ecological System might be susceptible to suffer from a disaster and thence requires attentive management, when narrowing the focus on human systems a pivotal role appears to be played by critical infrastructures (Pescaroli & Alexander, 2016). These are the physical and technical assets fundamental to perform social, economic or operational essential functions, both in routine and in emergency conditions (UNISDR, 2009). It is evident that the disruption of a critical infrastructure might endanger the overall system, while their efficiency has the potential to sustain a prompt response to adverse events. This potential resides in the distinctive feature of critical infrastructures, that is their inherent and extensive interconnection with the wider system. Hence, the panarchy heuristics seems rather appropriate to model such an interdependent and multilevel system, especially when examining the cascading potential of a failure in its critical components. Yet, it has been traditionally challenging to assess the width of this potential, thus to some extent it remains an unresolved uncertainty within disaster management efforts. Nonetheless, in this case the panarchy framework suggested that the cascade of collapses from critical infrastructures to other components of a system might occur only under the condition of an alignment of vulnerabilities. As a consequence, it should be encouraged a shift from the traditional analysis based on possible failures to an innovative approach that focuses on the points of vulnerability, that is the points of weakness in a complex chain of assets. In other words, when the range of possible sources of threat are too wide to be thoroughly anticipated, it might still be possible to identify the susceptible components and thus act on them, in order to inhibit the spread of undesired conditions (Pescaroli & Alexander, 2016).

The discussion employing the panarchy framework to shed some light on the processes of complex systems has been performed on several diverse stages, either natural, human or a combination of both. Even though the model was developed within the research perspectives looking at ecological systems, it effectively spread throughout other themes and disciplines, hence its application to complex Social-Ecological Systems can be assumed as well rooted and corroborated. A peculiar perspective seemed to progressively draw more attention, concerning a peculiar interface between natural phenomena and human processes: disasters appear as a paradigmatic example of complex social-ecological interactions. Throughout the research endeavours, it emerges a general trend of implementing the panarchy model not only to further the comprehension over system dynamics, but also to transform such insights into a base to inform local management. In other words, the *adaptive cycles* and panarchy tend to leak out of the merely speculative discussions to extend towards more operative questions (Angeler et al., 2015). As a consequence, there has been some significant attempts to enrich the original descriptive, qualitative nature of the panarchy by means of more quantitative approaches (Angeler et al., 2015, 2016; Soane et al., 2012; van Apeldoorn et al., 2011). On the whole, this heuristics appears suitable to address some relevant issues that emerge when designing management strategies: for instance, it proved beneficial in identifying pivotal drivers of change that could alter the inherent balance in human-nature interactions (Angeler et al., 2016; Soane et al., 2012); at the same time it allowed to evidence the fundamental role of human actors (Winkel et al., 2016), both positively, when endorsing and prompting innovative and adaptive behaviour, and negatively, when inducing disruptive feedbacks within the complex system (Holdschlag & Ratter, 2013, 2016); in general, this framework emphasises the multi-scale and multi-temporal interactions that occur among the components of a Social-Ecological System, thence suggesting that an attentive planning should acknowledge and account for such complex mutual feedbacks (Bunce et al., 2009; Park et al., 2012). Although these observations are relevant for the disaster resilience as well as for the environmental sustainability discourses, the research efforts allowed to reveal some significant aspects for these domains. In particular, it was possible to suggest that there should be caution in drawing conclusions about the level of resilience of a community: highly specialised systems might be unable to cope with events occurring at unusual spatial (van Apeldoorn et al., 2011) or temporal (B. H. Walker et al., 2009) scales. Ultimately, a management shift might be envisioned, where the focus is shifted from unforeseeable phenomena towards recognisable weaknesses, in order to anticipate and possibly inhibit the disruptive spread of undesired conditions among the interlaced levels of a Social-Ecological System (Pescaroli & Alexander, 2016). Similar concerns surrounding the consequences of adopting an excessively narrow approach have been expressed also within the sustainability discussion, where disregarding the role of human-nature interactions might be detrimental for the development of the overall Social-Ecological System (Berkes & Ross, 2016). Along with these remarks, the panarchy framework itself acquired further depth from such applications: for instance, it was possible to observe peculiar behaviours of Social-Ecological Systems, where the local processes distorted the *adaptive cycle*, revealing different shapes and paths (Soane et al., 2012;

van Apeldoorn et al., 2011). Nonetheless, the model appears to adequately fit the processes occurring within a Social-Ecological System, that is the overarching heuristics seems confirmed in its fundamental interpretative potential, since multi-level interactions, multi-stable states, *traps* and *phases* have been thoroughly recognised in applied practice (Vonck & Notteboom, 2016).

In a few words, from this brief exploration of the panarchy literature it emerges that this heuristics has been appreciated for its potential to interpret the multi-dimensional structure of a Social-Ecological System, addressing the detrimental consequences as well as the reinforcing potential of cross-scale interactions among different components of the system. Resilience and sustainability issues seem to benefit from the application of the panarchy perspective, especially when disruptive events bring to the surface the inherent interdependencies. At the same time, even though considered together, it seems that a real integration of resilience and sustainability discourse within the context of the panarchy heuristics is still at its dawn. Furthermore, although there have already been hints of possible differences in the structure of the *adaptive cycle*, it might be interesting to include a deeper discussion concerning the interactions and the potential implications of their reversed direction. Then, once this architecture was arranged, it might be possible to elaborate a peculiar view of the essence of resilience and of sustainability. Eventually, it might be possible to set the foundations for a quantitative approach directed towards the issue of comprehending local processes and informing local management strategies. The following paraphs aim at developing such themes: the objective is to move from the discussed research efforts towards the definition of the interpretivist paradigm that later would serve as a theoretical foundation of a positivist effort, that would seek for a quantification of disaster resilience and environmental sustainability.

2. A Social-Ecological Panarchy

In order to further the discussion concerning resilience and sustainability through the assumptions and terminology of the panarchy heuristics, it might be beneficial to focus on a specific Social-Ecological System. The idea is to set some variables and outline the main characteristics of a Social-Ecological System to be analysed, with the purpose of gaining a more focused and manageable ground of discussion, while retaining a certain level of generalisation. This need derives from the high flexibility of the panarchy model: as previously illustrated, the possible applications cover a wide range of arrangements in terms of natural and human components, hence establishing an hypothetical Social-Ecological System to be investigated might facilitate the visualisation and the interpretation of the inherent dynamics.

In the present case, it might interesting to commence from the roots of the panarchy theory: as it is an expression of the systems approach, that same approach might be employed to define the system, that is the Social-Ecological System, to be further investigated. Jackson and colleagues (Jackson et al., 2010) suggested a series of steps to guide the first steps when applying the systems approach:

1. Identification of the elements of a system
2. Division of elements into smaller elements
3. Grouping of elements
4. Identification of the boundary of a system
5. Identification of the function of each element
6. Identification of the interactions among the elements
7. Definition of the system's environment
8. Synthesis of the system
9. Proving the system
10. Identification of emergent characteristics of a system

Although the last two points are more operational in nature and thence might rather refer to the later efforts to introduce a quantitative dimension to the present framework, the defined architecture seems viable to this preliminary moulding of the Social-Ecological System.

Following the suggestions of Jackson and colleagues (Jackson et al., 2010), the first steps (1 to 3) require to identify the elements of the system of interest, then group them in overarching classes and thence form a hierarchy. In this case, the focus is Social-Ecological Systems, hence complex systems encompassing human and natural components. Consequently, in this case the elements of system encompass people, human structures and infrastructures, economic and social processes, as well as animals, plants, biophysical processes. Even though there are a multitude of actors participating in a Social-Ecological System, it is here necessary to simplify this structure: the previous research efforts support this phase, reminding that any complex system might be reduced at three to five main components, when visualising it through a panarchy (Resilience Alliance, 2010). In this case, it might be possible to recognise three main components: an anthropic component, including any process and asset that pertain to human activities, a first natural component, that describes the physical processes of the environment, and a second natural component, that comprises the broader ecosystem services. Although it is true that ecosystem services are performed and benefits provided by means of physical processes, hence this discrimination might appear not enough justified. Nonetheless, the intention here is to differentiate between the dynamics that occur at a local, rather small scale, that can be reduced to physical dynamics, and the wider processes that involve higher level of spatial scales and of complex feedbacks. In a few words, the purpose is to model both the local dynamics of natural phenomena, their local impacts, and the overarching dynamics that dominate a broader ecosystem: these elements operate at completely different scales, hence it might not be appropriate to cluster the in only one component. At this point, the question of spatial and temporal scales has already been introduced, hence it might be appropriate to further the discussion. In particular, the natural processes component focuses on a local scale, addressing phenomena that evolve in a rather rapid vein; on the contrary the natural ecosystems component unravels at a higher scale, with rather slow speed of change. The hierarchy that is thus appearing misses the anthropic component: it might be considered in between the two other components, since human activities have the potential to extend over local biophysical niches, while they are surrounded by the wider natural ecosystems. Once the constituting components are specified, what comes next is the definition of the boundaries of the complex system of interest. In particular, it is time to introduce discriminations in terms of separation from the other systems, identification of the functions performed and exposure of the possible mutual influences among the components. At this point, it might be beneficial to further focus on a specific Social-Ecological System for the present case, taking into account once more the outlook towards disaster studies: even though later some more details will be enclosed (see Ch. 6), even at this point it is significant to consider the relevance of flood risk for human and natural communities, that is every day more evident and its disruptive potential is even increasing, also due to the ongoing environmental changes (IPCC, 2014, 2018, 2019). Consequently, here a flood risk scenario is assumed as the overarching setting. It follows that the system of interest should capture flood dynamics, including biophysical as well as anthropic processes. This requirement seems to perfectly fit with the assumed layout of the present Social-Ecological System: the natural processes component would describe the local hydrological processes that might impact the anthropic component developed around the hazardous area. Although floods might come from riverine or marine water bodies as well as other meteo-hydrological events, in this case it might be beneficial to adopt a riverine area as an archetype, so that the overarching natural ecosystems component might be more clearly identified within a river basin. At this point, the boundaries of the system of interest emerge quite visibly: the watershed demarcate the hypothetical domain where natural ecosystems perform their functions and deliver the services that are fundamental for the overall system, especially for the anthropic assets, that in turn manage the territory, including the riverine area. It is a mutual and continuous flux of resources, energy and information, though the peculiarities of the interactions will be later discussed more extensively, as previously mentioned. Essentially, what lies within a river basin would be comprised within the system of interest, simplified through the three components described above, while what remains outside the watershed still might interact and influence the development of the system, but as an external driving force. Eventually, it is possible to condense all these observations and assumptions through the visualisation offered by the panarchy model (Fig. 2.1):

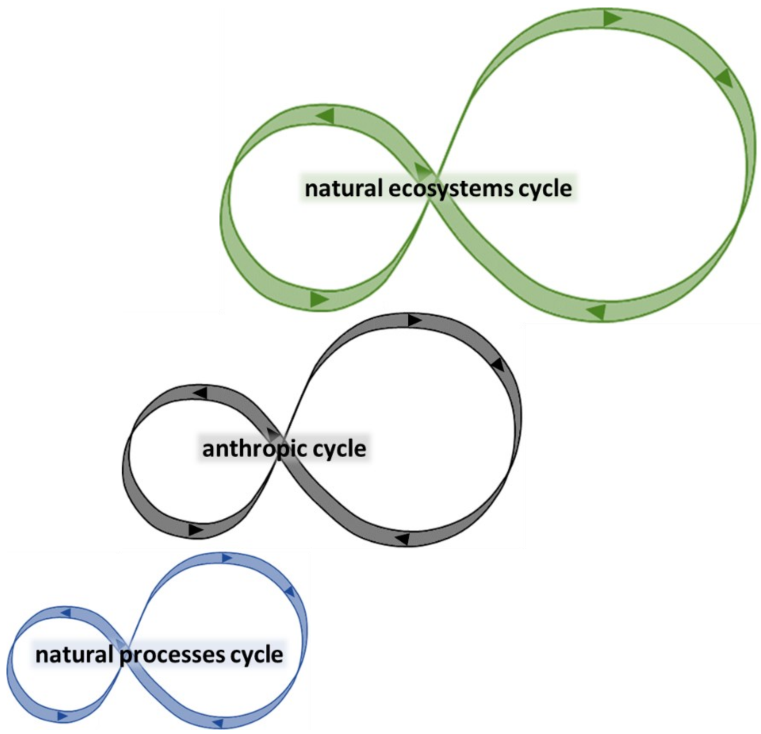


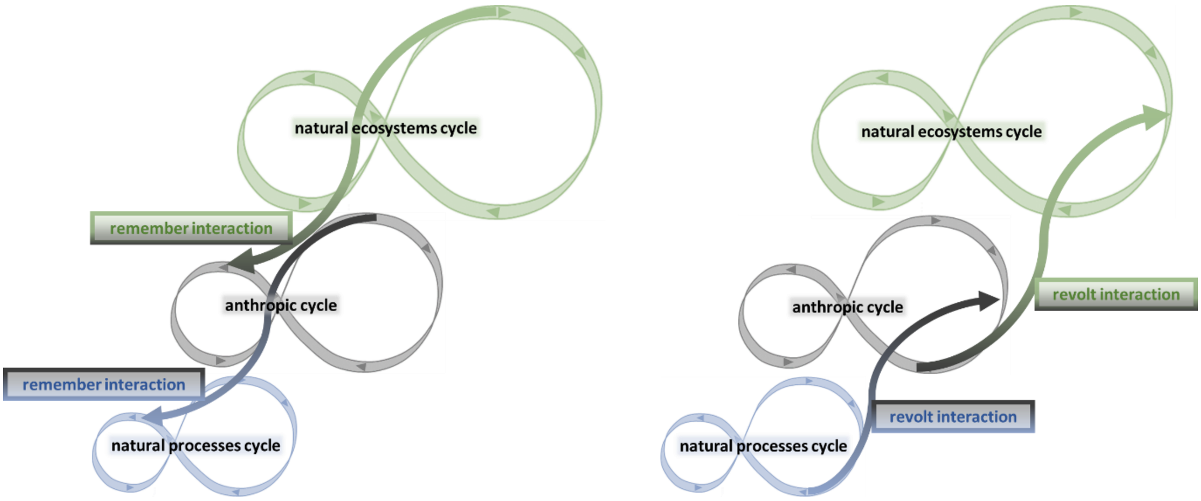
Figure 2.1 — A Social-Ecological System represented through the panarchy model. In this example, the social-ecological system is a river basin, hence the three adaptive cycles represents the functions of the ecosystems (natural ecosystems cycles), the human assets and processes (anthropic cycle) and the physical processes of the riverine area (natural processes cycle).

Here (Fig. 2.1) is represented an example of what could be considered a Social-Ecological Panarchy. From here onwards this will be the reference for the discussion concerning the possible interactions that might occur among the components, their mutual impacts and their consequences for the concepts of resilience and of sustainability.

2.1 *Phases* and interactions within a Social-Ecological Panarchy

The Social-Ecological Panarchy presented above adopts all the features previously described and that were corroborated by the presented research efforts. Nonetheless, the Social-Ecological Panarchy might also provide a base to investigate some further peculiarities. In particular, the characteristics of the *adaptive cycles* have revealed some deviations from the theorised behaviour when applied to operative questions, hence in this more conceptual phase of the present discussion it might not be possible to detect further peculiarities. Consequently, the focus will be shifted towards the interactions between the *adaptive cycles* that compose the Social-Ecological Panarchy.

In a first instance, it might be interesting to examine the interactions as originally developed by Gunderson and Holling (2002) as incorporated within the Social-Ecological Panarchy (Fig. 2.2).



(a) (b)

Figure 2.2 — A Social-Ecological Panarchy with the three constituting adaptive cycles *and the two main interactions,* remember *(a) and* revolt *(b), in the two possible configurations.*

In particular, some examples might facilitate the interpretation of their meaning in this context. The *remember* interaction describes a condition where a smaller *cycle* has suffered serious damages to its basic functions, thence a larger and stable *cycle* intervenes to support the break through the *back-loop* and the restoration of the fundamental assets in order to undertake a new development path (Fig. 2.2a). This might happen when a human community has suffered high damages from some kind of disrupting events: ecosystem services might be crucial in providing clean water to drink and to utilise in agricultural activities, the regulation of meteorological phenomena might stabilise adverse conditions, in the long term soil enhancement might restore fertility and support the human activities that rely on it. In other words, the ecosystems would provide the resources that are essential for the reorganisation on human activities, through processes that slowly but steadily develop and sustain the others. Nonetheless, a *remember* interaction might also descend from the anthropic *cycle* towards the natural processes *cycle*: this might happen when management activities are implemented in order to clean up a riverbed area that has accumulated weeds, logs and other remains that prevent the flow from following its natural course. That is, anthropic activities would intervene in order to re-establish an unconstrained water body. On the other hand, the *revolt* interaction describes the escalating potential of destructive events: the collapse of a smaller *cycle* that might impact on a larger *cycle* to the point of destabilising its equilibrium and forcing its collapse as well (Fig. 2.2b). For instance, local physical processes of a river might be rather stable throughout the year: the physical-chemical properties of a river are generally constant all year long. Nonetheless, when the flow rate dramatically increases in case of some unusual weather conditions, water might spread out the riverbed and flood the human settlement nearby. A flood might be considered as a *revolt* interaction prompting from an unusual event that rapidly evolves to impact and potentially destroy the human community. Similarly to the previous case, also the *revolt* interaction might spark from the anthropic *cycle*, here inducing grave consequences on the natural ecosystems. An exemplification of this kind of interaction might take place when human communities undergo deep changes in their structures, shifting from a productive system that relies on fragile equilibria with the natural environment to a productive system that destroys natural system to enhance engineered solutions. It would be as if the productive shift would destroy and reorganise the anthropic *cycle*, thus drawing also the stability of the natural ecosystem *cycle* into a crisis.

This brief presentation interprets the "original" interactions within this Social-Ecological Panarchy. Although the assumptions of the panarchy heuristics appear to be appropriate for describing these internal dynamics, some further questions might still raise, exploring what might happen within a Social-Ecological Panarchy: would it not be possible for anthropic activities to nurture a compromised natural ecosystem? Or, on the opposite, would it not be possible for some anthropic processes to fail and thus cause critical hindrances to local natural processes? Additionally, might the same dynamics find their triggering point in the natural *cycles* and thence influence the anthropic *cycle*? In order to address these questions, it appear relevant to delve into some suggestions that have already dotted the literature (see e.g. Redman & Kinzig, 2003), even though they might not be extensively discussed and structured yet. In particular, it might be appropriate to investigate the role and the implications of the *reverse* interactions, that are *reverse-remember* and *reverse-revolt*. The fundamental assumption is that the *reverse* interactions hold the same potential effect of the "original" ones, but they act on opposite directions: when the *remember* is a cascading force, the *reverse-remember* is an escalating driver, and when the *revolt* escalates, the *reverse-revolt* cascades (Fig. 2.3).

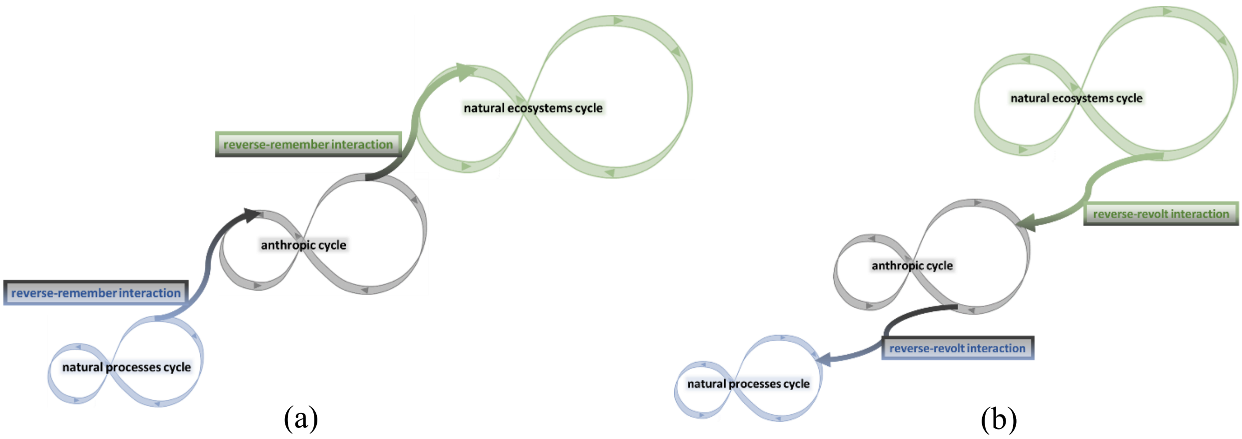


Figure 2.3 — A Social-Ecological Panarchy with the three constituting adaptive cycles and the two reverse *interactions,* reverse-remember *(a) and reverse-revolt (b), in the two possible configurations.*

In other words, a *reverse-remember* interaction represents the stabilising influence that a smaller *cycle* exerts on a larger, unstable *cycle* (Fig. 2.3a). This condition might occur when the physical processes of a river have consolidated a riverbed and an usual flooding area: this stable behaviour might inform the development path of a human settlement, in the sense that the human community would be able to recognise hazardous areas and thence exclude them from development plans. That is, stable physical processes would be able to influence the organisation and growth of anthropic activities. On a different scale, it might be the turn of the anthropic component to support the restoration of damaged natural areas. An attentive human community might indeed decide to dispose its resources with the purpose to sustain the compensation of occurred damages and thus to contribute to the recovery of ecosystem services. On the contrary, the effects of a *reverse-revolt* interaction would assume the shape of a cascading disruption: a larger *cycle* would suffer from a critical crisis that would compromise a smaller *cycle*, causing its collapse as well (Fig. 2.3b). The collapse of ecosystem services would evidently cause severe issues to the human activities: for instance, the raise of water tables might alter the salinity of the soil, compromising its fertility and consequently the agro-pastoral activities that rely on pastures and vegetation; in these conditions the anthropic component might be forced to abandon its previous productive habits and organise anew its development. In a similar vein, the collapse of human facilities might impact the local physical processes, to the point of precluding the usual performance of natural functions: the collapse of a dam might destroy the riverine area as well as the spill of polluting materials might compromise the local bio-physical processes.

In general, it emerges a picture where the *adaptive cycles* might determine the progress of each other *cycle* at any scale and direction: consolidating influences are not necessarily descending from wider and more stable components, while disruptive effects might propagate both upwards and downwards the hierarchy. In addition, it should be bared in mind that these interactions are not necessarily isolated, but rather mutual feedbacks might reinforce each other in a synergic potential to further consolidate or rather destabilise the Social-Ecological System: an informed development of human communities, based on the recognition and respect of natural boundaries, might prompt a deeper awareness of environmental issues and thence promote more sustainable activities. On the other hand, the collapse of natural services, which might become unable to deliver needed resources, might induce an adaptation of human activities that lead to the severe alteration of local natural equilibria. Essentially, this exploration confirms the hypothesis that the components of a complex Social-Ecological System might be more deeply interlaced than it might appear at a first glance and that the impacts of the internal dynamics of an *adaptive cycle* might easily spill over the other *cycles*, potentially with unanticipated effects, at any scale of the hierarchy. This might be especially relevant when dealing with disasters: at this point it appears that their disruptive impacts might escalate as well as cascade from a *cycle* to an other, amplifying their threatening potential. Nonetheless, it is relevant to observe that also the *reverse* interactions presume an "alignment of susceptibilities": correspondingly to the "original" interactions, their potential might be realised only if the appropriate conditions are met. In other words, also in this case, a propagation of effects, either reinforcing of detrimental, might take place only if the components of the Social-Ecological System lie in the *adaptive phases* viable to be affected from the interactions.

2.1.1 Implications of the Social-Ecological Panarchy for disaster risk management

This observation suggests, or rather strengthens the intuition that interactions define a potential force that prompts from a *cycle* and impends on the development of the other *cycles*, but has no effects until the appropriate conditions of susceptibility come into reality. This interpretation might be especially suggestive when approaching disaster dynamics. The Social-Ecological System adopted in the present case focuses on a river basin: as previously suggested, floods represent a natural hazard that involve the natural processes *cycle* and might impact the anthropic *cycle*. Whether the disruptive effects occur or not, it depends significantly on the conditions of the anthropic *cycle*: a human community that is flexible and adapted to the riverine dynamics has a higher probability to successfully deal with floods, surviving the event possibly unharmed, rather than a rigid and constrained human structure that might result unable to absorb the impact and thence suffer grave damages. Where the river constitutes a hazard, human communities must be vulnerable and exposed to that hazard in order to suffer from the impact. In this sense, the (*revolt*) interaction represents the risk, here the flood risk, that might or might not materialise (Fig. 2.4).

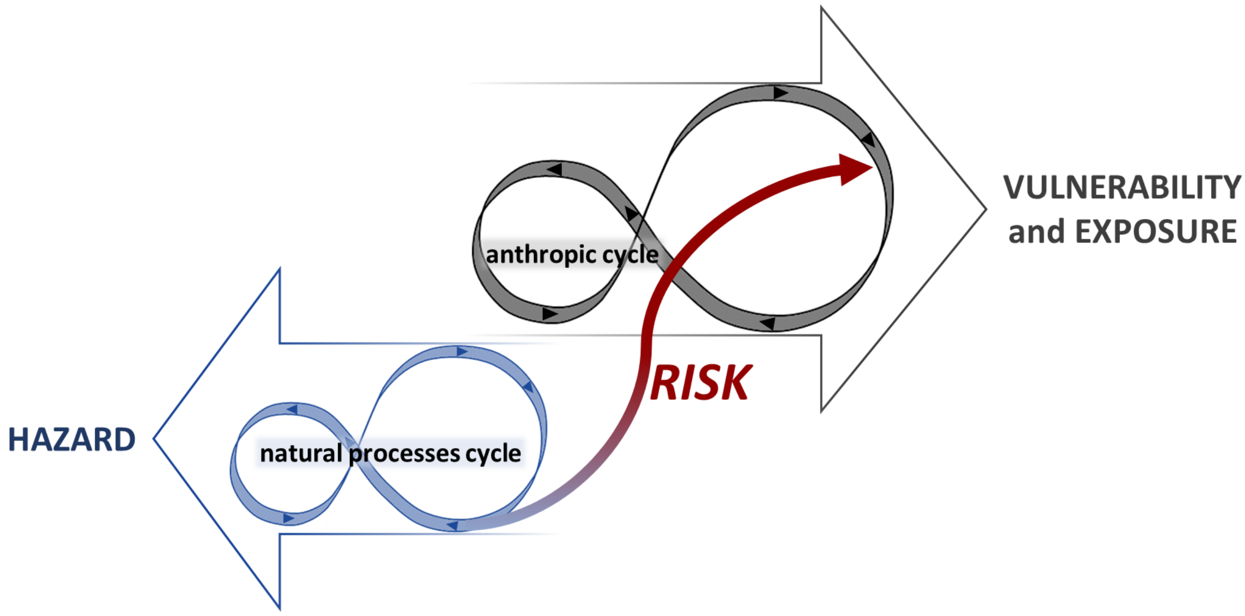


Figure 2.4 — An example of the dynamics of a disaster in terms of hazard, vulnerability, exposure and risk, within the framework of the Social-Ecological Panarchy.

Nonetheless, the previous observations lead to the suggestion that this configuration is far from the only possibility: as the *revolt* interaction might ascend as well as descend the levels of a panarchy, it derives a generalisation of the common adopted terminology. That is, within this framework, any *adaptive cycle* might be a threat to the others, but it manifests as a hazard when it reaches the *phase* of release, hence the state of collapse: from this state, it has the potential to affect the other *cycles*, thus a risk is moulded. Only if another *cycle* is vulnerable and exposed to the impacts, the risk can materialise: at this point, a disaster takes place, inducing the collapse of the impacted *cycle*. Significantly, this dynamic is not scale-dependent, in the sense that a disasters might strike larger or smaller scales than the originating one: it depends on the "alignment of the stars" (Holling, 2001, p. 404).

Following from these observations, the attempt to trace the conditions for such an alignment might be pursued. In other words, it might be relevant to point out the most sensible *phases* of the *adaptive cycle* for a component of the hierarchy. That is, which are the most critical conditions for a component of a Social-Ecological Panarchy? Which *phases* benefit most from the consolidating momentum of a *remember*-type interaction and which other *phases* contribute most to the detrimental impacts of a *revolt*-type interaction? When dealing with the effects of the *remember*-type interaction, it comes apparent that the crucial moments of the *cycle* lie in the conservation and in the *reorganisation phases* (Fig. 2.2a and 2.3a): if a component is stable enough, it might exert a supporting influence on an other component that is struggling to recover from a severe disruption. Nonetheless, these *phases* are located on the edge of some critical and volatile boundaries. Indeed, the *conservation phase* represents stability as well as it encloses and grows the seeds of the eventual fall. That is, the equilibrium reached at the peak of development is inherently fragile (except for possible *traps*, similarly unfavourable, see Ch. ii) and misleads into relying on a stability that is only "the lull before the storm". In particular, it is the transitional and unpredictable period when a *revolt*-type interaction might strike with its disruptive potential, hence it is a crucial nucleus of vulnerability. Even after the exhaustion of the force of impact, that "storm" might persistently rampage and extend its ravaging effects throughout a *back-loop*, which might constrain the reach towards the *reorganisation phase*. There a new path of development waits to be unravelled, but the proximity to the uncertainty of the previous period looms on that new beginning. As a consequence, it appears that the most desirable conditions for a component of a Social-Ecological Panarchy is to lie within the *fore-loop*: there the support of the *remember*-type interaction has led to the engagement in new opportunities, that are experimented and explored. In this condition, it is possible to benefit from the innovations without toughening over a rigid architecture. In other words, this discussion suggests that, ideally, the components of a Social-Ecological Panarchy should reside in the *fore-loop*: not too forwards, in order to distance itself from the dangerous edge of a collapse, while not too backwards, in order to overcome the uncertainty of a new beginning. In other words, a component should be testing new development paths, even favour one over the others, but never settling over a stiffened perspective. It means that the component remains flexible and adaptable, while enhancing its potential in terms of assets and resources. It pursues some solutions, though keeping open to innovation. It might be considered as a constant process of controlled destruction: creativity is encouraged, strategies are enacted, but internal restraints are destroyed before they could jeopardise the perspectives of the component, thence the experimentation starts again. From the *exploitation* to the *conservation*, then backwards along the *fore-loop*, destroying the constraints that would cause the fall in the *release phase* and continuously reshaping the component. This does not mean that a disaster would never be able to affect the component: unprecedented events, unforeseen feedbacks, external forces might still exert threatening influences. Nonetheless, focusing on what might happen would mean to be grounded on possibly unpredictable events, whereas promoting the permanence in the *fore-loop* encourages the mitigation of internal susceptibilities in order to reduce the disruptive potential of a disaster. It suggests a sort of oxymoron: a manifold of frequent and punctual disruptions that assists the preservation of the overarching integrity.

2.2 Resilience and Sustainability within a Social-Ecological Panarchy

The previous observations drew the main features of a Social-Ecological Panarchy and suggested some insights on the implications of the panarchical dynamics on such model, while also introducing the issue of preserving survivability through constant renovation. Thus, the ground appears sound enough to facilitate a broader discussion around the concepts of resilience and of sustainability.

In particular, it might be relevant to come back to the interactions: both *cores* are the expression of the mutual influence and interdependence among the components of a Social-Ecological System (SES), hence an exploration of their meaning within a Social-Ecological Panarchy should start from their very origin. Among the interactions illustrated above, a further categorising criterion emerges: rather than a differentiation based on their effects (*remember*-type vs *revolt*-type), an other discrimination might stem from their source (anthropic vs natural *cycles*). Namely, it is possible to group interactions depending on whether they impact the anthropic *cycle* or they prompt from the anthropic cycle, or else, conversely, whether they prompt from the natural *cycles* or they impact the natural *cycles* (Fig. 2.5 and 2.6).

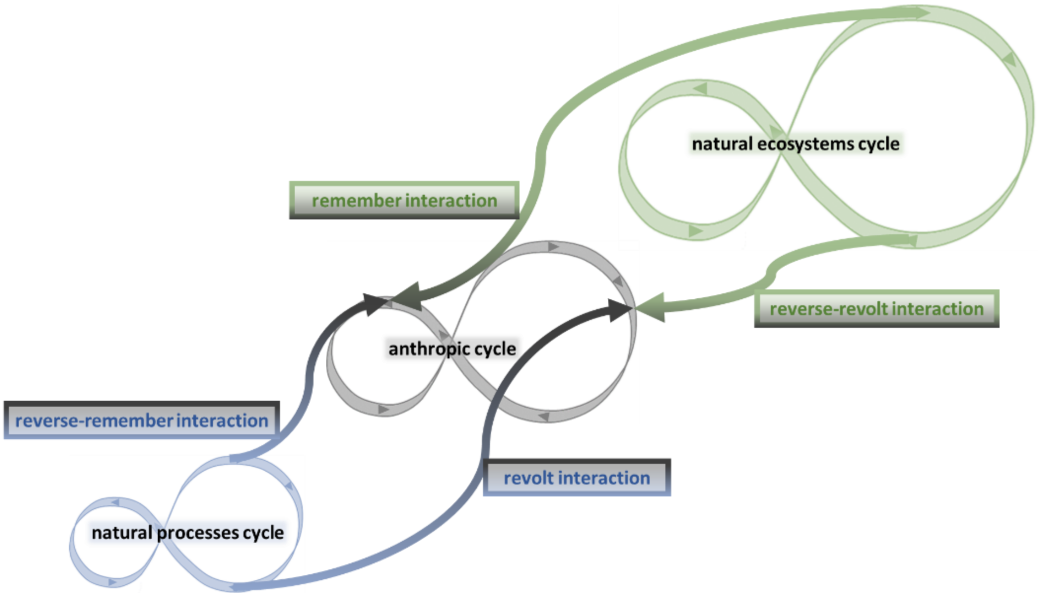


Figure 2.5 — A Social-Ecological Panarchy and the possible interactions that start from the natural cycles *and impact the anthropic* cycle.

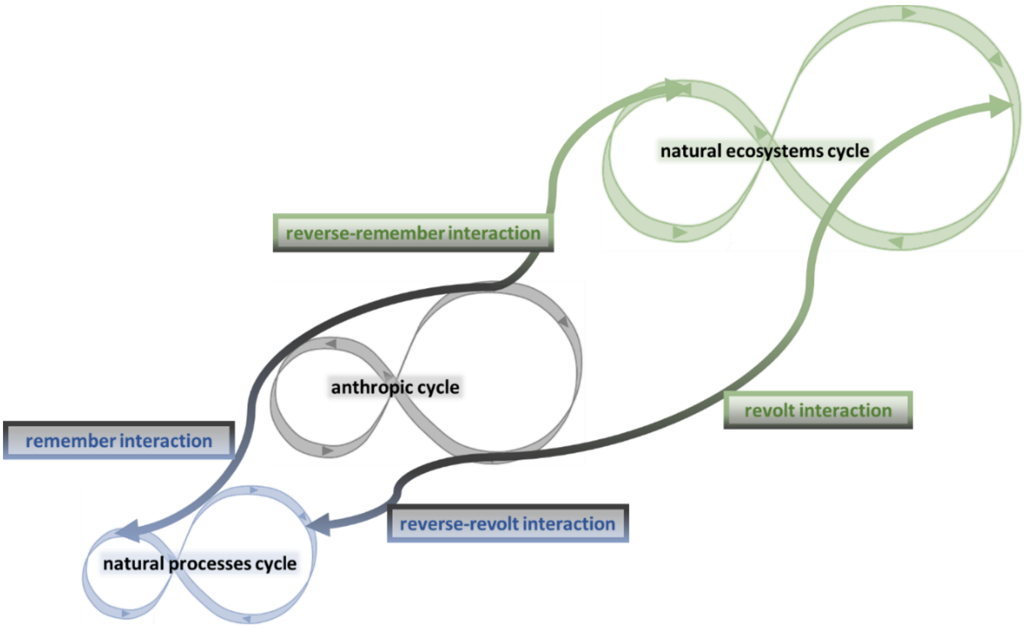


Figure 2.6 — A Social-Ecological Panarchy and the possible interactions that start from the anthropic cycle *and impact the natural* cycles.

A first condition that might be discussed is that occurring when all the possible interactions converge on the anthropic *cycle* (or, conversely, diverge from the natural *cycles*) (Fig. 2.5). What happens in this case? Every interaction would bring in a different contribution to the development of the anthropic *cycle*, hence it is interesting to grasp the overall influence that would be absorbed by this *cycle*. The *remember* interactions suggest a human component that is responsive to the feedbacks of the ecosystems: it develops according to the limits (*reverse-remember*) and to the support (*remember*) provided by natural processes. On the other side, the *revolt* interactions warn against an anthropic *cycle* that is vulnerable and exposed to the impacts of extreme pressures stemming from the natural processes (*revolt*) and functions (*reverse-revolt*), that might cause the disruption of human structures. Overall, the stabilising forces still correspond to an advantageous stimulus, whereas the destabilising forces confirm their undesirable threat. Consequently, assuming that human communities should and would mould their own development (rather than operating directly and exclusively on the other *cycles*), they should encourage a strategy that enhances the influence of the *remember*-type interaction, while preventing the *revolt*-type from taking place. In other words, an effective development strategy should promote a sounder integration with the natural environment, respecting natural processes (e.g. promoting buildings codes to control urban development within flooding areas), at the same time as human structures are designed not to suffer from losses from natural threats (e.g. implementing early-warning systems in order to allow locals to prepare for an extreme event). The central concept is that human components of a Social-Ecological System should learn from the processes of the natural dynamics as well as they should prepare in advance in case of severe hazards. This attitude is currently called *resilience*. Resilience is broadly defined as the capacity to learn from the environmental processes in order to cope and adapt to external pressures preventing heavy damages. In this case, resilience deals with encouraging *remember*-type interactions and inhibiting *revolt*-type interactions, all that converge on the anthropic *cycle*. In particular, *revolts* are prevented through modelling the anthropic cycle itself in terms of mitigating vulnerable and exposed conditions.

Nonetheless, this is just one side of the issue. Actually, the other four possible interactions diverge from the anthropic *cycle* and affect the natural *cycles* (Fig. 2.6). Similarly to the previous case, the human component might exert a force able to enrichen and support the development of natural systems (*remember*-type) or it might induce the destruction of natural equilibria (*revolt*-type). Once again, *remember*-type interactions lead to desirable, more stable conditions whereas the *revolt*-type ones prompt an unwelcome, disruptive chain of events. The assumption that the human component should and would act on its own development is still valid in this context. Additionally, it would still hold true that *remember*-type influences should be enhanced, while *revolt*-type interactions should be prevented. What differs in this arrangement is that these requirements would translate in human activities that are devoted to restoring damaged or endangered natural systems (e.g. planting vegetation in riverine areas severely misused), while extreme effort would be placed in minimising the human impacts on natural components (e.g. promoting regulations against hazardous spills). That is, the human component of a Social-Ecological System would nurture environmental systems, while limiting as far as possible its own detrimental effects. This attitude is currently called *sustainability*. Sustainability represents the overall endeavour of human communities to promote a sound coexistence with the bio-physical systems, where flux of resources and information is bi-directional, addressing human needs while never exceeding natural capacities. Once again, sustainability deals with encouraging converging *remember*-type interactions and inhibiting *revolt*-type interactions, but in this case they all diverge from the anthropic *cycle*. In particular, *revolts* are prevented through modelling the anthropic *cycle* itself in terms of mitigating hazardous conditions.

In light of the above considerations, it appears that the panarchy framework provides a peculiar perspective on the concepts of resilience and of sustainability. The panarchical modelling aligns with the definitions of resilience and of sustainability adopted in the wider literature, while immersing them in a unified, broader, more complex system. Through the panarchy, these two *cores* share the opportunity to act on a same system, hence it is possible to visualise the premises and consequences of both, and to evaluate their possible synergies or oppositions. In a few words, it is possible to dispose of a model that has the potential to allow for an integration of these domains. Although it is a qualitative representation, a Social-Ecological Panarchy might provide an integrated starting point for further discussions on the combinations of disaster risk reduction approaches and environmental-driven strategies. For the moment, it is possible to suggest some additional observations. For instance, it appears that both resilience and sustainability share the same attitude towards the interactions: that is, both rely on the encouragement of the consolidating *remember*-type interactions and the defusing of the destabilising *revolt*-type interactions. The difference lies in the outlook of these approaches. Resilience operates on the influences that act on the anthropic *cycle* (Fig. 2.5), whereas sustainability deals with the effects on the natural *cycles* (Fig. 2.6). The *cores* share the same principles, although the application follows opposite directions. At their roots, these *cores* might be more similar than it might appear. This might also imply that their integration in a common development strategy might be less complicated that it might be feared: the rooting concept is that human components should mould their own development path in order to pursue an equilibrium between furthering its own progress and acknowledging natural boundaries. In particular, given the non-linear, mutual feedbacks that take place within a Social-Ecological Panarchy, one *core* should not prevail on the other: both are necessary, but alone they are not sufficient. Indeed, going too far towards one direction would mean neglecting a significant portion of the interlaced nature of a Social-Ecological Panarchy. This is the reason behind the assumption of resilience and of sustainability both as *cores*, equally fundamental: the complex system cannot persist in the long period if failing to address either of them. The portrayal of human components that should aim to a balance between the resilience and the sustainability *cores* evokes an image already delineated: such an unstable equilibrium that fluctuates between two extremes reminds the suggestion of a fluctuation along the *fore-loop* as the most desirable state for a *cycle* (see Ch. 2.1). In this particular context, assuming that an anthropic *cycle* remains in the *fore-loop*, what would happen? To begin with, the *cycle* would be expanding its structure while still being receptive enough of the influences from the natural *cycles*: the anthropic functions would be consolidated enough to prompt new paths and at the same time they would be flexible enough to implement the flux of information from the natural components (*exploitation phase*, converging *remember*-type interaction). Yet, while experimenting, the anthropic structure would achieve a point where it is consolidated enough to support the natural components: resources would be carefully utilised and distributed, so that it would be possible to contribute to the overall stability of the system (*conservation phase*, diverging *remember*-type interaction). Nevertheless, rigidities would not be allowed to accumulate, in order to prevent the trigger of any kind of destructive force (*conservation phase*, converging and diverging *revolt*-type interaction). In other words, the human components of a Social-Ecological Panarchy should enhance an approach funded on a continuous renovation and adaptation to external pressures. In line with the recommendations that emerge from the common literature, the Social-Ecological Panarchy model advocates a constant, transformative adaptation of the human components to the surrounding natural environment. This approach would also limit the occurrence of an "alignment of susceptibilities". In particular, rather that minimising risk through the control of natural processes, that has often turned into unprecedented and unanticipated consequences, risk is deactivated by properly modelling human systems. That is, natural *cycles* are completely free to unravel (at most, they receive supporting influences), whereas the anthropic *cycle* is maintained in the *fore-loop*. It might be interesting to observe that in this way neither resilience nor sustainability are optimised: it is a compromise between these two tendencies. It is a common ground to build up and boost synergies. It should be also bared in mind that this does not mean that collapses would not be able to affect the anthropic *cycle* in any condition: it is more of a "*plan for the expected, prepare for the unexpected*" approach. It means that any possible effort should be put to prevent losses and damages, while accepting that when uncertainties exceed experience and anticipation, inevitable events might still take place. The Social-Ecological Panarchy acknowledges this possibility and provides a framework to guide a renovated development endeavour.

After modelling and discussing an hypothetical Social-Ecological System, the research interest might turn back to the local territories, where questions arose in the very beginning. After all, it is to deepen the understanding of local social-ecological dynamics that the modelling endeavour was prompted in the first place. Hence, at this point it might be relevant to come back and investigate human landscapes and communities, in order to take a renovated look at their status and perspectives through the lenses of the Social-Ecological Panarchy. In other words, it might be the right moment to shift from a conceptual heuristics to an interpretative effort that would then lead to a positivist approach. Given this, it is time to draw assumptions and design hypotheses to apply the perspective of the Social-Ecological Panarchy to operative questions and try to seek for concrete answers. In particular, it would be relevant to address some issues rising from local territories, where impacts are suffered as well as innovation might come to light: what is occurring in our territories? Is resilience enhanced? Is sustainability endorsed? How are the local *adaptive cycles* developing? In this context, the Social-Ecological Panarchy appears suitable to further the comprehension of local dynamics, providing a base to establish a quantitative outlook to these complex matters.

3. Assumptions, objective, hypothesis and questions

Communities and activities develop in a constant exchange with the natural ecosystems. Information, resources and energy flow in multiple directions and scales, pervading the whole Social-Ecological System. As a consequence, when addressing the question of survivability of human and of natural components, acknowledgement has been gathering around the resolution not to neglect either of them, but rather to comprehend both urgencies within a common perspective. More and more frequently, strategies to enhance resilience against extreme events envisage solutions that include functions and services of natural ecosystems, while the struggle to re-establish a sound coexistence with natural landscapes is advocated as a pivotal factor for human development. Nevertheless, such an endeavour requires a heuristics able to depict complex, non-linear dynamics.

The primary *objective* of this study is to further the understanding of human-nature interactions and of the consequences on the survivability of the overall Social-Ecological System. In order to pursue this objective, the panarchy model was adopted as a viable support in such an effort. Consequently, the discourse concerning disaster resilience and environmental sustainability was narrated through the terminology and the postulations of a Social-Ecological Panarchy. It was possible to delineate the possible behavioural trajectories of the components of the Social-Ecological System and to identify the most desirable conditions for the Social-Ecological System.

Stemming from the discussion proceeded through the literature discourse and through the panarchy viewpoint, an overarching *hypothesis* then emerged:

> *The most desirable condition of the adaptive cycle (fore-loop) of the Social-Ecological System corresponds to a condition of high levels of disaster resilience and of environmental sustainability.*

In other words, the increasing and urgent demands to advance towards more resilient and more sustainable communities might find a concrete answer only if those communities promote an attitude of constant renovation and adaptation, that is, lying within the *fore-loop* of their *adaptive cycle*. A Social-Ecological System might consolidate its survivability in the long period only if all of its *sub-units* move towards and along their *fore-loop*.

Thence, the scope is to turn towards local Social-Ecological Systems, identify the *sub-units* and assess the condition of resilience and of sustainability of each, later combining such evaluations and draw some insight on the overall condition on survivability of the Social-Ecological System. In particular, some questions arose and guided the further research development.

First, *how to assess resilience and sustainability? How to combine the levels of resilience and of sustainability? Is it possible to predict it?*

The panarchy model and the Social-Ecological Panarchy in particular provided a conceptual foundation for this study, but at this point it is necessary to take a step further and build on these heuristics to design an operative research framework. Although the interpretation of the local processes is essential, further understanding and managing social-ecological dynamics require quantitative tools. Possibly, it would be meaningful to hold a potentially predictive tool, so that trends could be anticipated and evolutions be traced. Hence, it is necessary to examine the proposed instruments, their applicability and limitations, their compatibility with the Social-Ecological Panarchy. At the end of this process, it might even result necessary to develop an integrated positivist approach.

Second, *what is the level of resilience and sustainability of the sub-units of a Social-Ecological System?*

Once a quantitative tool is ready, it should be promptly applied to a Social-Ecological System to investigate on local conditions of resilience and sustainability. In this phase, appropriate case studies should be identified and the assessment framework should be tailored to local peculiarities. The Social-Ecological System should be decomposed into *sub-units* and thence the assessment might start.

Third, w*hat is the tendency among those communities?*

Enhanced the quantitative approach, the condition of resilience and sustainability of each *sub-unit* appears. In particular, the effort is to evidence local different levels of resilience and sustainability, so that local peculiarities could be detected. The major interest lies in the position occupied by each *sub-unit* within their own *adaptive cycle*: how far from the *fore-loop*? Are they lingering in the uncertainties of the *back-loop*?

Fourth, *what is the overall condition of the Social-Ecological System?*

Once the *sub-unit* have shown their *adaptive* status, it is time to take back the overall hierarchy and consider the conditions of the Social-Ecological Panarchy. Are communities converging towards the *fore-loop*? Are there any critical issues? Is it possible to identify some peculiar geographies of panarchical behaviour?

After delineating these questions, a further issue emerged. Although it will be more thoroughly delved into later, it might be relevant to anticipate it here, since it prompted a couple of additional research hypotheses. The fact is that human communities are made of people. The needs, ambitions and beliefs of people are pivotal in drawing development paths. Hence, while quantitively assessing the level of resilience and sustainability is essential in operative terms, this positivist approach might be overlooking a fundamental element: people, indeed. What do locals think of resilience? What about sustainability? How do they judge the level of resilience and sustainability of their community? Does it align with measured levels? And even further: given that communities should correspond to people's expectations and desires, would not it be possible to design some crucial elements of the panarchy heuristics based on people's requirements? Eventually, are there any specific characteristics that might be pivotal in leading to certain perceptions?

As previously mentioned, these inquiries will be addressed later. At this point, it is time to move towards the definition of a positivist paradigm under the guidance of the interpretivist paradigm. It is time to associate a quantitative dimension to the concepts of the Social-Ecological Panarchy. The discussion that follows will proceed in this direction.

v. PART 2 – …*to practice*

4. Literature review: positivist paradigm through statistical surveys

The struggle to quantification has been a human ambition all along History. Although first considered philosophers, then alchemists and later scientists, the aim to reduce phenomena to numbers, hence to a dimension that could be comprehended and managed is innate to humankind. The themes of resilience and of sustainability are no exception. The one thing that differs is the relatively shorter lifespan of those strives. Indeed, the concepts of resilience and sustainability as relevant to this present discourse emerged only recently, hence recent is also the emergence of ways to model and then to quantify resilience and sustainability. This does not mean that there is a paucity in attempts of assessment. On the contrary, the literature offers a wealth of frameworks, methodologies and paradigms to be adopted and implemented. In order not to get lost in such a dense offer, it might be beneficial to identify some key points that could guide the search. In other words, what it is needed to assess resilience and sustainability within the framework of the Social-Ecological Panarchy model? What are the pivotal pillars to support the architecture of a possible comprehensive assessment methodology?

a. Quantification of resilience

   This point is only apparently obvious. When approaching the question of assessment, first and foremost it is important to define what to assess and how. Concerning the resilience theme, there is not a shared agreement on either of these two points.

b. Quantification of sustainability

   This point shares a similar fate to the previous, but another shared question might be introduced here: there must be an agreement over the possibility to quantify this dimension, otherwise any effort would remain worthless.

c. Objective indicators

   Once the previous points are cleared out, it is necessary to decide on what strategy to employ. "Quantification" is not an exhaustive answer: quantitative estimations can be derived in many ways, often involving experts and practitioners.

d. Disaster-related measures

   A long-term perspective should envisage and prepare for the threat of a disaster, characterised by both a short- and a long-onset: an assessment methodology should keep at its foundation this perspective and bridge the gap between times of disasters and times of quiescence.

e. Combination of resilience and sustainability

   The Social-Ecological Panarchy model assumes that resilience and sustainability must be nurtured in parallel, hence an assessment methodology should merge them towards a combined output.

f. Equal relevance of resilience and of sustainability

   The assumptions Social-Ecological Panarchy model suggest a step further: not only resilience and sustainability should be combined, but they should also hold equal relevance, as in the process as much in the output.

The above-mentioned points could be summarised as the need for a quantitative assessment methodology that employs variables collected through objective processes and related to disastrous events, in order to combine and balance resilience and sustainability. Unfortunately, to the knowledge of the author, such a methodology is yet to be comprehensively developed. In other words, the literature is still lacking an assessment methodology that would respond to all the quantitative (*a., b.*) and qualitative (*c., d.*) properties of the these requirements and apply them to resilience and sustainability at the same time (*e., f.*). Nonetheless, the literature provides all the necessary and valuable pieces that respond to the above-mentioned prerequisites and that support the present attempt to give it a shape. That is, as anticipated, such points might be effectively employed as guidance. Therefore, the efforts that enrichen the literature and that are relevant to the present discourse will be here presented and briefly discussed, so that a new methodology could be later introduced. As suggested, it is not possible to convey here examples of combined assessment of the cores, hence two different sections will treat resilience and sustainability. From here on, the above-mentioned requisites will be referred to as *strongholds*, as they represent the foundations for the assessment methodology to be later developed. Nevertheless, it seems significant to start with clarifying why such a strong focus is put on the quantification of the *cores*, that is especially exploring the *stronghold c. objective indicators*, but providing support also for *the stronghold a.* (*quantification of resilience*) and *b.* (*quantification of sustainability*). While all the other *strongholds* somehow straightforwardly relate to the characteristics of the Social-Ecological Panarchy model (resilience and sustainability, and their balanced combination are the foundations of the model; disasters are assumed to hamper short- and long-term survivability of a Social-Ecological System), it might not be obvious the reason that leads to the choice of an objective quantification of resilience and sustainability, though rapidly suggested here at the beginning. Hence a brief discussion will precede the exploration of resilience and sustainability assessment methodologies.

4.1 Quantitative assessment and objective indicators

As suggested before, the possibility to associate a number to an abstract entity holds a strong significance to humans and researchers in particular. Such effort enables to better comprehend and somehow grasp partial control over that entity or the related processes. Although it is true that not everything can be reduced to numbers and that some entities might suffer an impoverishment in their meaning by doing so, quantification is still a fundamental endeavour, that assists in transferring concepts into practice and understanding the consequences that follow. The resilience and sustainability discussion embraces such struggle, even though no definitive solution has been devised, yet. The fact that no common agreement has been reached over a framework to assess resilience or sustainability might be due to many causes, as many debates have suggested (see e.g. Cai et al., 2018). The very fundamental problem stems from the definition of the *cores*: without a common statement on what to measure, it is not reasonable to expect a common methodology to perform that. This unresolved problem has been already discussed before, but a related theme should be advanced: as it is obvious that different research perspectives emphasise different aspects of such complex concepts, the difficulty of finding a one-for-all framework increases. In addition, the matter of validation retains a specific importance, though sometimes underestimated. As a matter of facts, it happens that such abstract entities are associated with numbers or perceptions that are affected by several biases: for example, the very choice of what to evaluate is entrusted to the sensibility of the researcher, while practitioners might be in charge of sharing their corroborated experience in terms of judgments and analytical weights. As a consequence, without a proper validation, it is difficult to estimate the real ability of a measure to represent a specific condition, let alone to ground expressed perceptions, albeit based on extensive experience. A further critical issue concerns the essence of the concepts of resilience and of sustainability. It has been implied throughout the present discussion, but it is as well rather evident: they are complex in nature. This feature might be less trivial than it seems. Complexity itself maintains a multifaceted meaning: it denotes that many different aspects are interlaced and that their relation might far less linear than it would be desirable; likewise, it might be more difficult than expected to understand all that is comprised within those concepts and to gauge it, step much more preliminary than trying to model it. This is the point where indicators might express at most their potential in order to address the premises of the present paragraph, that clearly are still valid and compelling, in spite of the suggested difficulties.

It might be interesting to start from the very beginning: what is an indicator? The dictionary defines an indicator as "something that shows what a situation is like" (Cambridge English Dictionary, n.d.-a): in other words, it is a tool, able to represent a certain aspect of a multidimensional problem in certain point in time and space. When multiple indicators are collected, they can be combined to form a composite indicator, otherwise known as an index, that is able to condense the numerous details into one statement. This property is rather advantageous: an index results more manageable and immediate to comprehend compared to single values, while retaining all the information provided by the partial indicators (OECD, 2008). Indicators can be evaluated in different points in time (given a fixed point in space): in this way, indicators and the related index are able to portray trends and evolution of state of a study area. Alternatively, indicators and indices can be assessed for different points in space (given a fixed point in time), in order to compare the state of different study areas. such versatility is not immune to weaknesses: for example, the compact nature of an index might mislead towards misinterpretations and misunderstandings whether the underlying complexity was not comprehended or some limitations were not fully acknowledged. A review of the main strong and weak points of an index has been proposed by the OECD (2008), and it can be adopted as a valuable reference and reminder (Table 4.1).

Table 4.1 – Advantages and disadvantages of an index (adapted from OECD, 2008.

ADVANTAGES	DISADVANTAGES
▪ Can summarise complex, multi-dimensional realities with a view to supporting decision- makers. ▪ Are easier to interpret than a battery of many separate indicators. ▪ Can assess progress of countries over time. ▪ Reduce the visible size of a set of indicators without dropping the underlying information base. ▪ Thus make it possible to include more information within the existing size limit. ▪ Place issues of country performance and progress at the centre of the policy arena.	▪ May send misleading policy messages if poorly constructed or misinterpreted. ▪ May invite simplistic policy conclusions. ▪ May be misused, e.g. to support a desired policy, if the construction process is not transparent and/or lacks sound statistical or conceptual principles. ▪ The selection of indicators and weights could be the subject of political dispute. ▪ May disguise serious failings in some dimensions and increase the difficulty of identifying proper remedial action, if the construction process is not transparent.

▪ Facilitate communication with general public (i.e. citizens, media, etc.) and promote accountability. ▪ Help to construct/underpin narratives for lay and literate audiences. ▪ Enable users to compare complex dimensions effectively.	▪ May lead to inappropriate policies if dimensions of performance that are difficult to measure are ignored.

It should be acknowledged that the above-mentioned disadvantages represent some significant issues. However, when the problem statement is well-defined, the choices are clearly justified and the analytical process is explained in detail, somehow such difficulties can be limited; although recognised and kept in mind, these critical issues should not halt the effort towards the development of an assessment methodology.

In particular, how does the resilience and sustainability discourse benefit from the development of indicators and indices? Why does such endeavour appear to be so valuable? One of the major concern is related to the multi-dimensionality of resilience and of sustainability: it has been already extensively discussed here and in the literature (Cutter et al., 2008; Diaz-Balteiro et al., 2017; Ju, 2017), but it should be noted that such complexity cannot but increase when the two *cores* are considered at the same time, as in this case. Thence, it is essential to employ a tool that is able to compound a scattered picture into a single output. At the same time, each and every component of both resilience and sustainability represent a specific feature, that should not be blurred and completely lost (Linkov, Eisenberg, Bates, et al., 2013). In addition, as previously suggested, such tools can be evaluated regularly, allowing to unveil the evolution of a system in its spatial and temporal dimensions: this is of utter importance for both *cores* (Ju, 2017; Sahely et al., 2005), as they present a dynamic rather than static nature. In other words, indicators that can trace a specific trend and yet converge into a composite index seems to adequately respond to these requisites. Nonetheless, such an effort is not relegated to academic progress, but rather might and should be proved valuable also in assisting practical initiatives. In particular, indicators and indices can play a preeminent role in policy processes. The possibility to understand the conditions of a system can inform authorities and stakeholders during decision making processes, consolidating the scientific base upon which policies are built (Ju, 2017). Along these lines, such tools can also guide the identification of priorities, in terms of both actions to implement and areas to involve (Cai et al., 2018). Eventually, indicators and indices might be employed in the follow-up activities to monitor the performance of adopted measures and their impact on the system (González et al., 2018).

At this point, it might be beneficial to briefly run through the themes discussed here. The problem was posed by the statement of the *strongholds a., b.* and *d.* (respectively: *quantification of* *resilience; quantification of sustainability; quantitative indicators*). In particular, it seemed noteworthy to explore the issues posed by the quantification of resilience and of sustainability. Complex and dynamic in nature, any evaluation of such *cores* might be easily affected by personal biases, from the choice of the variables throughout the evaluation process, until the interpretation of the results. As a consequence, the multifaceted nature of indices seems appropriate to grasp the inherent multi-dimensionality, while their iterative estimation can follow the evolution of the system; in order to limit the possible biases as far as possible, quantitative indicators and statistical approaches seems to most likely give an objective fashion to the assessment. In light of these considerations, the use of indicators and indices appears justified within the present framework, hence the discussion can move forward the assessment of resilience and then of sustainability, as previously anticipated.

4.2 Assessment of resilience

4.2.1 Preliminary considerations

The tapestry of frameworks and methods that aim at quantifying resilience is indeed dense. Many different conceptualisations, indicators and indices, functions, analytical approaches, statistical techniques, have been proposed throughout the recent decades. One of the recurrent questions that dot the literature, though, is rather paradigmatic: "Resilience of what to what?" (Carpenter et al., 2001). It was originally introduced to highlight how securing the resilience of a specific system in a specific point in time is far from reassuring: that same resilience might come at the expense of the stability of other systems and of other times. In other words, when discussing and evaluating resilience it is important to keep in mind that effects, both positive and negative, might be transferred through temporal and spatial scales. That is, a system cannot be considered in isolation, not from other systems nor from its own unravelling development. All in all, these systems are complex systems and that of resilience is a complex conundrum. At the same time, the above-mentioned quotation came along the suggestion that resilience assessment tools should always state clearly the object of their interest since the very beginning. Evidently, it is fundamental to identify the main focus of a study and bound both time and area of analysis. However, the research efforts have been as well engaged in the qualification of resilience itself. Not only many definitions of resilience exist, but many different labels have been associated to resilience in order to display the specific and unique feature to be considered. In this manner, studies have appeared concerning social resilience (Adger, 2000; Fekete, 2018), community resilience (Cutter et al., 2014; L. Gunderson, 2010), urban resilience (Bertilsson et al., 2019; Meerow et al., 2016), just to cite some conceptualisations that can be encountered in the literature. However, they all share some traits in common, that are the fundamental properties of resilience that should always be the tenets of these endeavours. Along the narrative originally proposed by Holling (1973), resilience pertains 1. the entity of perturbation that a system can withstand maintaining the same structure and functions, 2. the ability to establish anew the pieces of organisation got lost, 3. the ability to retrieve lessons and implement them for a sounder consequent adaptation (Carpenter et al., 2001). In other words, such basic and pivotal features can be translated as the ability to 1. absorb, 2. recover and 3. learn. These tenets could be considered as *attributes* of resilience, as they represent specific assets that together create a resilient behaviour. Indeed, such paradigm is not new, but has been lying beneath or emerging in plain sight throughout the resilience discussion (Hosseini et al., 2016), even though some variations in terminology should be acknowledged (Table 4.2).

Table 4.2 – Some examples of the attributes of resilience (absorb, recover, learn) in the literature.

REFERENCE	ATTRIBUTES
(Resilience Alliance, n.d.)	"capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the system remains within the same regime, essentially maintaining its structure and functions. It describes the degree to which the system is capable of self-organization, learning and adaptation"
(Holling, 1973, p. 17)	"ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist"
(B. Walker et al., 2006, p. 2)	"capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity"
(Lhomme et al., 2013, p. 222)	"ability of a city to operate in a degraded mode (absorption capacity) and to recover its functions, despite the fact that some urban components are disrupted"
(Nan & Sansavini, 2017, p. 36)	"ability of the system to withstand a change or a disruptive event by reducing the initial negative impacts (absorptive cap- ability), by adapting itself to them (adaptive capability) and by recovering from them (restorative capability)"
(Chuang et al., 2018, p. 354)	"ability of a community to prepare and plan for, absorb, recover from, and adapt to adverse events in a timely and efficient manner, including the recovery and improvement of basic functions and structures of social systems"

As anticipated, the above-mentioned definitions are proposed for different qualifications of resilience, hence their blueprint effectively hold a value of general meaning. At the same time, resilience can be expressed in a variety of fields, hence different *dimensions* of resilience can be recognised. In other words, characteristics of resilience can be traced in many facets of a system. By the same token for the *attributes*, however, some recurrent *dimension* can be tracked throughout the common practice. In spite of some terminology variation as well, the overarching *dimensions* of resilience can be identified as: 1. demographic, 2. social, 3. economic, 4. health, 5. Infrastructural, 6. natural (Table 4.3).

Table 4.3 – Some examples of the dimensions (demographic, social, economic, health, infrastructural) of resilience in the literature.

REFERENCE	DIMENSIONS
(Cutter et al., 2008, p. 604)	ecological; social; economic; institutional; infrastructure; community competence
(Mayunga, 2009, p. 30)	human; social; natural; physical; economic
(Joerin et al., 2014, p. 547)	physical; social; economic; institutional; natural
(Shim & Kim, 2015, p. 14161)	biophysical; built-environment; socio-economic
(Beccari, 2016, p. 3)	governance; education, research, awareness and knowledge; information and communication; culture and diversity; preparedness; response; protection; exposure, experience and impact severity; resources; health and well-being/ livelihood; economic; adaptive capacity; coping capacity; innovation and capital; infrastructure and technical
(Cutter, 2016)	economic; social; institutional; information/communication; infrastructure; environmental
(Toseroni et al., 2016, p. 496)	social; economic; infrastructural; environmental; institutional
(Cai et al., 2018, p. 854)	social; economic; institutional; infrastructure; community; environmental/ecological; other

It is interesting to highlight that even when concerning a human system, resilience is usually represented through a natural dimension, recognising the dependence of human well-being on a supporting natural environment. This is a further corroboration of the assumption that human systems exist within complex Social-Ecological Systems, hence any human response can be understood and should be investigated only considering all the components of a Social-Ecological System, human or not. In order to recapitulate the previous findings, Table 4.4 provides an overview of the conceptualisation of resilience that can be deduced from the literature.

Table 4.4 – Common attributes and dimensions of resilience.

RESILIENCE	
attribute	*dimensions*
(resilience is the ability to...)	(resilience is expressed as…)
absorb	demographic
recover	social
learn	economic
	health
	infrastructural
	natural

It might still be interesting to spell out how resilience is operationalised, given this simplification. As follows from Table 4.2, resilience is considered as the ability to absorb an external impact well enough to able to recover the basic and then all the functions, taking the chance to learn strengths and weaknesses, in order to further adapt and develop the system. Such ability is expressed through some features that the systems shows, in terms of demography (characteristics of the population), society (e.g. social cohesion, social participation), economy (private and public wealth and resources), health (possibility to take care of the most vulnerable people), infrastructural (variety and safety of private and public assets), natural (characteristics of the environment).

The above considerations try to populate one of the *strongholds* presented at the beginning: resilience can be indeed quantified and some rather sharp boundaries can be outlined, as well (*stronghold a. quantification of resilience*). Now the question moves towards a further stage: how to quantify resilience? To what extent it is possible to directly include in such quantitative assessment factors about disaster events and environmental sustainability?

4.2.2 Assessment methodologies

The resolution to collect and describe all the methodologies that have been developed until now is far from reasonable. Actually, this is the reason why the above-mentioned *strongholds* were identified in the first place. Even so, the landscape of assessment methodologies is still so vast that it would be ridiculous to expect of being able to include an appropriate portrayal of all of them. Hence, here only a limited compendium will be sketched. The driving interest is identifying the methodologies most commonly employed and those with peculiar traits or analytical processes.

One of the efforts that would be impossible to overlook is the DROP (Disaster Resilience of Place) model (Cutter et al., 2008), that later served as a base for the BRIC (Baseline Resilience Indicators for Communities) model (Cutter et al., 2014). Both developed under the impulse of Cutter, they share an operationalisation of resilience by means of indicators and they have become a reference for all the subsequent works. The DROP model proposes a complex framework to understand "natural disaster resilience" (Cutter et al., 2008, p. 602). It acknowledges that human-environment interactions play a fundamental role both in triggering and in coping with a disaster, although the structure is willingly flexible enough to be adapted also to events not driven by natural forces. The framework encompasses two phases, one concerning the conditions that prelude to the disaster and one concerning what comes after the disaster, that is the way the disaster is dealt with. The BRIC model follows these assumptions, expanding the area of application, from the community of the

DROP model. The main objective is to evaluate the innate resilience of a system, in order to provide a reference to test policies and strategies against. Both the DROP and BRIC models answer the present requests to quantify resilience through indicators and to include some references to disaster behaviour. Nonetheless, they fail in comprehensively include environmental sustainability measures, although formally recognising the importance of environmental dynamics. Furthermore, such models have been criticised for lacking an empirical verification of their accuracy and reliability (Cai et al., 2018; Toseroni et al., 2016).

Another prominent figure in the disaster risk reduction discourse is Shaw. Among all his academic endeavours, the CDRI (Climate Disaster Resilience Index) framework (Joerin et al., 2014) stands. Within this model, the spatial scale is reduced to an urban area where the interaction among different communities takes place. The overarching danger is identified as climate-related hazards. Also in this case, the quantification of resilience passes through the evaluation of indicators, that comprehend all the facets of an urban system. However, similar is also one of the drawbacks: a natural dimension is included, but it does not expansively represent the state of the environment, even though some reference to the ecosystem services is mentioned. More critical is the matter of the variables collection: with the aim to keep track of the inherent variability within a city, data collection is performed through questionnaires delivered to local experts, generally engineers. Hence, experts are asked to provide their personal evaluation on specific urban assets and also on the relative their relative weight in influencing the broad resilience; later, the results are collected and analytically processed to produce a quantitative index. This is the most significant divergence from the *strongholds* presented here at the beginning: the CDRI introduces a factor of inherent variability, that is not allowed in the present framework.

From the literature emerges a further model that has gathered agreement and validation. Mayunga proposed the CDRF (Community Disaster Resilience Framework), taking the moves, among the others, from the DROP model developed just shortly before (Mayunga, 2009). The CDRF intends to combine quantitative indicators that encompass two main components: community assets and the phases of the disaster management cycle. Such indicators are primarily based on the suggestions of the DROP model, and data is collected from Statistical Bureaus and similar relevant sources; later, indicators are aggregated assuming equal weights, as no preferences over and within community assets or disaster phases' procedures were considered reasonable. By doing so, the preferred scale of implementation of the framework is the county level to address the most common level at which mitigation and risk reduction measures are undertaken (Mayunga, 2009). Although promising, the CDRF purposely excludes the natural asset: while recognising the importance of the natural environment on the development and resilience of human systems, the proposed focus on human communities prevent the framework from including nature-related indicators.

A variety of models have been designed to be applied to the national, county or urban/community level, as the discussion above here shortly illustrates. However, at least one step is missing, and that is the scale of the municipal level. Additionally, although several implementations and tests have involved areas all around the globe, there is still a paucity of models concerned with the resilience of the Italian region. Under these premises, an interesting work was proposed, named Comprehensive Disaster Resilience Index (CDRI) (Marzi et al., 2019). In this case, all the municipalities were involved in an analysis that covered the whole territory of Italy. The process follows from the widespread practice of collecting quantitative indicators, mainly, though not only, from the data offered by the Italian National Statistical Office. The indicators are later aggregated and different weights are introduced, statistically elaborated and verified. The authors also underline the importance for a framework to be replicable and applicable to other systems and contexts: the Comprehensive Disaster Resilience Index successfully respond to this wish. One of the major drawbacks of this methodology concerns once again the extensive inclusion of environmental indicators; in particular, the included ones, though highly significant, are treated at the same level of the other "human" ones, hence suggesting that their deficiency could be compensated by human capitals; this problem of compensation, or rather, substitutability plays a fundamental role in the present discourse, and while just mentioned here, it will be further explored later. In any case, an additional critical issue concerning the Comprehensive Disaster Resilience Index is related to disasters: even though the very name of the model carries such a suggestion and the indicators are selected to represent disaster resilience, measures of community behaviour in times of an extreme event are still not directly represented.

In this context, Toseroni proposed another example of modelling efforts applied to local Italian territories (Toseroni, 2017). Also in this case, indicators are employed, selected in order to represent the multifaceted characteristics of local communities, including aspects related to disaster risk. Indicators are collected to be merged by means of an analytical approach: in simple terms, the result, the IIR (*Indice di Impatto Reale*, that is Real Impact Index), is a score, easy to be interpreted, that aims at highlighting the strengths and the weaknesses of a human system. In this way, the IIR intends to assist local authorities in their commitment in reducing disaster risk, e.g. by identifying the areas that need to be more throughout improved. While the objective and the ambition of this model are easily embraceable, the methodology contrast with the *strongholds* presented at the beginning. In particular, similarly to the CDRI proposed by Shaw and briefly described above, the quantification of the indicators is a quali-quantitative process, meaning that experts are required to give a numerical value to the different options; furthermore, even though an analytical procedure (an AHP, Analytical Hierarchy Process) leads to the final index, it is still experts that are asked to express a preference to the different sub-groups of indicators, later becoming the relative weights of the sub-groups. It should be acknowledged that also in this case such approach is justified by the resolve to mirror as faithfully as possible the features of local communities. Yet, in this way the IIR introduces a relevant factor of variability that diverges from the present requisites, along with the absence of environmental evaluations.

There is a shared agreement over the need to include the knowledge of local communities in any strategy and framework (UNDRR, 2015): models make no exception, as some of the above mentioned research efforts evidence, by including the judgements of local experts in the resilience assessment. The Resilience Matrix (RM) model proceeds in this direction, while at the same time addressing an other concern, that is including explicit references to the phases and management of a disaster (Fox-Lent et al., 2015; Linkov, Eisenberg, Bates, et al., 2013; Linkov, Eisenberg, Plourde, et al., 2013). The model is based on the engagement of local experts and laypeople in the development of all the main steps of the process, from identifying the threatening scenario to consider, to identifying the critical functions to evaluate, to selecting the appropriate metrics to adopt. The collected information is then structured within a matrix, that relate the functions recognised as critical with the disaster cycle phases. Hence an analytical process is performed, in order to produce a numerical value that can be interpreted as a score: the matrix is coloured in different shades, depending on the level of resilience exhibited. This tool is intended to assist in identifying the areas of disaster management that need to be improved, thus helping local authorities in furthering risk reduction. An other relevant feature of the RM model derives from its foundation on the involvement of local communities: it does not only mean that local peculiarities are captured and highlighted, but also that it is highly flexible and it can be completely adapted to represent different geographical scales, different local characteristics, different specific needs. While acknowledging the relevance of this point, it has already been discussed why this feature cannot fit in the present framework, that is to say the impossibility of standardisation that affects the procedure.

The RRM (Risk and Resilience Monitor) proposes a solution to such critical issue (González et al., 2018). Local peculiarities are captured by focusing on small scales, rather than on wide areas that would blur the evaluation: in this case, the analysis is carried on at a commune and at a urban level. Quantitative indicators are thence collected from common official sources and elaborated to produce the RRM, that works as a sort of score, similarly to previously discussed models. What is highlighted here is the manageable visualisation of such result: the maps presented for the case study are highly effective in representing the local spatial variation of the state of risk and of resilience, hence suggesting the suitability of this kind of narrative for indices that describe levels of resilience over different areas. In addition, the analysis underlines the role of spatial scales in the shape of the results: as the RRM show a significant variation whether computed for the urban or the commune area, as well as for urban areas of different dimensions. This is suggested to be of extreme relevance for local planners and it also states once more the need to discuss over the proper scale to assess resilience.

In particular, when addressing a specific risk, it might meaningful to take into account the distinctive characteristics of the related hazard in order to identify the most suitable boundaries for the study area. In this regard and with reference to flood risk, a suitable level of assessment might be the river basin. Along these lines, a research was conducted that focused on a urban area developed within a river basin (Bertilsson et al., 2019). The quantitative assessment collects data concerning several dimensions, including measures related to the factors of flood risk (hazard, exposure, vulnerability), subsequently aggregating the indicators to produce the S-FResI (Spatialized Urban Flood Resilience Index). One of the objective of the methodology is to evaluate the variation of such index whether or not mitigation strategies would be implemented, in the present and in the future; in other words, the S-FResI is intended to both assess present resilience and to estimate resilience under different scenarios. Furthermore, the S-FResI is conceived to return a spatial representation of the different levels of resilience within the study area, hence allowing an immediate understanding of the conditions within the borders of the river basin. Although considerations about the conditions of the environment are not envisioned, this model offers an interesting perspective on modelling resilience through space and time.

Similar objectives are shared by yet an other model that is the RIM (Resilience Inference Measurement) model (Lam et al., 2016). Specifically, the model aims to associate a different level of resilience to every geographical unit included in the study area. Nonetheless, the research effort also took the chance to provide an answer, although preliminary, to the call for flexibility of assessment tools: the RIM model can be applied to different geographical settings, spatial scales, temporal contexts, hazard threats, without losing efficacy and requiring only to be adjusted to specific local features (Lam et al., 2016). This is evidenced by the several implementations of the RIM model in different points of time, space and risk scenarios that can be traced in the literature until now (Cai et al., 2016; Lam et al., 2016; K. Li, 2011; X. Li et al., 2016). The RIM model is based on quantitative indicators that go through a two-phase analytical process. Once the researcher has selected a study area and a specific disaster to investigate, the first phase is a cluster analysis that involves indicators directly related to the disaster and to the response showed during that disaster. The result consists in a grouping based on similar behaviour during disaster occurrence. Later, the second phase of analysis employs a discriminant analysis to identify the specific characteristics that can explain that behaviour; in this case the indicators follows the direction paved by previous research efforts devoted to identifying socio-economic and physical environment indicators relevant to resilience assessment. Such second phase also serves as a validation of the previous one, providing an answer to the need for substantiation of validity and internal consistency. Additionally, the discriminant analysis produces a predictive function that holds more than one advantage: it allows to comprehend the context that developed a specific disaster behaviour, but it provides as well a predictive tool for future disaster conditions. In other words, it assesses the present level of resilience and then it informs on the evolution of such level by employing common statistical variables.

It might be noteworthy to introduce here a study that takes extensive advantage of spatial indicators to approach the question of resilience, focusing on a county/city level (Fekete, 2018). In this case, an index of resilience is not produced as indicators are purposely left disjointed, but the relevance of this effort resides in another feature. The objective is to evaluate the effect of different definitions of resilience over its assessment, and then the explanatory power of some quantitative indicators, specifically considering their spatial variation. From the research emerges the relevance of the choice of indicators itself, highlighting how few are enough to describe specific aspects of resilience. This also implies that the meaning attributed to resilience significantly affects its quantification and representation. Additionally, the question of scale gains more strength, as the author recommends considering very small and local evaluations of disaster effects. Thence, locality demonstrates once more to carry conceptual meaning and operative manageability.

The review proposed above is evidently partial, as many more models and assessments tools enrichen the literature. In spite of this limitation, however, it is still possible to draw some significant conclusions. In this regard, it might be helpful to come back to the *stronghold* presented at the beginning. First of all, it might be relevant to remind that this section treated only resilience assessment methodologies. Unfortunately, resilience and sustainability were not found to be effectively combined, although some efforts were made to include environmental conditions into resilience computations (see e.g. Joerin et al., 2014; Marzi et al., 2019). As a consequence of not extensively treating environmental sustainability in the above lines, the *strongholds b., e., f.* (respectively: *quantification of sustainability*, *combination of resilience and sustainability*, *equal relevance of resilience and of sustainability*) should be excluded for the moment. Hence, what about resilience *per se*?

All the above mentioned models propose a different procedure to associate a numerical dimension to resilience, hence it appears reasonable to assume valid the hypothesis that resilience might indeed be quantified (*stronghold a. quantification of resilience*), in agreement with the findings of the previous chapter (4.2). Now, how to do this holds a multifaceted answer. Some of the quantitative indices presented above (see e.g. Fox-Lent et al., 2015; Joerin et al., 2014; Toseroni, 2017) substantially relies on quali-quantitative assessment techniques, based on the judgements of local experts: it has already been discussed that such approach unfortunately contrast with the present framework (*stronghold c. objective indicators*). Nonetheless, other researches show that it is possible to implement objective quantitative indicators and some early works (see e.g. Cutter et al., 2014, 2008) still hold a pivotal role in this direction. Then, the question of integrating disaster-related variables arises (*stronghold d. disaster-related measures*) and the answer seems affirmative: many combinations have been proposed, some also considering common socio-economic and physic variables along with disaster behaviour (see e.g. Lam et al., 2016; Mayunga, 2009). It might be noteworthy that in this context the identification of the proper assessment scale assume a major role (see e.g. Fekete, 2018) and many studies involve rather small geographical units (see e.g. González et al., 2018). At the same time, some efforts have been spent also to provide assistance in estimating future conditions of resilience (see e.g. Bertilsson, Wiklund, de Moura Tebaldi, et al., 2019; Lam et al., 2016).

At this point, many pieces have found their place in the wider picture of an integrative assessment tool for resilience and sustainability. However, as mentioned before, one of the two halves still demand a meaningful discussion. Thus, in the following section the question of sustainability assessment will be investigated.

4.3 Assessment of sustainability

4.3.1 Preliminary considerations

When it comes to environmental sustainability, the attention is necessarily torn between the natural environment and the human communities. It has been already suggested that “sustainability” is an anthropocentric concept, but at this point it becomes a critical issue: what should be measured? What about nature and what about humans? As this *core* brings to the fullest the expression of the inter-relation between natural and human systems, it seems legit to question how to measure sustainability: does it concern only characteristics of the environment or should it rather represent only human processes? In this case, Social-Ecological Panarchy model provides a guidance, especially in the definition of what is intended with “sustainability” within the present framework. In other words, what should be investigated. Also, the previous discussion about resilience might be considered as well as a significant reference for comparison: since the present attempt is to outline an innovative assessment methodology that encompasses two main *cores*, it might be appropriate that the two halves are treated in a specular fashion. Hence, it might be significant to recall the key points unravelled until now.

The first element is represented by the definition of sustainability. This *core* describes the ability of a human system to carry on its functions without hampering the survival of ecosystems. As a consequence, features related both to human activities and to natural processes are needed to explain sustainability. At the same time, resilience has been previously defined through *attributes*, that represent the multifaceted essence of resilience, along with *dimensions*, that represent the areas in which resilience is expressed. A similar procedure might be developed for sustainability. Accordingly, it might be interesting to identify some *attributes* that would be evidently affected by the anthropic system, especially when such *attributes* could be considered as a sort of threshold for a disaster. In other words, here sustainability must be described by some *attributes* that represent a condition of the ecosystems that can be directly and evidently affected by anthropic activities or, conversely, characteristics of the anthropic system that can directly affect the condition of the ecosystems; in both cases the extreme extent of such interaction would mean falling into a state of disaster. Then, some *dimensions* would portray the different aspects that could be a symptom of a sustainable behaviour. That is, *dimensions* would comprise several features of both ecosystems and anthropic processes that are directly interrelated and can work as a symptom of a sound human-nature coexistence. It might be noteworthy to spend some more words on the fact that, conversely to resilience, sustainability is necessarily evaluated by a mix of human and natural features, some that grasp their interrelation. This should not be considered as a contradiction to the definition of sustainability as a human feature: within the Social-Ecological Panarchy model sustainability is definitely an anthropocentric concept as it captures an attitude of the anthropic system, as much as resilience does. Nonetheless, sustainability is also the *core* more related to the natural ecosystems, hence it logically encompasses features of the natural environment itself. Additionally, it might be interesting to remind that resilience assessment tools often include some environmental dimension and that it has been anticipated that this theme would be developed later: this is the point where such dimension comes under the spotlight. This does not imply that sustainability is a proxy of resilience: they are distinct *cores*, yet they are both equally necessary for a sound survivability of the Social-Ecological System. In other words, where sustainability and environmental concepts are collapsed into a mere *dimension* of resilience, in this present framework the focus is on survivability, hence the “natural” theme gains a specific and equivalent worth to the resilience one.

At this point, coming back to the ongoing discussion, it might be assumed that the above considerations partially address the *stronghold b.* (*quantification of sustainability*): it might be assumed that sustainability should be assessed through *attributes* and *dimensions*, and the desired characteristics of such *attributes* and *dimensions* have been sketched. However, a further question raises: what should be actually assessed? Furthermore, how to manage this matter through indicators? Once more, the literature can provide fundamental prompts.

4.3.2 Assessment methodologies

Given the overarching structure settled just above (that is the representation of sustainability through *attributes* and *dimensions*, along with its quantification through indicators), it would be beneficial to explore the efforts already spent to identify the peculiar characteristics of sustainability, how it is expressed and which variables are commonly adopted to portray this *core* in terms of ecosystem wellbeing and human processes.

When discussing about ecosystems, one of the most important guides is provided by the Millennium Ecosystem Assessment. This initiative was prompted by the United Nations Secretary in 2000. The major objective was to “assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being” (Millennium Ecosystem Assessment, n.d.). Along these lines it is possible to recognise the acknowledgement of the unavoidable mutual influence between humans and nature, that is addressed by the Millennium Ecosystem Assessment providing several references over a wide range of related topics. It might be interesting here to start the exploration from the very beginning, that is ecosystems themselves. In particular, it might be noteworthy to shed some light on their functions and services (Millennium Ecosystem Assessment, 2003b). Actually, within an anthropocentric framework, the concept of ecosystem service fits rather well: they support so extensively human processes and activities, that the soundness of ecosystem services has become a synonym for ecosystem wellbeing. In a few words, ecosystem services represent the natural benefits that humans take advantage of in a Social-Ecological System. That is, humans rely on ecosystems in order to receive services that sustain every aspect of life. In this regard, four main categories of ecosystem services have been identified: provisioning, regulating, cultural, supporting. However, it appears significant to remind that another element come to play a key role: ecosystem functions, or the physical processes that allow the performance of services, hence the provision of benefits (Burkhard & Maes, 2017). In basic terms, services would not exist without functions. By this time the complexity of the problem should emerge quite clearly. The Millennium Ecosystem Assessment itself suggests that ecosystem services (and functions) represent a multifaceted question that inevitably requires a multidimensional approach, although at the same time it reassures on the possibility to translate such complexity in quantitative terms (Millennium Ecosystem Assessment, 2003b). Before that, another element might be introduced: integrity. The Millennium Ecosystem Assessment suggests and other studies seems to confirm (Morimoto, 2011) that a measure of the ability of the ecosystems to perform functions and deliver services is represented by the inner biodiversity, especially with regard to functional redundancy. What is emerging is that ecosystem wellbeing is related to comprising a wide variety of species and processes, that develops several different roles, that in some cases overlay (so that, e.g. different species perform the same role). Naturally, an ecosystem would consist of a certain assortment of species, constantly evolving and adapting: human activities, including management efforts, are able to hinder this equilibrium; even when the aim was to protect the status quo, often the approach would be directed towards rigid conservation, that does not respect the inherent variability of ecosystems. This is the reason behind the introduction of integrity as a significant feature of ecosystems: integrity represents how pristine is an ecosystem or, conversely, how much an ecosystem has been negatively affected by human interferences. It might be significant to point out here that integrity does not reject the inherent change of ecosystems, but rather it intends to trace the hindrance of humans over such processes. At this point, it seems that the *attributes* of sustainability can be identified. From here on, sustainability will be characterised by the state of ecosystem services and functions, along with their integrity.

Furthermore, the brief above presentation might appear to introduce a preliminary exploration over the *dimensions* of the sustainability *core*. Indeed, established that a sound coexistence between humans and nature founds its grounds on a stable performance of ecosystem services, this feature holds such a relevant meaning that it should not be disregarded, even when considering the areas in which *sustainability* can be recognised. In this regard, the Millennium Ecosystem Assessment might offer a significant perspective. When approaching the question of valuation, the focus is explicitly on the benefits provided by ecosystems and the suggested strategy focuses on the economic value that can be consequently attributed (Millennium Ecosystem Assessment, 2003a). At the same time, it is interesting to stress that the aim of the Millennium Ecosystem Assessment is centred on ecosystem management activities. In particular the objective is to provide a base to comprehend the impact of different management regimes, in terms of both improvements and losses. It also highlighted that even though some benefits might be effectively quantified in economic terms, some others, such as ecological or sociocultural values, should rely on different types of evaluation, although included in management evaluations as well. In other words, the Millennium Ecosystem Assessment suggests that a quantification of ecosystem services is necessarily interlaced with human interventions on such ecosystems, while recognising that not all values can be assessed by using the same metrics.

However, the centrality of ecosystems and the interrelation with human processes is not suggested only along the lines of the Millennium Ecosystem Assessment. For instance, it has been noticed that managing sustainability should necessarily account for ecosystems and their characteristics (Berkes et al., 2003). In particular, it is affirmed that sustainability finds its expression in management activities that do not force natural systems over their thresholds, but rather nurture diversity, variability, and possibly redundancy, rejecting the present common trend of optimising resources. In terms of assessment, the authors suggest that while quantitative analysis holds a relevant role, qualitative approaches, intended to grasp the overall functioning of a complex system, are indeed valuable and can be complementary to the others.

Sustainable management of ecosystems comes into the spotlight also when addressing the survivability of human systems (e.g. a city) under serious threats, such as climate changes. In particular, the discussion around the role of biodiversity and the importance of preserving it has gained momentum, to the point of advocating a critical role for biodiversity *per se* in human development and specifically in urban planning (Morimoto, 2011). At the same time, the author invites for a constructive debate over long-term local and management issues, that would include questions about ecosystem services and, consequently, biodiversity. In other words, the development of an urban setting is once more entangled to the integrity and well-being of ecosystem services.

In the previous presentation, the role of scale when treating complex systems has already been examined: the question of sustainability is not exempted from these considerations. In particular, the related discourse has been transferred from the urban planning level to the immediately higher level, that is landscape planning (Termorshuizen et al., 2007). In this regard, it has been remarked that sustainability should be considered as a pillar within landscape management, along with social and economic themes. Furthermore, it is advised that the effects of land use would be carefully evaluated in advance, as alterations to spatial patterns of human and natural areas might severely affect ecosystem services. Nonetheless, it is also acknowledged that the quantification of the relation between ecosystem benefits and ecosystem characteristics is still missing reliable and approved tools. Unfortunately, this issue also undermines a sound comprehension of the process through which the effects of human intervention on landscapes translates into loss of ecosystem services. Despite this weakness, the role of biodiversity is affirmed once more, as it is highlighted that a functionally connection with healthy ecosystems has already been proved, hence that might serve as a focus for further research developments.

The difficulties of identifying a causal relation between human and natural drivers of change, and alterations of the ecosystems are a serious and well-documented problem (Janetos et al., 2005). As mentioned above, this especially hinders assessment efforts, obstructing a clear identification of possible direct linkages between ecosystems changes and their delivered benefits, all the more when human systems and their wellbeing are concerned. Nevertheless, also in this case biodiversity assumes a pivotal role: drivers of biodiversity loss appear to be fairly well comprehended and they are mirrored in alterations of terrestrial and aquatic environments. This reveals its significance when combining it with the recognised relation between biodiversity and ecosystem services (Termorshuizen et al., 2007)

Thus far the exploration of quantification strategies has primarily focused on ecosystems. Still, this kind of measures could be classified as “environmental indicators”, as opposed to “sustainability indicators” (Pissourios, 2013). It is noteworthy, though, that this division comes in handy for descriptive purposes, but it might be less strict than it seems. Actually, both kind of indicators could be ascribed to “sustainability”, due to the unsettled broadness of the sustainability concept. In other words, if “sustainability” is considered only in terms of environmental impacts, then “environmental indicators” are definitely exhaustive, but when “sustainability” is approached as a broader concept, encompassing environmental, social and economic aspects, then a larger set of indicators requires to be included (Pissourios, 2013). As mentioned before, the Social-Ecological Panarchy model implies a broader interpretation of sustainability, hence it is interesting to explore some of the proposed assessment methodologies that adopt this same perspective.

Many research endeavours have fulfilled the objective of modelling sustainability indicators. As a matter of facts, a plethora of indicators can be traced in the literature, thus witnessing the interest and the urgency for a tool to measure and monitor resilience (Babcicky, 2013; Pissourios, 2013). Part of these indicators can be considered as "single indicators", in the sense that they tend to represent only one specific aspect of environmental quality, possibly in relation to human processes: examples are carbon dioxide, heavy particles, water quality as well as deforestation, national well-being and export flows (Babcicky, 2013). It is evident that this kind of indicators might be highly efficient in capturing a very specific characteristic of a complex system, but due to their specialised nature, they are unable to portray the wider picture composed of environmental, social and economic issues. In this perspective, the other kind of indicators appears to be more appropriate, that is "composite indices". It should be stressed that neither composite indicators have been exempted from criticism. In general terms, they might exhibit flaws both in the conceptual structure and in the methodological process, although this has not prevented nor limited their implementation (Babcicky, 2013). On the contrary, this unresolved dilemma represents a compelling demand for investing even more resources in this field.

Yet, some important achievements already represent significant references. At the European level, several efforts have been carried out to unravel the question of sustainability quantification, both at a national and at a local level. European Countries have been evaluated and ranked through a core set of indicators, identified by the European Environment Agency (EEA, 2005). The evaluation is focused on 10 main themes (Table 4.5) that comprise a total of 37 indicators. Such indicators are retrieved from public agencies (e.g. Eurostat, European Environment Agency, International Energy Agency) and are objective in nature. On the other hand, the main focus of the European Common Indicators (ECI) promoted by the European Commission (EC) are local communities, represented by either cities or municipalities (EC, 2003). In this case, ECI includes 10 central indicators (Table 4.5): for each indicator an headline indicator is identified and, depending on the kind of information needed, data is collected through a variety of means, ranging from surveys and questionnaires to objective data, always centring on local communities. It is interesting to observe that in both cases indicators pertain environmental issues along with human processes, hence suggesting that drivers of change (human activities) and their effects (environmental conditions) are complementary is marking the extent of sustainability of a certain area, be it regional or local.

In terms of scale, the national level is rather widespread. This might be due to the need of evaluating the efficacy of national and international policies related to environmental problems, hence the need to compare and rank the performance of countries. While the ECI was developed to allow for such a comparison within the European Union, another tool, the Environmental

Performance Index (EPI), was thought to involve countries all over the world (Yale Center for Environmental Law and Policy - YCELP - Yale University et al., 2012). In this case, 22 relevant indicators are identified and distributed into 10 policy domains (Table 4.5), whose stated objectives seek to reduce environmental pressures on human health and to promote ecosystems wellbeing along with sound environmental management (NASA Socioeconomic Data and Applications Center (SEDAC), 2012). It might be interesting to notice that the EPI is the evolution of the Environmental Sustainability Index (ESI), likewise developed by the Yale University and the Columbia University, in collaboration with the World Economic Forum and the Joint Research Centre. In its original configuration, the ESI encompasses 21 indicators that collapse into 5 dimensions of sustainability (Table 4.5): the parallel representation of natural and of human features is clearly stated (Abayomi et al., 2011). At the same time, it should be acknowledged here the extensive attention triggered by the ESI: several implementations and discussions have sparked around this tool, along with critical reviews aimed at furthering the discourse over sustainability quantification through indicators (Babcicky, 2013; Jha & Bhanu Murthy, 2003).

It has been hinted before that a major trend moves towards an assessment of sustainability at a national level and the above framework are aligned in this perspective. Nonetheless, the ECI suggests that that there is also the other way, that of looking at smaller scales. This kind of downscaling might reveal to be more pertaining when dealing with specific issues, such as water management. When this question is flanked with sustainability concerns, it might be more effective to address it at the level of a river basin. Yet, a paucity of research endeavours have embraced this challenge, hence the Watershed Sustainability Index (WSI) was developed to fill this gap (Chaves & Alipaz, 2007). Along with the missing attention over small geographical dimensions, the authors suggest that sustainability assessments should not be constrained by political boundaries, but rather cover the area most suitable for the purpose of the assessment itself. At the same time, they acknowledge that sustainability is a multifaced problem, hence a multi-dimensional tool is essential, one that would encompass both human and natural facets of the same system. Consequently, the WSI envisages 4 main indicators that comprise a total of 5 pressure parameters (Table 4.5).

A further downscaling can be pursued, though, one that the ECI has already anticipated: cities might the target of the evaluation. This interest is well justified by the growing power of attraction that cities are gaining worldwide: it makes sense to question their sustainability when people are converging towards expanding epicentres (Mori & Yamashita, 2015). The City Sustainability Index (CSI) moves some preliminary steps in this direction, establishing some pivotal cornerstones for any sustainability assessment concerned with cities. Among these, it is fiercely affirmed that sustainability should not be pursued (nor measure) accepting a compromise between the basic components, that are the physical, social and human capitals (Mori & Yamashita, 2015). Later it will be more widely discussed, but, in other words, the CSI assumes as crucial the principle of strong sustainability, meaning that every and each component of sustainability is equally important and thence should be considered, even in operative terms. In addition, the CSI recognises that cities are not independent nor isolated from the surrounding area, hence any sustainability assessment should take into account limits and thresholds not directly defined by the city borders and capacities. Eventually, the methodological structure is outlined: it is based on maximisation indicators, that describe the assets and products yielded by the city, and constrain indicators, that address environmental and equity issues (Table 4.5). That is, the CSI proposes once more the complementarity of human and natural aspects when discussing about sustainability, stressing how each component is necessarily affected and influenced by the other.

Table 4.5 – Indicator frameworks of sustainability.

METHODOLOGY	DEVELOPER	SCALE	ASSESSMENT STRUCTURE
EEA core set of indicators	EEA	national	1. air pollution and ozone depletion 2. biodiversity 3. climate change 4. terrestrial 5. waste 6. water 7. agriculture 8. energy 9. transport 10. fisheries
European Common Indicators (ECI)	EC	local	1. citizens' satisfaction with the local community 2. local contribution to global climate change 3. local mobility and passenger transportation 4. availability of local public open areas and services 5. quality of the air 6. children's journey to and from school 7. sustainable management of the local authority and local enterprises 8. noise pollution 9. sustainable land use 10. products promoting sustainability
Environmental Performance Index (EPI)	Yale University, Columbia University	national	1. environmental burden of disease 2. air pollution (effects on human health) 3. water (effects on human health) 4. air pollution (ecosystem effects) 5. water (ecosystem effects)

			6. biodiversity and habitat 7. forestry 8. fisheries 9. agriculture 10. climate change
Environmental Sustainability Index (ESI)	Yale University, Columbia University	national	1. environmental systems 2. environmental stresses 3. human vulnerability 4. social and institutional capacity 5. global stewardship
Watershed Sustainability Index (WSI)	(Chaves & Alipaz, 2007)	local	1. Hydrology 2. Environment 3. Life 4. Policy Issues
City Sustainability Index (CSI)	(Mori & Yamashita, 2015)	local	1. maximisation indicators 2. constrain indicators

At this point, it might be significant to recollect the main concepts unravelled through the above brief exploration of sustainability assessment frameworks, bringing back to mind the *strongholds* introduced at the beginning. The previous discussion (see Ch. 4.3.1) solved the issue posed by the *stronghold b. quantification of sustainability*, validating the pursue for a methodology to quantify this *core*. Thus, the above investigation was directed towards the identification of *attributes* and of *dimensions* of sustainability, questioning at the same time if the employment of quantitative indicators would be reasonable. A preliminary examination of the issues related to ecosystems revealed the pivotal role played by ecosystem services, the physical processes that yield them and the integrity of the equilibria that grant this functions (Burkhard & Maes, 2017; Millennium Ecosystem Assessment, 2003b, 2003a; Morimoto, 2011). Consequently, the *attributes* of sustainability can be overall identified as: 1. services; 2. functions; 3. integrity (Table 4.6). In other words, when studying a Social-Ecological System, the essence of sustainability is represented by a natural system that is able to soundly perform functions that deliver consistent benefits, profiting from an integrity granted by the human system.

At the same time, these considerations are reflected into the frameworks that aim to assess sustainability. Stated the urgent call for a quantitative tool, able to measure and monitor this *core* (Babcicky, 2013; Pissourios, 2013), the national scale of assessment seems to dominate the field (EEA, 2005; Morse & Morse, 2019), although attempts to downscale this efforts have been proposed, too (Chaves & Alipaz, 2007; Mori & Yamashita, 2015). Apart from this discrepancy, all frameworks converge in recognising the interrelation between human actions and natural responses. Consequently, the methodologies tend to include indicators related to the state of the environment (Abayomi et al., 2011; EEA, 2005), in some cases also encompassing the physical processes that are performed (Chaves & Alipaz, 2007). At the same time, ecosystems are evaluated also in terms of the effects suffered from external pressures (Mori & Yamashita, 2015; Morse & Morse, 2019). In parallel, complementary indicators generally tend to portray the human system that coexist and interact with the natural counterpart, spanning from political and productive issues to environmental awareness and local vulnerabilities (Babcicky, 2013; Chaves & Alipaz, 2007; EC, 2003). Accordingly, it is possible to identify some major topics that can serve as *dimensions* for the present purposes: 1. ecosystem integrity; 2. ecosystem benefits; 3. physical processes state; 4. external pressures; 5. human vulnerabilities (Table 4.6). In other words, sustainable characteristics of a Social-Ecological System can be traced in the richness of the services provided and in the entity of the benefits yielded; at the same time, the physical processes should proceed as much smooth and unaltered as possible and external drivers of change should be monitored; however, a sustainable management of the Social-Ecological System would not be possible if the human system was not stable and environmentally conscious.

Table 4.6 – Attributes and dimensions of sustainability.

SUSTAINABILITY	
attribute	*dimensions*
(sustainability is the defined through ecosystem...)	(sustainability is expressed through…)
services	ecosystem integrity
functions	ecosystem benefits
integrity	physical processes state
	external pressures
	human vulnerabilities

This might be the right place to spend some words on the *strongholds*: how does the research around sustainability issues populate them? In terms of indicators, the dominating trend seem to generalise the adoption of quantitative, objective indicators, hence confirming the validity of the *stronghold c.* (*objective indicators*) and the previous exploration also provides some hints to identify the appropriate variables to measure. Unfortunately, no direct mention of disaster pertaining the sustainability discourse was traced in the literature, thus the *stronghold d.* (*disaster-related measures*) appears not to be easily satisfied. It might be relevant to wonder, though, if "disaster" is actually a concept pertaining sustainability. That is, even without employing the term "disaster", the same meaning of an unprecedented loss of functions and potential might be implied, for example, when directing the spotlight on the importance of not altering natural equilibria or on the boundaries posed by natural processes. Moving towards the *strongholds a., e., f.* (respectively:

quantification of resilience, *combination of resilience and sustainability*, *equal relevance of resilience and of sustainability*), it might be relevant to observe how the situation is similar and specular to that of resilience. Once more, there seems to be a severe paucity of methodologies that explicitly merge the *cores* of resilience and of sustainability, thence neither in this discussion it was possible to identify an assessment methodology able to solve the issue posed by the above mentioned *strongholds*.

At this point it is significant to stress that in the above brief exploration only assessment methodologies that employed some kinds of indicators were included, given the prospect to meet the requests of the *stronghold c. quantitative indicators*. This translates in an inevitable exclusion of other assessment methodologies that still address sustainability, but adopt a different approach. In other words, the above exploration did not mean to overlook their relevance in the sustainability discourse. Nonetheless, although widespread and sound, methodologies like could not be included here. An example is provided by the analyses based on the concepts of emergy, exergy and ecological footprint (Kharrazi et al., 2014). These methodologies are deeply rooted in the sustainability discourse: emergy analysis might be one of the first most reliable instruments in the hands of researchers (Kharrazi et al., 2014). Their essence resides in the conversion of various flows, of energy or of products and waste, into a singular specific metric, as a common point of contact of the ecological and the economical domains. Their relevance and reliability is recognised and widely discussed, still, they do not fit the present framework: for instance, the present focus is not tend towards an economic centre; at the same time, resolving the analysis around a singular common denominator limits the collection and implies the loss of other precious and relevant information.

4.4 Viable indicators for a quantitative assessment

In spite of the presented difficulties, the above discussions about resilience and sustainability allowed to substantiate some fundamental *strongholds*. Since not all of such requisites could be satisfied, though, this might be a significant opportunity to introduce an innovative methodology in an attempt to bridge the identified gaps. Without any doubts, these would be just preliminary steps, but they might turn valuable, nonetheless. Nevertheless, before deepening the exploration of that potentially novel path, there is still some relevant information that might be retrieved from the previous research endeavours and that would be highly instructive. Indeed, the examined assessment strategies provide a collection of indicators that could serve as a basis for the selection of those proxies that would be eventually employed in the description of designated case studies.

Consequently, it might be beneficial at this point to recapitulate the indicators that have most widely been adopted throughout the previous investigations, starting from the resilience *core* (Table 4.7).

Table 4.7 — Collection of frequently employed indicators for the quantitative assessment of resilience, associated to relevant categories and themes, along with some examples of implementation.

CATEGORY	THEME	INDICATOR	SOURCE
DEMOGRAPHY	*age*	% population below 5 years old	(Lam et al., 2016)
		% population between the ages of 15 and 64 years old	(Joerin et al., 2014) (X. Li et al., 2016)
		% population below 65 years old	(Cutter et al., 2014) (Morrow, 2008)
		% population over 65 years old	(Morrow, 2008) (Shim & Kim, 2015) (Cai et al., 2016) (Marzi et al., 2019)
	race	race	(Cutter et al., 2008) (Lam et al., 2016)
		% non-Han Chinese population	(X. Li et al., 2016)
	gender	gender	(Cutter et al., 2008)
		ratio of males to females	(X. Li et al., 2016)
	population stability	% population not foreign-born persons who came to US within previous five years	(Norris et al., 2008) (Sherrieb et al., 2010) (Cutter et al., 2014)
		population change over previous five year period	(Sherrieb et al., 2010) (Cutter et al., 2014)
		population change from 2000 to 2010	(Cai et al., 2016)
		population growth	(Joerin et al., 2014) (Lam et al., 2016) (X. Li et al., 2016) (González et al., 2018)
		% population born in state of current residence	(Norris et al., 2008) (Sherrieb et al., 2010) (Cutter et al., 2014)
		% population that were native born and also live in the same house or same county	(Cutter et al., 2010) (Cai et al., 2016)
		% population proficient English speakers	(Mayunga, 2009) (Messias et al., 2012) (Cutter et al., 2014)
SOCIAL ISSUES	*social cohesion*	number of religious organisations/adherents	(Mayunga, 2009) (Cutter, 2016)
		persons affiliated with a religious organization	(Walsh, 2007) (Sherrieb et al., 2010) (Cutter et al., 2014)
		number of civic organizations	(Walsh, 2007) (Mayunga, 2009) (Sherrieb et al., 2010)(Cutter et al., 2014) (Cutter, 2016)
		Red Cross volunteers	(Cutter et al., 2014)
		Red Cross training workshop participants	(Godschalk, 2003) (Cutter et al., 2014)
		% population in communities with Citizen Corps program	(Godschalk, 2003) (Simonovich & Sharabi, 2013) (Cutter et al., 2014)
		spending on social programmes	(González et al., 2018)
		% population participating in political elections	(Peacock, 2010) (Sherrieb et al., 2010) (Cutter et al., 2014) (Lam et al., 2016) (Marzi et al., 2019)
	risk reduction policies	Ten year per capita spending for mitigation projects	(Godschalk, 2003) (Cutter et al., 2014)
		Presidential disaster declarations divided by number of loss-causing hazards	(Tierney & Bruneau, 2007) (Cutter et al., 2008) (Cutter et al., 2014)
	education	educational attainment/equality	(Mayunga, 2009) (Joerin et al., 2014) (Cutter, 2016) (Marzi et al., 2019)
		population over 25 but no schooling complete	(Cutter et al., 2010) (Cai et al., 2016) (Lam et al., 2016)

		negative absolute difference between % population with college education	(Morrow, 2008) (Sherrieb et al., 2010) (Cutter et al., 2014)
		% population with less than high school education	(Morrow, 2008) (Sherrieb et al., 2010) (Cutter et al., 2014) (Marzi et al., 2019)
		% population with diploma of senior secondary school and technical secondary school and above	(X. Li et al., 2016)
		local government finance expenditures for education	(Lam et al., 2016) (González et al., 2018)
ECONOMICS	*employment*	% of economically active population	(Shim & Kim, 2015)
		employment	(Cutter et al., 2008) (Mayunga, 2009) (Cutter et al., 2010) (Sherrieb et al., 2010) (Rose & Krausmann, 2013) (Cutter et al., 2014) (Cai et al., 2016) (Lam et al., 2016) (X. Li et al., 2016)
		% workforce that is female	(Joerin et al., 2014) (Lam et al., 2016) (Marzi et al., 2019)
	economic sectors	farms marketing products through Community Supported Agriculture	(Berardi et al., 2011) (Cutter et al., 2014)
		% labour force employed by federal government	(Rose & Krausmann, 2013) (Cutter et al., 2014)
		% employees not in farming, fishing, forestry, extractive industry, or tourism	(Sherrieb et al., 2010) (Rose & Krausmann, 2013) (Cutter et al., 2014)
	wealth and inequities	wealth generation	(Cutter et al., 2008)
		financial dependence ratio	(Shim & Kim, 2015)
		income	(Mayunga, 2009) (Sherrieb et al., 2010) (Brody et al., 2012) (Cai et al., 2016) (Cutter, 2016) (Lam et al., 2016) (González et al., 2018) (Marzi et al., 2019)
		savings deposit balances per capita	(X. Li et al., 2016)
		value of property	(Cutter et al., 2008) (Lam et al., 2016)
		gross domestic product per capita	(X. Li et al., 2016)
		% population living in poverty	(Cutter et al., 2014) (Joerin et al., 2014) (Cai et al., 2016) (Lam et al., 2016) (González et al., 2018) (Marzi et al., 2019)
		negative absolute difference between male and female median income	(Sherrieb et al., 2010) (Cutter et al., 2014)
		negative Gini coefficient	(Norris et al., 2008) (Sherrieb et al., 2010) (Cutter et al., 2014)
	assets	% vacant units that are for rent	(C. Johnson, 2007) (Cutter et al., 2014)
		% population that rents	(Lam et al., 2016)
		median value of owner occupied housing units	(Mayunga, 2009) (Cutter et al., 2014) (Cai et al., 2016)
		owner occupied housing units	(Mayunga, 2009)
		% female householder	(Cutter et al., 2010) (Cai et al., 2016) (Lam et al., 2016)
		% households with at least one vehicle	(Tierney, 2009) (Peacock, 2010) (Cutter et al., 2014) (Joerin et al., 2014)
		% households without a vehicle	(Cutter et al., 2010) (Cai et al., 2016)
		% households with telephone service available	(Cutter et al., 2010) (Burger et al., 2013) (Cutter et al., 2014) (Joerin et al., 2014) (Cai et al., 2016)
		% population with access to broadband internet service	(Cutter et al., 2014) (Joerin et al., 2014)
	tax revenue	municipal finance/revenues	(Cutter et al., 2008) (González et al., 2018)
		local tax revenue	(Shim & Kim, 2015) (Lam et al., 2016)
		local government finance general expenditures	(Lam et al., 2016)
	di sa st	property damage	(Cai et al., 2016) (Lam et al., 2016) (González et al., 2018)

		flood loss	(Brody et al., 2012)
		direct economic loss per capita	(X. Li et al., 2016)
PUBLIC HEALTH	*health status*	absence of psychopathologies	(Cutter et al., 2008)
		% population without sensory, physical, or mental disability	(Davis & Phillips, 2009) (Cutter et al., 2014) (Lam et al., 2016)
	health services	number of hospital beds	(Mayunga, 2009) (Cimellaro et al., 2010) (Cutter et al., 2014) (X. Li et al., 2016)
		number of social welfare homes beds	(X. Li et al., 2016)
		number of health care facilities	(Few, 2007) (Mayunga, 2009) (Joerin et al., 2014) (Cai et al., 2016) (González et al., 2018)
		number of psychosocial support facilities	(Springgate et al., 2011) (Cutter et al., 2014)
		number of doctors	(Cutter, 2016)
		non-federal active medical doctors	(Lam et al., 2016)
		number of physicians	(Norris et al., 2008) (Mayunga, 2009) (Chandra et al., 2011) (Cutter et al., 2014)
		% population under age 65 with health insurance	(Chandra et al., 2011) (Cutter et al., 2014)
BUILT ENVIRONMENT	*land use*	population density	(Ryu et al., 2011) (Shim & Kim, 2015) (Cai et al., 2016) (X. Li et al., 2016)
		impervious surfaces	(Cutter et al., 2008) (Brody et al., 2012) (Brody et al., 2014) (Cutter, 2016)
		% perviousness	(Cutter et al., 2014)
		total housing units per sq. mi.	(Cutter et al., 2010) (Cai et al., 2016) (Lam et al., 2016)
		% mobile homes	(Cutter et al., 2010) (Joerin et al., 2014) (Cai et al., 2016) (Lam et al., 2016)
	facilities	number of commercial and manufacturing establishments	(Cutter et al., 2008)
		number of large retail stores	(Rose & Krausmann, 2013) (Cutter et al., 2014)
		number of recreational centres and sport organisations	(Mayunga, 2009)
		number of hotels/motels	(C. Johnson, 2007) (Mayunga, 2009) (Tierney, 2009) (Cutter et al., 2014)
		number of public schools	(Ronan & Johnston, 2005) (Cutter et al., 2014)
		number of schools	(Mayunga, 2009) (Cutter et al., 2010) (Cai et al., 2016) (González et al., 2018)
		transportation network	(Cutter et al., 2008)
		rail miles per sq. mi.	(Cutter et al., 2008) (Cutter et al., 2014)
		total length of roads per sq. km	(Cutter et al., 2010) (Joerin et al., 2014) (Cai et al., 2016)
		megawatt hours per energy consumer	(Cutter et al., 2014) (Joerin et al., 2014)
		% population within 10 mi. of nuclear power plant	(Cutter et al., 2014)
		inverted water supply stress index	(Cutter et al., 2014)
	building age	% of housing that is permitted before 1985	(Shim & Kim, 2015)
		residential housing stock and age	(Cutter et al., 2008)
		% housing units built prior to 1970 or after 2000	(Cutter et al., 2014)
		% housing units built after 2000	(Cutter et al., 2010) (Cai et al., 2016)
	risk reduction facilities	% of area with facilities and installation for disaster prevention	(Shim & Kim, 2015)
		lifelines and critical infrastructure	(Cutter et al., 2008)
		buildings of various types (emergency management, government power, bridges, commercial)	(Cutter, 2016)
	disaster exposure	number of times a block group was hit by coastal hazards from 2000 to 2010	(Cai et al., 2016)
		number of times a community was hit by hurricanes or climate-related hazards	(Lam et al., 2016)
		intensity of the Wenchuan earthquake	(X. Li et al., 2016)

It might be interesting to observe how in the practice many indicators have been specifically tailored to the community that they addressed, in order to capture the peculiar feature of that case. Consequently, apart from quantifications of hazards events that are necessarily characterised through local measures, it also happens that some considerations on specific local organisations or policies might not be directly transferable in any other case study. Nevertheless, such indicators might still retain their meaning in terms of promoting (or depleting) resilience or sustainability capacities, hence they still might serve as a model to correspondingly select the appropriate proxy for the specific further case study.

As previously mentioned, a similar collection of indicators that have consistently dotted the literature might be summarised also when concerned with the quantitative assessment of sustainability (Table 4.8).

Table 4.8 — Collection of frequently employed indicators for the quantitative assessment of sustainability, associated to relevant categories and themes, along with some examples of implementation

CATEGORY	THEME	INDICATOR	SOURCE
INTEGRITY	*vegetation cover*	% herbaceous vegetation	(Brody et al., 2014)
		% shrubs	(Brody et al., 2014)
		area with natural vegetation	(Chaves & Alipaz, 2007) (Morimoto, 2011)
	protection efforts	species diversity	(Millennium Ecosystem Assessment, 2003b) (EEA, 2005) (Janetos et al., 2005) (Morimoto, 2011)
		size of protected area	(EC, 2003) (Termorshuizen et al., 2007) (Wendling et al., 2018)
		designated areas	(EEA, 2005)
		protected species	(EEA, 2005) (Termorshuizen et al., 2007) (Wendling et al., 2018)
	alien species	predominant invasive species	(Morimoto, 2011)
		threatened species	(EEA, 2005) (Morimoto, 2011)
SERVICES	*sustainable production*	availability of "sustainable products"	(EC, 2003)
		status of marine fish stocks	(Millennium Ecosystem Assessment, 2003b) (EEA, 2005) (Janetos et al., 2005) (McCartney et al., 2015) (Wendling et al., 2018)
	sustainable use	renewable energy consumption	(EEA, 2005)
		renewable electricity	(EEA, 2005) (Janetos et al., 2005) (McCartney et al., 2015)
FUNCTIONS	*environmental alteration*	tree cover loss	(Millennium Ecosystem Assessment, 2003b) (Janetos et al., 2005) (Babcicky, 2013) (Mori & Yamashita, 2015) (Wendling et al., 2018)
		proportion area change in wetland cover	(Brody et al., 2012)
	regulating capacities	wetland cover	(Millennium Ecosystem Assessment, 2003b) (Brody et al., 2014)
		use of freshwater resources	(EEA, 2005) (Janetos et al., 2005) (Chaves & Alipaz, 2007) (Wendling et al., 2018)

PHYSICAL PROCESSES	*precipitations*	precipitation per month	(Brody et al., 2014)
		number of times precipitation exceeded the 75th percentile	(Brody et al., 2012)
	water systems	extension of floodplain	(Brody et al., 2014) (McCartney et al., 2015)
		hydrology	(Millennium Ecosystem Assessment, 2003b) (Termorshuizen et al., 2007) (McCartney et al., 2015)
	water quality	oxygen-consuming substances in rivers	(EEA, 2005)
		quality of freshwaters	(Millennium Ecosystem Assessment, 2003b) (Janetos et al., 2005) (Babcicky, 2013)
		nutrients in freshwaters	(Millennium Ecosystem Assessment, 2003b) (EEA, 2005) (Janetos et al., 2005) (Chaves & Alipaz, 2007) (Termorshuizen et al., 2007)
		nutrients in transitional, coastal and marine waters	(EEA, 2005) (Janetos et al., 2005) (Termorshuizen et al., 2007)
	air quality	emission of carbon dioxide	(Janetos et al., 2005) (Babcicky, 2013) (Mori & Yamashita, 2015) (Wendling et al., 2018)
		emission of particulate	(EEA, 2005) (Termorshuizen et al., 2007) (Babcicky, 2013) (Mori & Yamashita, 2015) (Wendling et al., 2018)
		emission of acidifying substances	(EEA, 2005)
		emission of ozone precursors	(EEA, 2005)
		exceedance of air quality limit values in urban areas	(EEA, 2005)
HUMAN PROCESSES	*land production*	extension of croplands	(Millennium Ecosystem Assessment, 2003b) (Janetos et al., 2005) (Brody et al., 2014)
		breeding activities	(McCartney et al., 2015)
	water production	fishing fleet capacity	(EEA, 2005) (Janetos et al., 2005)
		aquaculture production	(EEA, 2005) (Janetos et al., 2005)
HUMAN IMPACT	*land use alteration*	% vegetation cover	(Brody et al., 2014)
		green spaces	(Brody et al., 2014)
		ecosystem fragmentation	(Janetos et al., 2005) (Termorshuizen et al., 2007)
		cleansing of contaminated land (area)	(EC, 2003)
		new buildings on virgin area	(EC, 2003)
		new buildings on contaminated or derelict area	(EC, 2003)
	waste production	municipal waste generation	(EEA, 2005)
		urban wastewater treatment	(EEA, 2005) (Wendling et al., 2018)

In this case as well as in that of the assessment of resilience, some indicators might constitute an inspiration rather than a proxy to be straightforwardly implemented. Indeed, for example, considerations on the state of marine ecosystems might be not appropriate when the aim is to describe the features of a varied case study, that might not have access to the sea throughout its territory: in this sense, that specific indicator might introduce a bias, although the suggestion to include some measures on the environmental health would still be significant.

As the variety of consolidated practice in terms of employed indicators was also outlined, it is possible to move forward and in particular to capitalise on the wealth of experiences, suggestions and perspectives enriching the literature. As a consequence, in the following chapter a new methodology will be presented, one that moves from the previous research endeavours explored just above to address every and each *stronghold* suggested before.

5. Quantitative methodology

At this point, the investigation has entered a rather specific domain. Indeed, the present direction of research points towards the quantification of the conditions of a Social-Ecological System, pivotal to comprehend the current scenario and the potential perspectives. Nevertheless, it might significant to bear in mind that this is only one half of the overall assessment strategy. Though the discussion will shortly proceed towards the delineation and exploration of such numerical evaluations, later the discussion will come back to an analogous stage where some more methodological considerations will be required in order to develop a qualitative comprehension of the dynamics unfolding in local Social-Ecological Systems.

5.1 Statement of the problem

A general overview of the path that has led the discussion to this point might turn beneficial. In this section a brief recall of the main questions that have arisen and of the extent of the answers retrieved from the literature will be provided.

The overarching concern of the present discourse is the survivability of the human systems within the natural system. The Social-Ecological Panarchy model suggests that the survivability of a Social-Ecological System might be granted if disaster resilience and environmental sustainability are nurtured together. The model shows that the prerogatives of the human system and those of the natural system should not prevail one over the other. Rather, an equilibrium should be achieved between resilience and sustainability. In order to pursue this objective, the features of the human system should be modelled so as to address the boundaries posed by both resilience and sustainability. As a consequence, resilience and sustainability have herein identified as *cores* of the present problem. Given the need to manage the human system, assessment methodologies become critical to understand the current state and the possible enhancements. The first step focused on providing some insights on the characteristics of the *cores*. The previous research endeavours allowed to identify some *attributes* and some *dimensions* of the *cores* (Table 5.1). This means that for each *core*, it is possible to identify some peculiar traits that broadly describe their essence (*attributes*) and some specific areas that keep trace of their presence or absence (*dimensions*).

Table 5.1 – Attributes and dimensions of resilience and of sustainability.

CORE	*ATTRIBUTES*	*DIMENSIONS*
resilience	absorb	demographic
	recover	social
	learn	economic
		health
		infrastructural
		natural
sustainability	services	ecosystem integrity
	functions	ecosystem benefits
	integrity	physical processes state
		external pressures
		human vulnerabilities

The second step moved beyond, collecting and analysing operative answers to the assessment concern. In light of the wealth of proposed methodologies, some *strongholds* were elaborated to guide the exploration first and the adaptation later (Table 5.2).

Table 5.2 — Strongholds of the assessment methodology.

STRONGHOLDS	
a.	quantification of resilience
b.	quantification of sustainability
c.	objective indicators
d.	disaster-related measures
e.	combination of resilience and sustainability
f.	equal relevance of resilience and of sustainability

Unfortunately, the previous research efforts could not address all the requisites posed by the *strongholds*. Hence, the present investigation calls for a new assessment methodology.

5.2 Proposed Coupled Assessment of Resilience and Sustainability (CARES)

5.2.1 Development of the methodology

As anticipated, the new assessment tool should present some specific features. In a few words, the assessment methodology should employ objective techniques to collect indicators (*stronghold c.*), quantitative in nature (*stronghold a.* and *b.*) and referred to disasters (*stronghold d.*), devoted to bring together (*stronghold e.*) on an equal plane (*stronghold f.*) resilience and sustainability.

The methodology herein developed can be considered a Combined Assessment of Resilience and Sustainability (CARES). This methodology might be applied to a Social-Ecological System: the units of analysis would be fractions (*sub-units*) of the Social-Ecological System (e.g. a Region, sub-units: municipalities), thence the overall condition of a Social-Ecological System would be retraced *a posteriori*. The overarching structure comprises two main *operative lines* of analysis, one per each *core*, resilience and sustainability, following the same analytical process. Each *operative line* is independent from the other during the analysis, while the results are paired to obtain a final common output. Each *operative line* employs different quantitative indicators and utilises them in a two-phases process. The first phase of the analytical process might be considered a *classification* endeavour. The aim is to aggregate the *sub-units* based on their behaviour in the event of a disaster. The indicators used in this phase are the manifestation of the *cores*, hence they refer to the *attributes* of the *cores*. The procedure applied is a cluster analysis. Pairing the results for the *cores*, the Resilience and Sustainability Level emerges. The second phase of the analytical process might be considered a *characterisation* endeavour. The aim is to trace the features that explain a specific behaviour of the *sub-units* in the event of a disaster. The indicators used in this phase are the constitution of the *cores*, hence they refer to the *dimensions* of the *cores*. The procedure applied is a discriminant analysis, based on the grouping provided by the previous cluster analysis. Pairing the results for the *cores*, the Predictive Function of the Resilience and Sustainability Level emerges.

In the following lines the two phases will be presented and discussed. Nonetheless, it might be interesting to spend some preliminary words on the overarching structure. An important point to explain a bit further is centred on the *attributes* and on the *dimensions*. In the previous review, the features that arise from the literature have been presented (Table 5.1). Unfortunately, they cannot be retrieved and employed as they are in the present methodology, because they derive from research efforts that, for example, do not comprehensively combine resilience and sustainability. As a result, some areas overlap between the *cores*. This condition is not acceptable in here, though, as source of interdependence might hinder the reliability of the analytical procedure. This is the reason why the *resilience core* is limited to the *attributes* and *dimensions* that pertain the human system, while the *sustainability core* encompasses only *attributes* and *dimensions* that are relevant to the natural system. It might be interesting to stress that this difference does not concern the specific variables later employed to describe *attributes* and *dimensions*, as long as they describe relevant features of the human and of the natural systems, respectively for the *resilience* and the *sustainability core*. In light of this, the *attributes* and *dimensions* adopted by the methodology proposed within this research framework are refined and presented in Table 5.3. In a nutshell, the “natural” *dimension* is excluded from the *resilience core* and the “human vulnerabilities” *dimension* is excluded from the *sustainability core*.

Table 5.3 — The attributes and the dimensions per each core of the CARES methodology

CORE	*ATTRIBUTES*	*DIMENSIONS*
resilience	absorb	demographic
	recover	social
	learn	economic
		health
		infrastructural
sustainability	services	ecosystem integrity
	functions	ecosystem benefits
	integrity	physical processes state
		external pressures

Once that this focal point has been clarified, the overarching structure can be visualised, highlighting the centrality of the disaster theme (Fig. 5.1).

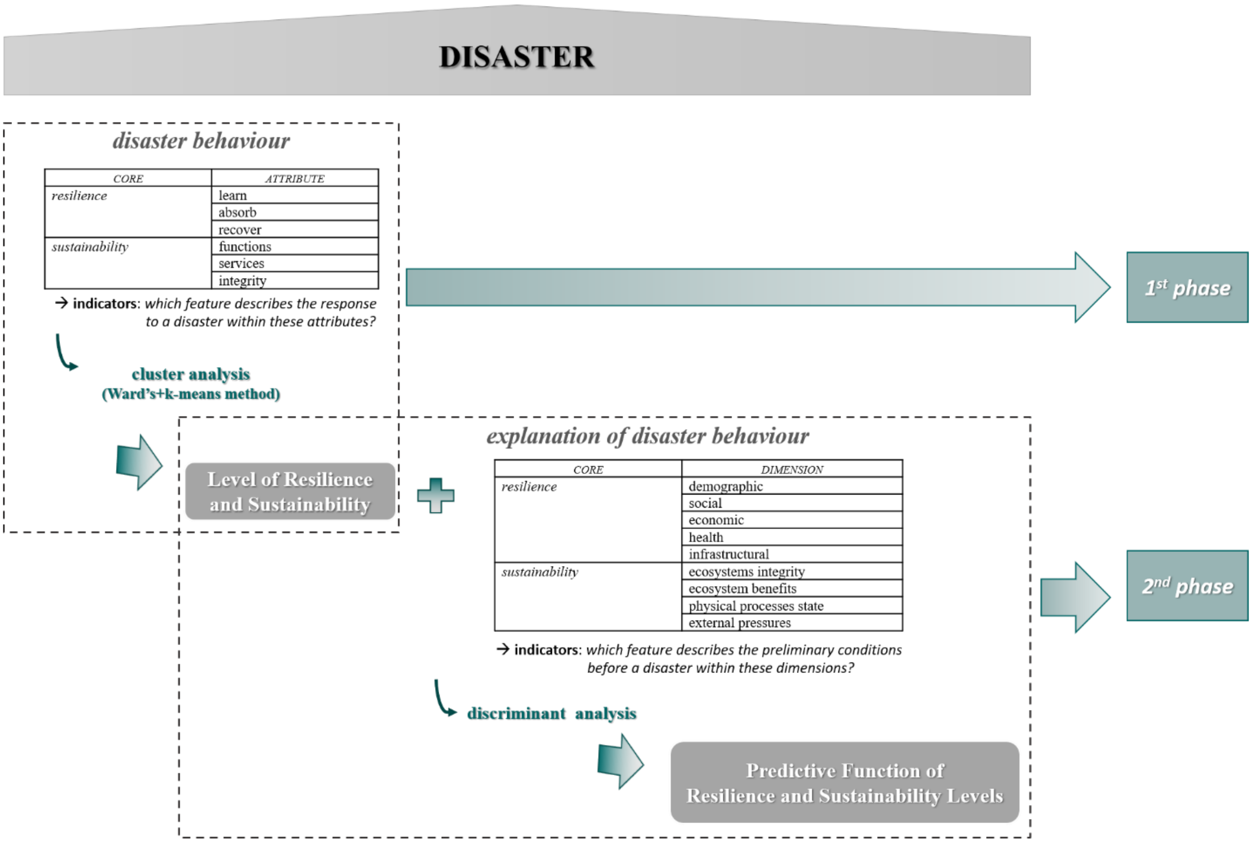


Figure 5.1 — Structure of the proposed methodology

It might be noteworthy to identify the main references to the previous research efforts that find an evident correspondence in the proposed methodology. The structure organised over two major phases and employing different kind of quantitative indicators was inspired by the RIM model (Cai et al., 2016; Lam et al., 2016; K. Li, 2011; X. Li et al., 2016). Nevertheless, the conceptual framework deviates from that of the RIM model, since in the present case the Social-Ecological Panarchy model provided the theoretical background. As a consequence, the main features do not correspond and, more importantly, the question of sustainability is developed within the methodology proposed for this research study. Another deviation results in the indicators chosen for the analysis, although the RIM model itself envisions this possibility, as each application should be adapted to the peculiarities of the specific case study.

The meaning carried by the indicators and their distribution between the two analytical phases are definitely retrieved from the RIM model. At the same time, the choice of the indicators, especially for the second phase of analysis, is primarily based on the research performed by Cutter (Cutter, 2016; Cutter et al., 2014, 2008), as her contribution is essential for the resilience theme, and on the narratives of the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2003b, 2003a), as it is a milestone in the sustainability discussion. Many other inputs constitute valuable sources for the development of indicators within the proposed methodology, for both *cores*, and for both *attributes* and *dimensions.* Such research efforts are not meant to be belittled, though the above-mentioned remain pivotal.

5.2.2 Structure of the quantitative methodology

In this section, the phases of the of the methodology proposed within the present investigation will be discussed more comprehensively. It should be kept in mind that before applying this methodology, some preliminary arrangements should be finalised. In particular, the geographical setting and the disaster conditions should be fixed. This preliminary step is crucial. For example, the Social-Ecological System should be divided into smaller fractions, that can be addressed as *sub-units*, and these are the real protagonists of the following analysis. At the same time, choosing a Social-Ecological System (SES) and a type of risk influences the choice of indicators, as they respond to the peculiarities of the place and of the menace. In a few words, when overlooking the structure of the proposed methodology, it should be considered that the conditions of the analysis are well-established in advance and affect the operative features of the process. As a consequence, in the following lines only the general characteristics of the methodology will be presented. Furthermore, it is fundamental to bear in mind that the analytical procedure is exactly the same for the two *cores*, resilience and sustainability. Hence, it is here stated that the described process is valid for both *operative lines* and this will be assumed throughout the discussion.

Classification — A matter of cluster analysis

The first phase of the methodology proposed within the present research framework aims to gather together the *sub-units* of the Social-Ecological System accounting for their behaviour in the event of a disaster. In this sense the first phase operates a classification, that is allocate the *sub-units* in different classes on the basis of their response to a disaster. For this purpose, the more suitable statistical technique is the cluster analysis.

Actually, the term "cluster analysis" does not refer to a specific technique, but rather to a set of algorithms, able to unveil the underlying structure of a dataset. In particular, such algorithms can bring to the surface the inherent groupings, that is exactly the objective of this first phase of the proposed methodology. In this case, each *sub-unit* is described through the indicators associated to the *attributes* (Table 5.3). In general terms, clustering algorithms classify items (e.g. *sub-units*) by means of variables (e.g. indicators). The clustering algorithms employ such variables to identify similarities that justify the grouping of the items in a same cluster. The similarity is treated as a matter of "distance": the closer the items are, the more similar they are, thence the higher probability of belonging to the same cluster (R. A. Johnson & Wichern, 2007). In other words, the cluster analysis relies on the concept of distance as conceived in geometrical terms. Consequently, when the question of how to measure such distance arises, the answer is almost trivial: the Euclidean definition of distance (Eq. 2) is valid and immediate for this purpose.

$$d(\vec{x},\vec{y}) = \sqrt{(x_1 - y_1)^2 + \cdots + (x_n - y_n)^2} \tag{2}$$

Considering the definition of the Euclidean distance and its application in this case, a visualisation of the cluster procedure occurs: it is like each *attribute* is a dimension of the space (in this case, 3 *attributes* mean a 3D space) and each *sub-unit,* as an item, is a point. The indicators, as variables, represent the coordinates of each point: different values of the indicators localise the points in different areas of the space. At the same time, the cloud of points naturally separates in visible groups, given that an underlying structure exists. Hence, the smaller the distance among points, the more probability of being part of the same group. It is relevant to notice that the Euclidean distance is not the only available procedure: many other definitions have been proposed; nonetheless, it is also recognised that the Euclidean definition can be considered the "truest" possible distance between two items, hence its use is encouraged whenever possible (R. A. Johnson & Wichern, 2007).

The wealth of clustering techniques is not only due to the manifold of way to quantify a distance. Once this aspect is fixed, more operative terms require attention. In other words, it is necessary to choose among the several methods that have been developed to create the clusters. Broadly, the major difference stands between hierarchical and non-hierarchical methods. Hierarchical methods allow to unravel all the possible clusters (hence the maximum number of clusters would equal the number of items, in the case that each item is considered as a stand-alone cluster). The procedure might rely on a agglomerative or on a divisive strategy: in the first case, clusters are progressively populated, until no item is excluded; in the second case, on the contrary, clusters are progressively disaggregated until every item is by itself. Consequently, as the procedure progresses, it is impossible to move misplaced item: that is, whether some errors in the attribution of the cluster would occur, the hierarchical methods would not allow any correction by reallocation. Non-hierarchical methods develop on a different base. Although also in this case several techniques are available, they share a common approach. The items are paired, their distance evaluated and their belonging to a cluster established; this allocation affects the position of the centre of the cluster, called centroid, that is thence calculated again. Then, another item is considered and the cycle repeated, while verifying the appropriateness of the allocation of each item every time the centre is moved. In this way, reallocations are allowed and, even more, performed: indeed, the cyclical process ends when no more reallocations are necessary, meaning that the clustering is rather stable. It is interesting to notice that, conversely to hierarchical methods, an initial set of information is needed to implement a non-hierarchical method: either the first items or the centroids must be provided to begin the iterative procedure. Another peculiar feature is that the number of the clusters might be required in advance or it can be discovered as part of the procedure. In front of such a wealth of nuances in the available techniques, the temptation to demand a "Jack-of-all-trades" technique might be triggered. Unfortunately, such a request would fall unheard: hierarchical as well as non-hierarchical methods present both advantages and shortcomings, hence it is not possible to pinpoint a solution to any kind of operative question. Rather, different techniques should be applied to different problems, and the robustness of each answer should be carefully verified (R. A. Johnson & Wichern, 2007). One more path is accessible, though, one that leads to an attempt of compensating the weaknesses through other strengths. That is, it might be possible to combine different clustering techniques in order to optimise the combined performance. The methodology proposed for the present research study tries to address this challenge.

The adopted strategy envisions two clustering techniques, that is a hierarchical method that prepares the ground for a subsequent non-hierarchical method. In other words, the first phase of the proposed methodology runs a twofold, mixed clustering procedure: a preliminary process identifies a tentative clustering structure, hence providing some reasonable centroids; then, the refinement and definitive establishment of the structure follows. In the first step the Ward's method is adopted, while the k-means is employed in the second step. The Ward's method is a hierarchical technique especially appreciated for limiting at most the loss of information when groups are formed (R. A. Johnson & Wichern, 2007). Furthermore, in spite of belonging to the hierarchical methods, the Ward's clustering technique is particularly similar to non-hierarchical techniques, to the point of being considered as an anticipation of the latter (R. A. Johnson & Wichern, 2007). Consequently, this method seems to optimise some criterions when assigning items to a given number of clusters (R. A. Johnson & Wichern, 2007). Despite all these encouraging features, the Ward's method is still a hierarchical technique, hence suffers from some relevant drawbacks: for example, as mentioned before, it does not allow to re-assign an item, whether the first attempt revealed to be inadequate. Nonetheless, this aspect does not hamper the proposed methodology: the Ward's peculiarities makes it especially suitable to model a preliminary shape of the groups and identify their reasonable centroids. It is up to the following technique to verify and adjust it: for this purpose, the k-means clustering technique ensues. Among the non-hierarchical techniques, the k-means method is one the most common (R. A. Johnson & Wichern, 2007). As mentioned, the clustering procedure is iterative: an initial partition in k clusters or k initial centroids constitute the starting point; then, the distance of items from centroids is calculated: items might be moved, affecting the position of centroids; hence distances are evaluated again, for new items and for every other already assigned, until all items are stably assigned to a cluster (R. A. Johnson & Wichern, 2007). From this brief description appears evident a rather advantageous strength, as well as a subtle flaw of the k-means method. As a matter of facts, the essence of the k-means techniques relies on a continuous re-allocation of items: it might almost seem as an optimisation of the possible distribution of items over the clusters, compensating for subsequent misplacements until the minimisation of the error. This feature is especially relevant when pairing the k-means method with the Ward's method, since it mitigates this inherent limitation of hierarchical techniques. At the same time, the k-means method is particularly sensible to the initial set of clusters or centroids: a biased or unfortunate choice might hamper the reliability of the whole process. It is here that the Ward's method comes to compensate this weakness, providing a reliable foundation for the following iterative process. Both of these clustering techniques, eventually, allow to adopt the

Euclidean measure of distance, hence the metric might be consistent between the Ward's and the k-means methods.

At this point it is significant to come back to the methodology proposed for this research study and spend some words on the outcome of the first phase. In the above exploration, the procedure was described, but what is the objective? Clearly, the aim is to allocate each *sub-unit* of the Social-Ecological System to a cluster: why though? The rationale behind the different clusters is the different behaviour in the event of a disaster. Such behaviour has been previously quantified in terms of indicators representing the *attributes* of resilience and of sustainability. By the end of the clustering procedure, each cluster has a stable centroid and each centroid is associated with a set of different values, referred to the *attributes*. As a consequence, the comparison among such values (associated to the centroids) allows to identify a sounder or poorer behaviour of each cluster. In other words, the first phase of the proposed methodology enables to identify a higher or lower level of resilience and of sustainability per each cluster, thence per each *sub-unit* of the Social-Ecological System. That is, each cluster corresponds to a different Level of Resilience and a different Level of Sustainability. As a consequence, at the end of the first phase, each s*ub-unit* owns a Level of Resilience and a Level of Sustainability, that combined together form a Level of Resilience and of Sustainability. As mentioned, the qualification of the disaster behaviour is based on the comparison of the values associated to the centroids: in this case, three *attributes* (and three indicators, thence three values) per each *core*. Given the complexity of such interpretation and in order to limit the possible biases in comprehending the overall structure, it is here assumed that it would be more convenient to opt for a limited number of clusters, thus a limited number of Levels. In this case, three (High – Medium – Low) Levels of Resilience and three (High – Medium – Low) Levels of Sustainability are considered. Consequently, nine possible Levels of Resilience and of Sustainability are admitted within the proposed methodology (Table 5.4 and 5.5).

Table 5.4 – Possible Levels of Resilience and Levels of Sustainability resulting from the first phase the proposed methodology.

CORE	LEVEL OF THE *CORE*		
Resilience	high (H)	medium (M)	low (L)
Sustainability	high (H)	medium (M)	low (L)

Table 5.5 – Possible Levels of Resilience and Sustainability resulting from the first phase the proposed methodology.

	High (H) to Low (L) Level of Resilience (R)		
High (H) to Low (L) Level of Sustainability (S)	HR-HS	MR-HS	LR-HS
	HR-MS	MR-MS	LR-MS
	HR-LS	MR-LS	LR-LS

Actually, a further back step might be undertaken, returning to theoretical foundation of this operative approach. The methodology proposed within the present research framework was developed in order to investigate the condition of resilience and of sustainability of local Social-Ecological Systems. Hence, once those Levels are assessed, what do they mean within the framework of the Social-Ecological Panarchy? In other words, is it possible to associate the Levels of Resilience and Sustainability to the *phases* of the *adaptive cycle*? Such an attempt would allow to position each *sub-unit* within its own *adaptive cycle*, thus estimating the more or less proximity to threatening edges or rather to more explorative conditions. Nonetheless, to the knowledge of the author such an attempt could not be traced in the wider literature, hence in the present case an interpretation of the association of Levels of Resilience and Sustainability to the *phases* of the *adaptive cycle* is proposed (Fig. 5.2).

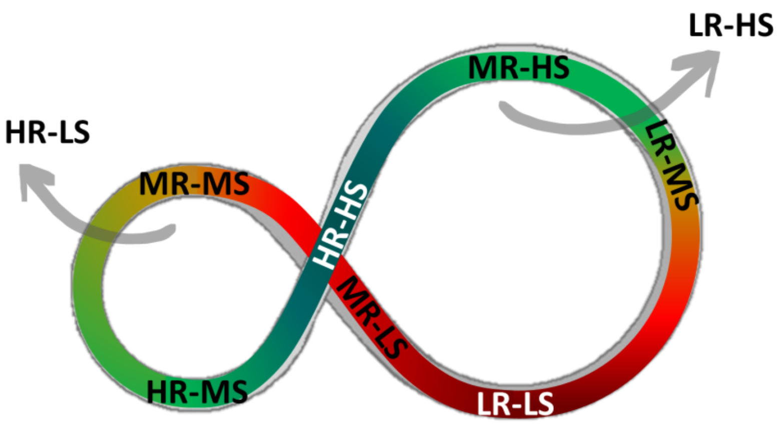


Figure 5.2 — Levels (low L, medium M, high H) of Resilience (R) and of Sustainability (S) associated to the phases of the adaptive cycle.

The first tenet descends from the previous discussion (se Ch. 2) and the hypothesis of this study (see Ch. 3): the endeavours to enhance resilience and sustainability in local communities should translate in a convergence towards the *fore-loop*, that is towards dynamics of constant renovation and adaptation. Consequently, the highest Levels of Resilience and of Sustainability should be assumed to reside there (HR-HS): once this is ascertained, it is possible to move along the *cycle* and investigate what happens to those Levels. By moving forwards, the *sub-unit* is optimising the use of resources and assets, though rigidities are building up as well, and it is approaching the critical threshold before the eventual collapse. In this case, it might be considered that the Level of Sustainability remains high, because the *sub-unit* tends to conserve rather than to misuse capitals, whereas the Level of Resilience is declining, given the increasingly susceptible conditions (MR-HS). In a similar vein, the more the *sub-unit* progresses towards the *release phase*, the less resilient it appears, while also its sustainable characteristics are less and less consistent, since the survival needs might prevail over environmental care (LR-MS). Eventually, the collapse of the fundamental functions of a *sub-unit* would induce the minimisation of those Levels: once that serious failures affect the *sub-unit*, any activity or initiative is inhibited, only basic survival is crucial in order to outlive those critical times (LR-LS). Later, the basic functions are slowly restored: even though the conditions within the *back-loop* are still highly susceptible, the capacity to cope with external pressures is increasing, although environmental issues might still not be addressed given the unstable situation (MR-LS). Nevertheless, once assets and structures are being consolidated, an increasing amount of resources might be allocated to a more sustainable development (MR-MS). Even if the priority might of the *sub-unit* remain the consolidation of its internal structures and dynamics (HR-MS), in time resources and information would be available to enhance a sounder coexistence with the environment (HR-HS). With this, the *cycle* is completed, since the *fore-loop* is reached once more. Hence, the fluctuation along the *fore-loop* represents a domain closely surrounding the most desirable Levels (HR-MS, HR-HS, MR-HS). At this point, a large part of the possible combinations of the Levels of Resilience and Sustainability (Table 5.5) might find an explanation in the previous presentation. Even so, two dyads are missing, those that represent the combination of the respective highest and lower Level (HR-LS and LR-HS). From the previous discussion, it might appear that these pairs might not find their place within the *adaptive cycle*, but this turn not to be an issue: similarly to the *traps* identified in the first unravelling of the panarchy theory (see Ch. ii), also in this case the presence of some peculiar *traps* could be postulated. In particular, it might be supposed the existence of a *Resilience Trap* (HR-LS) and of a *Sustainability Trap* (LR-HS). In the first case (HR-LS), the *sub-unit* is recovering its fundamental functions, maximising the efforts to build back a stable and responsive structure. In this effort, though, environmental issues are not envisaged, even less integrated. The *sub-unit* might be able to enhance the overall capacity to face adverse events, but the undertaken development path diverges from the *cycle* presented here, because it is missing one of the two essential *cores* for a long-term survivability. Similarly, when resources, assets and capacities would be optimised to reduce to the broadest extent the human impact on the environment, it might turn detrimental for the flexibility and adaptability of the *sub-unit* (LR-HS): excessively strict and rigid structures might undermine the capacity of the *sub-unit* to deal with unexpected and extreme events. This approach would compromise the survivability of the system as well, hence the development path moves away from the *adaptive cycle* presented here also in this case. It might be noteworthy to consider that, stemming from these postulations, a maximising endeavour towards either of the *cores* might boost the capacities one side, but at the same time it might be destabilising on the other side. Resilient strategies that dismiss environmental issues might induce fatal disequilibria in the environment that could trigger disruptive consequences in the long period. In a similar vein, sustainability strategies that underestimate human necessities might limit human ability to adapt to change. The suggested fluctuation along the *fore-loop*, on the contrary, would bind together the resilient and the sustainable viewpoints, preventing either of the *cores* to prevail on the other, that is preventing the spill over the *cycle* towards undesirable traps of rigid optimisation. With this interpretative attempt, some objections might be raised, especially to the positioning of some dyads. For instance, following the decreasing trend, the combination of the medium Levels (MR-MS) could also be placed on the verge of the collapse (substituting LR-MS), rather than over the *reorganisation phase*. In the present interpretation, this configuration was not adopted because it appeared that the more the *sub-unit* approaches risk conditions and the more rapidly it loses resilient (compared to sustainable) features, hence an imbalance of the *cores* seemed more significant to represent those critical conditions. Conversely, when approaching the *reorganisation phase*, the *sub-unit* is preparing for a new development path, promising in terms of both resilience and of sustainability, where the *cores* could grow back once more. Nonetheless, it is acknowledged here that the proposed association (Fig. 5.2) is a first attempt to combine a qualitative estimation of resilience and sustainability with the panarchy metaphor, hence further discussion might be significant too enrichen and enlighten this issue.

At this convergence of the interpretivist and of the positivist paradigms, the first phase of the proposed methodology might be assumed to be concluded. Such effort is fundamental to differentiate the nuances in the ability of the Social-Ecological System when coping with an extreme event, but at the same time it also models the indispensable base for the second phase of the methodology, in order to perform the subsequent analysis.

Characterisation — A matter of discriminant analysis

The second phase of the methodology proposed for this research study moves from the classification performed in the previous phase in order to uncover the peculiarities that correspond to a specific disaster behaviour. In other words, the second phase of the methodology aims at identifying which features are most relevant in determining a specific behaviour in case of a disaster. In this sense, the analysis operates a characterisation: the characteristics of the *sub-units* are examined and combined in order to best correspond to the previous clustering effort. The discriminant analysis is especially suitable to pursue such an objective. In this case, the procedure involves the indicators associated with the *dimensions* of the *cores* (Table 5.3).

A manifold of techniques is available to investigate multivariate dependence. Multiple regression analyses are probably the most common and widely employed (Hair et al., 2014). Multivariate regressions are specifically appropriate when applied on metric continuous variables: unfortunately, by the end of phase one, a set of categorical data is produced, that requires to be related to continuous data. That is, the second phase should unveil a correspondence between the Levels of Resilience and of Sustainability expressed through the clusters (categorical data) and the indicators of the *dimensions* (continuous data). Evidently, multivariate regressions are not able to address this operative problem. An other common technique might be suggested to fulfil the purpose: indeed, logistic regression might well solve the question (Hair et al., 2014). The critical issue in this case resides in the inherent structure of the technique: it admits only binary categorical data (e.g. yes/no), thence it does not adhere with the present requirements. It is at this point that the discriminant analysis emerges. Belonging to the family of the multivariate analyses similarly to clustering techniques, the discriminant analysis treats categorical data in terms of *dependent variables* and continuous data in terms of *independent variables*. The technique seeks to explain and predict the *dependent variables* modelling a function of several *independent variables*. In other words, the objective is to design a linear combination of *independent variables* that corresponds to the *dependent variables*. In this way, *discriminant functions* are generated (Eq. 3):

$$Y_{jk} = a + w_1 x_{1k} + w_2 x_{2k} + \cdots + w_n x_{nk} \tag{3}$$

where Y_{jk} is the score of the j-th discriminant function for the k-th unit of analysis, a is an adimensional coefficient, $w_n x_{nk}$ is the product of the n-th w weight with the n-th x variable for the k-th unit of analysis. It might relevant to draw attention to the inherent potential of the discriminant analysis. Indeed, this technique holds the power to both discriminate and classify. This power might be less trivial than it seems, because it means that one technique has the capacity to optimise the differentiation in groups within a set of items based on their diverse features, on one hand, and the capacity to assign an item to a group based on its features, on the other hand (R. A. Johnson & Wichern, 2007). In this perspective, the twofold power of the *discriminant function* appears: based on every k-th unit of analysis, the Y_{jk} are employed as references to identify the most proper a and assign the most appropriate weight w_n to the x_{nk} variable, in order to maximise the differentiation among the groups; at the same time, the *discriminant function* is able to assign a value of Y_{jk} to a new item (hence allocate it to a class), providing that the item is described by the same set of x_{nk} variables and leaving unaltered a and the w_n weights. As a final remark, it is noteworthy to point out that, in general terms, it is necessary to discuss about a plurality of *discriminant functions* produced by the analysis: the number of the *functions* depends on the characteristics of the specific application.

At this point, clarifying the significance for the case of the proposed methodology might help to shed some light on these terms and outcomes. In this case, each *sub-unit* is assigned a Level of Resilience and a Level of Sustainability, referred to different clusters, stemming from the previous cluster analysis. In addition, each *sub-unit* is associated with several indicators, describing the *dimensions* of the *cores.* The discriminant analysis is useful for collapsing the multivariate question posed by the indicators into the univariate answer provided by the clusters. Consequently, the clusters serve as categorical *dependent variables,* while the indicators supply the continuous *independent variables*. The purpose of the analysis is to arrange the indicators in order to explain at best the clusters. Nonetheless, this valuable coin owns two sides: on one side, at the end of the process the generated *discriminant function* is able to highlight the most influencing indicators in determining the cluster, that is the disaster behaviour of the *sub-units*. Consequently, in following applications, the range of quantified indicators might be limited, in order to lessen the burden of such a resource-intensive process. On the other side, the *discriminant function* might be employed to sort into clusters "new" *sub-units*, provided that the conditions of the "new" and "old" Social-Ecological Systems are comparable; in other words, it is possible to estimate the Levels of Resilience and of Sustainability of a different Social-Ecological System, if its characteristics are similar to those of the original Social-Ecological System. This ability of the *discriminant function* might also translates in a monitoring endeavour of the a specific Social-Ecological System: the *function* allows to verify the cluster of each *sub-unit* without the need to perform a cluster analysis; in other words, there is no need to wait for an other disaster to take place (to quantify *attributed* fundamental for the cluster analysis), as the quantified *dimensions* are more than enough to follow the development of resilience and sustainability in Social-Ecological System through time. Similarly, in this way it is also possible overcome the static nature of widely accepted methodologies; this feature has been often criticised (Cai et al., 2018): resilience and sustainability are perpetually evolving, not crystallised in time, hence an assessment methodology should be able to easily follow this continuous transformation and the methodology proposed within this research framework fulfils this requirement. In spite of these perspectives of further applications, a more operative value might be added to the discriminant analysis, as it provides a kind of validation of the methodology itself. Indeed, the clusters resulting from the first phase and those estimated through the second phase, might be compared: the more similar they result and the more robust is the overall analytical process (Cai et al., 2016). At the same time, the discriminant analysis itself supplies some internal checkpoints to validate the soundness of the results, strengthening the reliability of the operative procedure. A concluding observation brings back the mention that this technique potentially produces a manifold of *discriminant functions*: how to deal with such numerous possibilities? As a matter of facts, this does not hamper the second phase of analysis: rather, it enables to opt for the most appropriate *function* among all the available ones, polishing even more its predictive power. In light of this considerations, the selected *function* takes the name of Predictive Function of the Resilience and Sustainability Levels. Bearing in mind that both the cluster and the discriminant analyses follow independent *operative lines* for the two *cores*, as well as each *sub-unit* is described by a specific Level of Resilience and a specific Level of Sustainability, it is also provided with a distinct *discriminant function* per each core. Consequently, actually the Predictive Function of the Resilience and Sustainability Levels is a system of *functions*, one for resilience (R) and one for sustainability (S), for every (k-th) *sub-unit* of the Social-Ecological System (Eq. 4).

$$\begin{cases} R_k = a + w_1 x_{1k} + w_2 x_{2k} + \cdots + w_n x_{nk} \\ S_k = b + v_1 z_{1k} + v_2 z_{2k} + \cdots + v_n z_{nk} \end{cases} \tag{4}$$

A matter of combination

After performing the second phase of analysis until the very last steps, the overall assessment procedure is completed. It might be beneficial to recollect here some significant features and move forwards some points that are worth further attention.

The assessment procedure requires some preliminary arrangements that must be performed before the analysis might commence. In particular, a specific condition of risk must be selected, thence a Social-Ecological System must be identified and divided into *sub-units*. Then, data must be collected: indicators describing the *attributes* and the *dimensions* of the *cores* (Table 5.3) are gathered and related to each *sub-unit*. Settled these preliminary conditions, the analysis might start on parallel *operative lines*, one for the resilience *core* and one for the sustainability *core*. The first phase consists of a cluster analysis: *attributes* are concerned, so that each *sub-unit* is allocated in a cluster. Three clusters are available per each *core*, as they represent a different Level of each *core*. As a consequence, by the end of the first phase, each *sub-unit* is associated to a Level of Resilience and a Level of Sustainability that, combined, result in one of the nine possible Level of Resilience and of Sustainability (Table 5.5). Based on this classification and involving the *dimensions* of the *cores*, the second phase implements a discriminant analysis. A discriminant function is consequently selected among those generated and each *sub-unit* receives a Predictive Function of Resilience and Sustainability Levels, resulting from the combination of the functions characterising the two *cores* (Eq. 4).

A specific feature of the methodology is worth of mention, since it carries a crucial conceptual meaning. That is, the two *operative lines* are completely independent one from the other and when they come in contact, they still hold the same weight, as one is not in the condition to outclass the other. In other words, the operative steps of the proposed methodology are designed to respond at best to the *strongholds* (Table 5.2) profiled at the beginning of this discussion: resilience and sustainability are quantified (*stronghold a.* and *b.*) through objective indicators (*stronghold c.*), some of which directly related to disaster behaviour (*stronghold e.*). The results of the analyses are combined (*stronghold e.*) and here lies the critical issue: resilience and sustainability questions are effectively treated as equivalent (*stronghold f.*). This appears evident when observing how the Level of Resilience and of Sustainability is obtained: the clusters resulting from the two *operative lines* are simply put one along the other, without any weight to give more relevance to one instead of the other. Similarly, once the *discriminant functions* are designated, they form a system when shaping the Predictive Function of Resilience and Sustainability Levels, so that also in this case the same relevance is acknowledged to resilience and sustainability. This aspect holds a powerful underlying significance. In order to better explore it, it might be beneficial to come back to the literature. In particular, this issue emerged when investigating the matter of employing indices and indicators in sustainability quantification. When building a complex index, a manifold of indicators a usually employed: once quantified, indicators usually undergo a process of normalisation and of standardisation to allow for comparison among different entities. At this point, it becomes possible to aggregate such indicators into a single index: care should be paid here, as this process of combination implies the crucial questions of weights and aggregation. More precisely, the matter of weights questions the relative importance among the indicators, while the aggregation procedure expresses the question of substitutability among indicators (Gan et al., 2017). In other words, assigning different weights translates into scaling the relevance of each indicator compared to the others. At the same time, aggregation procedures establish whether and to what extent an indicator might compensate for the others. As a consequence, the matter of combining the results of the *operative lines* is actually less trivial than it might appear. The choice of rejecting any kind of weight related to such results affirms that resilience is as relevant as sustainability, and *vice versa.* The choice of simply putting side by side such results affirms that any feature of resilience cannot substitute a feature of sustainability, and *vice versa*. In other words, these choices express the underlying choice of adopting the concept of "strong sustainability". This idea was brought to light in the early 1990s, when discussing the extent to which manmade capital might compensate for natural capital (Daly, 1995). It might be argued that human activities are able to produce assets that can replace the lost natural resources: the concept of "weak sustainability" assumes that there is no limit to the compensation of natural capital through the generation of novel human capital (Daly, 1995). On the contrary, it might be advocated that human activities should develop within the boundaries set by natural systems: in other words, the concept of "strong sustainability" minimises the substitutability of manmade capital and natural capital, admitting human development as long as natural processes are preserved (Daly, 1995). In this perspective, the proposed methodology adopts the standpoint of "strong sustainability": the *attributes* and the *dimensions* of a *core* are not allowed to prevail on those of the other *core*, as previously mentioned; at the same time, the enhancement of each *core* is encouraged, provided that it does not inhibits the other *core* from prospering. After all, this assumption is rather obvious, as the present methodological approach derives from the Social-Ecological Panarchy model, which assumes that human development should be pursued and shaped on the acknowledgement of the importance of a flourishing environment.

6. The cases to study

The first part of the present discussion was dedicated to exploring a conceptual problem that resolved into the formulation of some research hypotheses (see Ch. 3). As a consequence, a theoretical model was developed to substantiate and visualise the conceptual framework. Yet, the research questions that descended from the hypothesis resulted still not solved: the proposed methodological framework addresses this demand. At this point, as the assessment methodology has been delved into, it is time to come to mere operative terms and seek for answers in an application of such methodology. In order to fulfil this purpose, first it is necessary to define the conditions that set the ground for the operative endeavour. In other words, it is necessary to model a case study. In particular, it is essential to settle two aspects: what kind of conditions of risks should be assumed? And which Social-Ecological System should be investigated?

In the following lines, the stage for the present research study will be presented, developing the reasons behind the risk assumed and the territories involved. Later, the methodology will be brought back, outlining the adaptation of the assessment methodology to the developed case study.

6.1 The risk scenario

The Social-Ecological Panarchy model as well as the methodology proposed within the present research exploration envision a broad-spectrum of possible conditions. On one hand, the theoretical discourse embraces inherently complex systems, that are characterised by a manifold of processes and activities, natural just as human made. On the other hand, the assessment methodology is rather flexible and is suitable to be tailored to the specific operative and investigative needs. At the same time, holding a critically wide range of variables might disappoint the research expectations. That is, Social-Ecological Systems are indeed complex and even though it might be desirable to maintain all their inherent peculiarities and mechanisms, this might turn into a critical difficulty in achieving operative results. This question pertains the matter of risk. It is undeniable that Social-Ecological Systems are affected by multiple and multifaced risks, descending from known and unknown hazards that threaten vulnerable and exposed structures. Consequently, it is as well undeniable that a comprehensive description should consider all these conditions of risk. Unfortunately, in operative terms, this might turn unmanageable, severely affecting the possibility to achieve a defined, although partial, result. Following this line of thoughts, the present study has focused on a specific condition, that is flood risk.

Among the many hazards that menace our common living space, floods have confirmed their role as an outstanding reason of worry, at least for the human community. In 2018, floods have manifested in the highest number of disaster events compared to all the other hazards, while affecting the highest proportion of population, accounting for the 50% of the total affected by a disaster (Below et al., 2019). At the same time, floods maintain a relevant role on the human and economic losses, sharing the highest impacts with other hazards (Below et al., 2019) (Table 6.1).

Table 6.1 – Impact of the most relevant disasters for 2018. The two highest values are in bold for each impact, the row corresponding to flood is highlighted.

HAZARD	NUMBER OF EVENTS	TOTAL AFFECTED (MILLION)	DEATHS	SHARE OF ECONOMIC LOSSES (%)
drought	16	10.8	0	9.7
earthquake	20	1.4	**5264**	7.1
extreme temperature	26	0.3	536	0
flood	**127**	**34.2**	**2879**	19.7
landslide	13	>0.1	275	0.9
mass movement (dry)	1	0	17	0
storm	**95**	**19.4**	1734	**70.8**
volcanic activity	7	1.9	878	0.8
wildfire	10	0.3	221	**22.8**

Source: adapted from Below et al., 2019.

Considering the past events, floods evidently represent a threat for survivability, of human and natural systems. Nonetheless, when looking at the future another actor comes to play a critical role: climate change. It has been evidenced that floods will be probably affected by the ongoing environmental changes, aggravating their already severe pressure on Social-Ecological Systems (IPCC, 2014, 2018, 2019). Arising from both inland and coastal water bodies, such disasters have the potential to compromise the development of communities and ecosystems, especially when considering the overall worsening conditions. It has been observed that large part of the most vulnerable communities resides in floodplains and coastal areas: when including the communities that rely on climate-sensitive sources (Huang-Lachmann & Lovett, 2016), the concern can not but deepen. Furthermore, cities are in the condition to play a key role in dealing with hazards and risks associated with water systems (Patterson, 2018): while urbanisation is proceeding at a growing rate, European and Asian cities appear to recognise the pending threat, without acknowledging the real breadth of the menace (Huang-Lachmann & Lovett, 2016). Consequently, it is becoming more and more crucial for cities to secure a sound response to water-related events. At the same time, green and rural areas should not be neglected. In particular, well-managed naturalised areas that surround as well as penetrate urban areas, provide efficient alternatives for adaptation and management of flood-related criticalities, while also supplying fundamental services and products:

successful examples might be found all across the Countries and Regions (EEA, 2017; Mukherjee & Takara, 2018; Natuhara, 2013; Venema, 2009). As a consequence, it might be reasonably argued that flood risk represents a significant threat for our societies, and it will probably continue even in the future. It is a critical issue that concern the whole Social-Ecological System, yet that same complex System retains the sources, both human and natural, to effectively cope with flood risk. Therefore, it represents a matter that draws meaningful attention.

6.2 Case study: Marche Region

On the eastern edge of central Italy, the Marche Region stretches its coasts along the Adriatic Sea, surrounded by the Republic of San Marino and Emilia-Romagna, Toscana, Umbria, Lazio, Abruzzo Regions (proceeding North to West to South) on the other sides (Fig. 6.1).

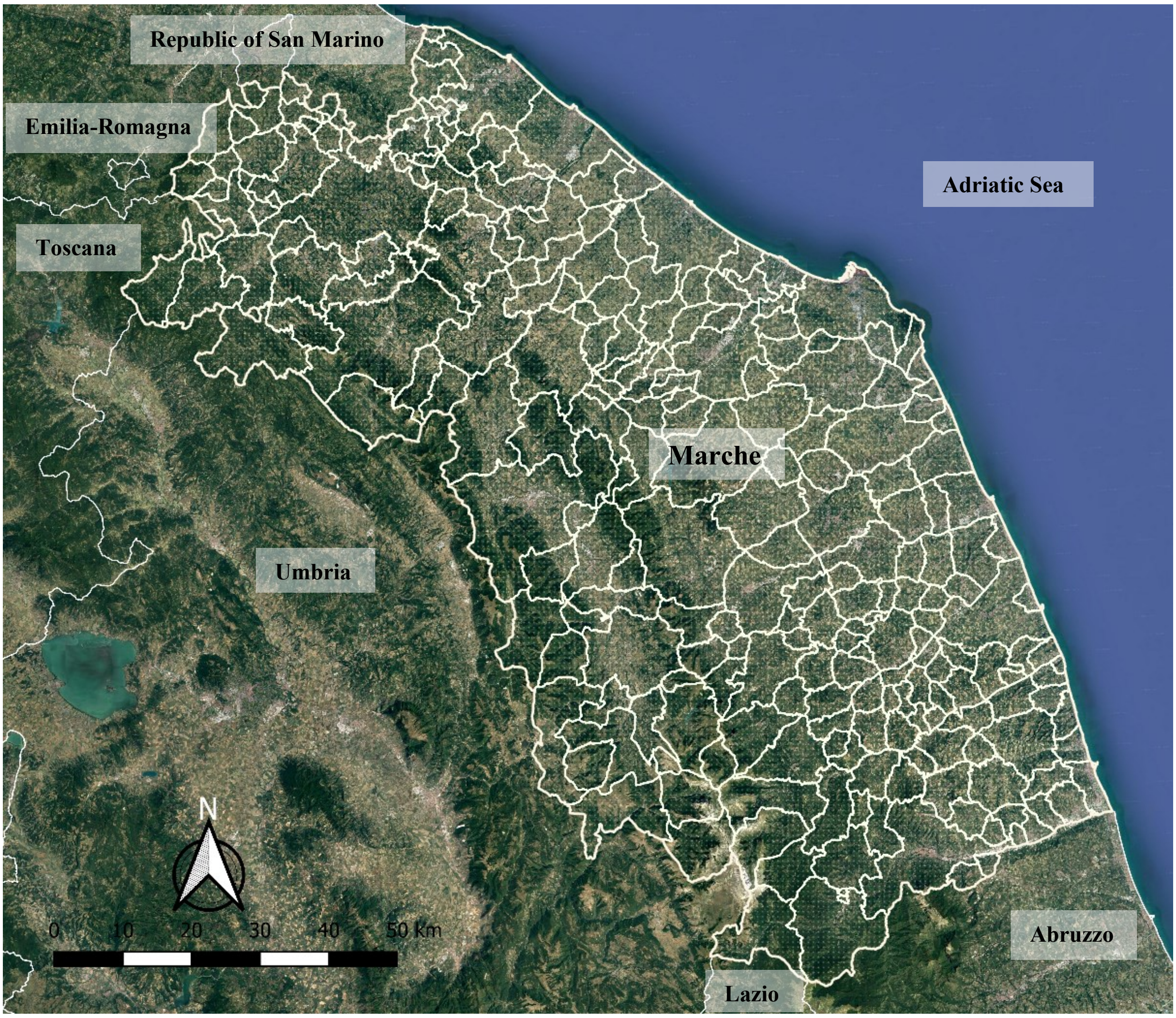


Figure 6.1 — The Marche Region, partitioned into its Municipalities, the Adriatic Sea, the neighbouring Regions and Republic of San Marino

Even though the territory covers a rather limited area, the population is not particularly numerous (ISTAT, 2019) and the residential structure still retains some of the historical features similar to a net spread throughout the Region (Enciclopedia Treccani, n.d.) (Table 6.2). The 229 Municipalities that compose the Region are gathered into 5 Provinces (Pesaro-Urbino, Ancona, Macerata, Fermo, Ascoli Piceno, from North to South): the administrative centre is based in Ancona (Table 6.3).

Table 6.2 — Main characteristics of the Marche Region as of 2018.

	AREA (KM^2)	POPULATION (PERSONS)	POPULATION DENSITY (PERSON/ KM^2)	MUNICIPALITIES
Marche Region	9 401	1 525 271	162.25	229

Source: adapted from ISTAT, 2019.

Table 6.3 — The Municipalities of the Marche Region, divided per Province and associated to their ID code

MUNICIPALITY	PROVINCE	ID
Acqualagna	Pesaro e Urbino	41001
Apecchio	Pesaro e Urbino	41002
Auditore	Pesaro e Urbino	41003
Belforte all'Isauro	Pesaro e Urbino	41005
Borgo Pace	Pesaro e Urbino	41006
Cagli	Pesaro e Urbino	41007
Cantiano	Pesaro e Urbino	41008
Carpegna	Pesaro e Urbino	41009
Cartoceto	Pesaro e Urbino	41010
Fano	Pesaro e Urbino	41013
Fermignano	Pesaro e Urbino	41014
Fossombrone	Pesaro e Urbino	41015
Fratte Rosa	Pesaro e Urbino	41016
Frontino	Pesaro e Urbino	41017
Frontone	Pesaro e Urbino	41018
Gabicce Mare	Pesaro e Urbino	41019
Gradara	Pesaro e Urbino	41020
Isola del Piano	Pesaro e Urbino	41021
Lunano	Pesaro e Urbino	41022
Macerata Feltria	Pesaro e Urbino	41023
Mercatello sul Metauro	Pesaro e Urbino	41025
Mercatino Conca	Pesaro e Urbino	41026
Mombaroccio	Pesaro e Urbino	41027
Mondavio	Pesaro e Urbino	41028
Mondolfo	Pesaro e Urbino	41029
Montecalvo in Foglia	Pesaro e Urbino	41030
Monte Cerignone	Pesaro e Urbino	41031
Monteciccardo	Pesaro e Urbino	41032
Montecopiolo	Pesaro e Urbino	41033
Montefelcino	Pesaro e Urbino	41034
Monte Grimano Terme	Pesaro e Urbino	41035
Montelabbate	Pesaro e Urbino	41036
Monte Porzio	Pesaro e Urbino	41038
Peglio	Pesaro e Urbino	41041
Pergola	Pesaro e Urbino	41043
Pesaro	Pesaro e Urbino	41044
Petriano	Pesaro e Urbino	41045
Piandimeleto	Pesaro e Urbino	41047
Pietrarubbia	Pesaro e Urbino	41048
Piobbico	Pesaro e Urbino	41049
San Costanzo	Pesaro e Urbino	41051
San Lorenzo in Campo	Pesaro e Urbino	41054
Sant'Angelo in Vado	Pesaro e Urbino	41057

Sant'Ippolito	Pesaro e Urbino	41058
Sassocorvaro	Pesaro e Urbino	41059
Sassofeltrio	Pesaro e Urbino	41060
Serra Sant'Abbondio	Pesaro e Urbino	41061
Tavoleto	Pesaro e Urbino	41064
Tavullia	Pesaro e Urbino	41065
Urbania	Pesaro e Urbino	41066
Urbino	Pesaro e Urbino	41067
Vallefoglia	Pesaro e Urbino	41068
Colli al Metauro	Pesaro e Urbino	41069
Terre Roveresche	Pesaro e Urbino	41070
Agugliano	Ancona	42001
Ancona	Ancona	42002
Arcevia	Ancona	42003
Barbara	Ancona	42004
Belvedere Ostrense	Ancona	42005
Camerano	Ancona	42006
Camerata Picena	Ancona	42007
Castelbellino	Ancona	42008
Castelfidardo	Ancona	42010
Castelleone di Suasa	Ancona	42011
Castelplanio	Ancona	42012
Cerreto d'Esi	Ancona	42013
Chiaravalle	Ancona	42014
Corinaldo	Ancona	42015
Cupramontana	Ancona	42016
Fabriano	Ancona	42017
Falconara Marittima	Ancona	42018
Filottrano	Ancona	42019
Genga	Ancona	42020
Jesi	Ancona	42021
Loreto	Ancona	42022
Maiolati Spontini	Ancona	42023
Mergo	Ancona	42024
Monsano	Ancona	42025
Montecarotto	Ancona	42026
Montemarciano	Ancona	42027

Monte Roberto	Ancona	42029
Monte San Vito	Ancona	42030
Morro d'Alba	Ancona	42031
Numana	Ancona	42032
Offagna	Ancona	42033
Osimo	Ancona	42034
Ostra	Ancona	42035
Ostra Vetere	Ancona	42036
Poggio San Marcello	Ancona	42037
Polverigi	Ancona	42038
Rosora	Ancona	42040
San Marcello	Ancona	42041
San Paolo di Jesi	Ancona	42042
Santa Maria Nuova	Ancona	42043
Sassoferrato	Ancona	42044
Senigallia	Ancona	42045
Serra de' Conti	Ancona	42046
Serra San Quirico	Ancona	42047
Sirolo	Ancona	42048
Staffolo	Ancona	42049
Trecastelli	Ancona	42050
Apiro	Macerata	43002
Appignano	Macerata	43003
Belforte del Chienti	Macerata	43004
Bolognola	Macerata	43005
Caldarola	Macerata	43006
Camerino	Macerata	43007
Camporotondo di Fiastrone	Macerata	43008
Castelraimondo	Macerata	43009
Castelsantangelo sul Nera	Macerata	43010
Cessapalombo	Macerata	43011
Cingoli	Macerata	43012
Civitanova Marche	Macerata	43013
Colmurano	Macerata	43014
Corridonia	Macerata	43015
Esanatoglia	Macerata	43016
Fiastra	Macerata	43017

Fiuminata	Macerata	43019
Gagliole	Macerata	43020
Gualdo	Macerata	43021
Loro Piceno	Macerata	43022
Macerata	Macerata	43023
Matelica	Macerata	43024
Mogliano	Macerata	43025
Montecassiano	Macerata	43026
Monte Cavallo	Macerata	43027
Montecosaro	Macerata	43028
Montefano	Macerata	43029
Montelupone	Macerata	43030
Monte San Giusto	Macerata	43031
Monte San Martino	Macerata	43032
Morrovalle	Macerata	43033
Muccia	Macerata	43034
Penna San Giovanni	Macerata	43035
Petriolo	Macerata	43036
Pieve Torina	Macerata	43038
Pioraco	Macerata	43039
Poggio San Vicino	Macerata	43040
Pollenza	Macerata	43041
Porto Recanati	Macerata	43042
Potenza Picena	Macerata	43043
Recanati	Macerata	43044
Ripe San Ginesio	Macerata	43045
San Ginesio	Macerata	43046
San Severino Marche	Macerata	43047
Sant'Angelo in Pontano	Macerata	43048
Sarnano	Macerata	43049
Sefro	Macerata	43050
Serrapetrona	Macerata	43051
Serravalle di Chienti	Macerata	43052
Tolentino	Macerata	43053
Treia	Macerata	43054
Urbisaglia	Macerata	43055
Ussita	Macerata	43056

Visso	Macerata	43057
Valfornace	Macerata	43058
Acquasanta Terme	Ascoli Piceno	44001
Acquaviva Picena	Ascoli Piceno	44002
Appignano del Tronto	Ascoli Piceno	44005
Arquata del Tronto	Ascoli Piceno	44006
Ascoli Piceno	Ascoli Piceno	44007
Carassai	Ascoli Piceno	44010
Castel di Lama	Ascoli Piceno	44011
Castignano	Ascoli Piceno	44012
Castorano	Ascoli Piceno	44013
Colli del Tronto	Ascoli Piceno	44014
Comunanza	Ascoli Piceno	44015
Cossignano	Ascoli Piceno	44016
Cupra Marittima	Ascoli Piceno	44017
Folignano	Ascoli Piceno	44020
Force	Ascoli Piceno	44021
Grottammare	Ascoli Piceno	44023
Maltignano	Ascoli Piceno	44027
Massignano	Ascoli Piceno	44029
Monsampolo del Tronto	Ascoli Piceno	44031
Montalto delle Marche	Ascoli Piceno	44032
Montedinove	Ascoli Piceno	44034
Montefiore dell'Aso	Ascoli Piceno	44036
Montegallo	Ascoli Piceno	44038
Montemonaco	Ascoli Piceno	44044
Monteprandone	Ascoli Piceno	44045
Offida	Ascoli Piceno	44054
Palmiano	Ascoli Piceno	44056
Ripatransone	Ascoli Piceno	44063
Roccafluvione	Ascoli Piceno	44064
Rotella	Ascoli Piceno	44065
San Benedetto del Tronto	Ascoli Piceno	44066
Spinetoli	Ascoli Piceno	44071
Venarotta	Ascoli Piceno	44073
Altidona	Fermo	109001
Amandola	Fermo	109002

Belmonte Piceno	Fermo	109003
Campofilone	Fermo	109004
Falerone	Fermo	109005
Fermo	Fermo	109006
Francavilla d'Ete	Fermo	109007
Grottazzolina	Fermo	109008
Lapedona	Fermo	109009
Magliano di Tenna	Fermo	109010
Massa Fermana	Fermo	109011
Monsampietro Morico	Fermo	109012
Montappone	Fermo	109013
Montefalcone Appennino	Fermo	109014
Montefortino	Fermo	109015
Monte Giberto	Fermo	109016
Montegiorgio	Fermo	109017
Montegranaro	Fermo	109018
Monteleone di Fermo	Fermo	109019
Montelparo	Fermo	109020
Monte Rinaldo	Fermo	109021

Monterubbiano	Fermo	109022
Monte San Pietrangeli	Fermo	109023
Monte Urano	Fermo	109024
Monte Vidon Combatte	Fermo	109025
Monte Vidon Corrado	Fermo	109026
Montottone	Fermo	109027
Moresco	Fermo	109028
Ortezzano	Fermo	109029
Pedaso	Fermo	109030
Petritoli	Fermo	109031
Ponzano di Fermo	Fermo	109032
Porto San Giorgio	Fermo	109033
Porto Sant'Elpidio	Fermo	109034
Rapagnano	Fermo	109035
Santa Vittoria in Matenano	Fermo	109036
Sant'Elpidio a Mare	Fermo	109037
Servigliano	Fermo	109038
Smerillo	Fermo	109039
Torre San Patrizio	Fermo	109040

Although highly partitioned, the characteristics of the Marche Region are rather homogeneous, especially the physical features (Fig. 6.1). From West to East, mountains descends into smooth hills, that soften the profile of large part of the territory (around 69%), until reaching the Adriatic shores: plains are almost absent, except for some narrow fluvial valleys (Enciclopedia Treccani, n.d.). The climate results affected by these features, presenting traits more similar to the Mediterranean type along the coast, transitioning to a more Continental type towards the mountains: in general terms, it is a temperate climate, where it is possible to recognise four distinct seasons and the precipitations are more frequent in the coldest months (Regione Marche, n.d.-b). As a further consequence of the complex topography of the Region, the hydrology results in common peculiar traits: torrential regimes and reduced courses along a West-East direction (Enciclopedia Treccani, n.d.). The 30 river basins enclosed within the regional boundaries mainly follow the same direction, although some of them are shared with the neighbouring Regions, hence in these cases their features as well as their management present some peculiar traits (*Piano Stralcio Di Bacino per l'Assetto Idrogeologico Dei Bacini Di Rilievo Regionale (PAI) 21.01.2004*, 2004) (Fig. 6.2). Nevertheless, studies concerning flood risk have evidenced the general critical conditions of the river basins, as a high proportion (39%) of the area retains proved flooding potential (*Piano Stralcio Di Bacino per l'Assetto Idrogeologico Dei Bacini Di Rilievo Regionale (PAI) 21.01.2004*, 2004). As a matter of fact, the recent years have been dotted by flooding events. The archive of the Regional Civil Protection offers an overview of the latest events (Regione Marche, n.d.-f): among them, those that triggered the declaration of the State of Emergency certainly hold particular relevance (Regione Marche, n.d.-d). Leafing through the available documents, it is possible to observe that even severe hydrological events usually do not affect the whole territory of the Region, but rather it might well happen that some areas remain untouched. Although this is an encouraging aspect for disaster management, it is a critical for the present methodology: since the aim of the first phase is to compare disaster behaviour, it would be impossible if not all municipalities had the occasion to perform their capabilities. As a consequence, in the present study, the temporal span is extended from 2011 to 2015. By doing this, the majority of the municipalities of the Marche Region was involved at least once in an event so much grave that a State of Emergency was declared (Table 6.4 and 6.5).

Table 6.4 — Events considered in this case study and related number of affected municipalities

EVENT		NUMBER OF AFFECTED MUNICIPALITIES	PERCENTAGE OF AFFECTED MUNICIPALITIES
YEAR	*MONTH*		
2011	March	165	72.05%
2012	November	49	21.40%
2013	November-December	183	79.91%
2014	May	126	55.02%
2015	March	158	69.00%

Table 6.5 — Number and percentage of municipalities per number of events

	NUMBER OF EVENTS						
	0	1	2	3	4	5	TOTAL
NUMBER OF MUNICIPALITIES	6	33	36	56	82	16	229
PERCENTAGE OF MUNICIPALITIES	2.62%	14.41%	15.72%	24.45%	35.81%	6.99%	100%

The flooding period was not extended further because no other major events took place (by the end of 2019), while no antecedent events were included because excessively far back in time, potentially hampering the availability of data. In addition, in this way the time span is relatively compressed, hence it could be expected a relatively minor variation of the characteristics studied in the second phase of the methodology. That is, if the period is too broad, it might not be reasonable to select information fixed in a specific time to represent the whole time span, which, on the contrary, is the exactly the aim of the second phase of analysis.

In a few words, the Marche Region presents a landscape that has been shaped and is prone to be subjected to recurrent flood events. As a consequence, flood risk is a relevant component of the risk scenario and it is worth to be explored here. In this case, the Marche Region embodies a Social-Ecological System and the 229 Municipalities constitute the *sub-units* of analysis. This assumption might be considered reasonable because the natural as well as the social characteristics of the Marche Region are approximately homogeneous throughout the territory. Furthermore, the Regional Authority acts as an overarching management body, providing the blueprint of the local management that is later adjusted and enforced by the Mayors: in other words, the Region might be considered as a Social-Ecological System, that faces and copes with a disaster, with local peculiarities expressed through Municipalities. Once this spatial dimension is set, the temporal dimension should be explicated: in the present study, the temporal scale spans from 2008 to 2018, centring on the years 2011-2015, in order to give a chance to the majority of the Municipalities to demonstrate their capacities in dealing with extreme flooding events, have the possibility to track changing characteristics and adjust the collection of data to the available sources.

6.3 Case study: Hokkaidō (北海道)

Surrounded by Sea of Okhotsk, the Sea of Japan and the Pacific Ocean, Hokkaidō (北海道) stretches the borders of Japan to Northernmost extremes: the nearest mainland is part of the Russian Federation, witnessing the peculiar position of this among the four main island of the Japanese archipelago, while the nearest Japanese Prefecture is Aomori, laying on the main Japanese island of Honshū (Fig. 6.2).

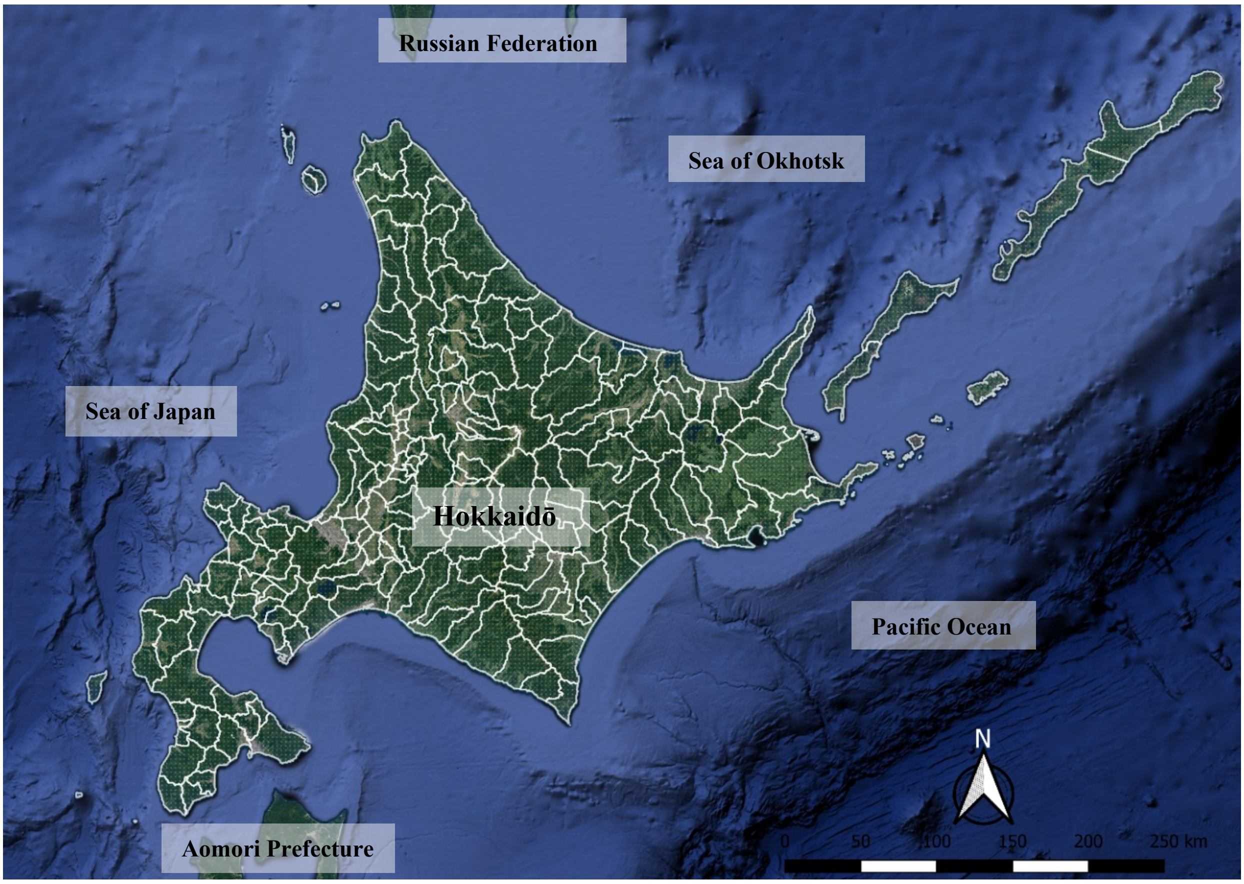


Figure 6.2 — Hokkaidō, partitioned into its Municipalities, the Sea of Okhotsk, the Sea of Japan, the Aomori Prefecture and the Pacific Ocean.

The extension of the available area is rather remarkable, ant it surely is enough to keep the mean population density to very low levels, even though the population of Hokkaidō is rather high in number (Table 6.6). One of the preliminary details that are worth some words of explanation concern the specific peculiarities of the nomenclature. In the first place, it is interesting to observe that, while owning the condition of a Prefecture, the area is referred to as Hokkaidō, without adding the suffix 県 (*ken*) or 府 (*fu*), as commonly happens for the other Prefectures or Urban Prefectures, respectively. This is due to the fact that the name "Hokkaidō" includes in itself the suffix 道(*dō*), representing the origin as a Circuit: actually, 北海道 (*hokkaidō*) means "Nothern Sea Circuit". The other relevant aspect to bear in mind is that the lowest administrative levels, in Hokkaidō as well as in Japan, are represented by three different entities: Cities 市 (*shi*), Towns 町 (*chō* or *machi*) and Villages 村 (*mura*). In this case, in order to harmonise the terminology and facilitate the discussion, this administrative level will be referred to as "Municipality", although it is acknowledge that it represents a simplification and an inaccuracy with regards to the official

Japanese nomenclature. Furthermore, for the sake of legibility, in the present discussion the transliteration (called romaji) of the Japanese toponymy is implemented, adapted from the official *furigana* toponymy (Japanese Government Statistics, n.d.-a). As a final remark, it is important to bear in mind that the Kuril Islands, are not included in the present study, because of their controversial administrative position. Under all these preliminary clarifications, it follows that Hokkaidō is considered to be composed of 179 Municipalities, where the capital city is based in Sapporo-shi (Table 6.7).

Table 6.6 — Main characteristics of Hokkaidō as of 2018.

	AREA (KM^2)	POPULATION (PERSONS)	POPULATION DENSITY (PERSON/ KM^2)	MUNICIPALITIES
Hokkaidō	83 424	5 286 000	63.36	179

Source: adapted from Japan Government of Statistics, n.d.

Table 6.7 — Municipalities of Hokkaidō (in kanji, furigana *and transliterated form) and their ID code.*

MUNICIPALITY			ID
KANJI	*FURIGANA*	RŌMAJI	
札幌市	さっぽろし	Sapporo-shi	01100
函館市	はこだてし	Hakodate-shi	01202
小樽市	おたるし	Otaru-shi	01203
旭川市	あさひかわし	Asahikawa-shi	01204
室蘭市	むろらんし	Muroran-shi	01205
釧路市	くしろし	Kushiro-shi	01206
帯広市	おびひろし	Obihiro-shi	01207
北見市	きたみし	Kitami-shi	01208
夕張市	ゆうばりし	Yubari-shi	01209
岩見沢市	いわみざわし	Iwamizawa-shi	01210
網走市	あばしりし	Abashiri-shi	01211
留萌市	るもいし	Rumoi-shi	01212
苫小牧市	とまこまいし	Tomakomai-shi	01213
稚内市	わっかないし	Wakkanai-shi	01214
美唄市	びばいし	Bibai-shi	01215
芦別市	あしべつし	Ashibetsu-shi	01216
江別市	えべつし	Ebetsu-shi	01217
赤平市	あかびらし	Akabira-shi	01218
紋別市	もんべつし	Mombetsu-shi	01219
士別市	しべつし	Shibetsu-shi	01220
名寄市	なよろし	Nayoro-shi	01221
三笠市	みかさし	Mikasa-shi	01222
根室市	ねむろし	Nemuro-shi	01223
千歳市	ちとせし	Chitose-shi	01224
滝川市	たきかわし	Takikawa-shi	01225
砂川市	すながわし	Sunagawa-shi	01226
歌志内市	うたしないし	Utashinai-shi	01227
深川市	ふかがわし	Fukagawa-shi	01228
富良野市	ふらのし	Furano-shi	01229
登別市	のぼりべつし	Noboribetsu-shi	01230
恵庭市	えにわし	Eniwa-shi	01231
伊達市	だてし	Date-shi	01233
北広島市	きたひろしまし	Kitahiroshima-shi	01234
石狩市	いしかりし	Ishikari-shi	01235
北斗市	ほくとし	Hokuto-shi	01236
当別町	とうべつちょう	Tobetsu-chō	01303
新篠津村	しんしのつむら	Shinshinotsu-mura	01304
松前町	まつまえちょう	Matsumae-chō	01331
福島町	ふくしまちょう	Fukushima-chō	01332
知内町	しりうちちょう	Shiriuchi-chō	01333
木古内町	きこないちょう	Kikonai-chō	01334
七飯町	ななえちょう	Nanae-chō	01337
鹿部町	しかべちょう	Shikabe-chō	01343
森町	もりまち	Mori-machi	01345
八雲町	やくもちょう	Yakumo-chō	01346
長万部町	おしゃまんべちょう	Oshamambe-chō	01347
江差町	えさしちょう	Esashi-chō	01361
上ノ国町	かみのくにちょう	Kaminokuni-chō	01362
厚沢部町	あっさぶちょう	Assabu-chō	01363
乙部町	おとべちょう	Otobe-chō	01364
奥尻町	おくしりちょう	Okushiri-chō	01367
今金町	いまかねちょう	Imakane-chō	01370
せたな町	せたなちょう	Setana-chō	01371
島牧村	しままきむら	Shimamaki-mura	01391
寿都町	すっつちょう	Suttsu-chō	01392
黒松内町	くろまつないちょう	Kuromatsunai-chō	01393
蘭越町	らんこしちょう	Rankoshi-chō	01394
ニセコ町	にせこちょう	Niseko-chō	01395
真狩村	まっかりむら	Makkari-mura	01396
留寿都村	るすつむら	Rusutsu-mura	01397
喜茂別町	きもべつちょう	Kimobetsu-chō	01398
京極町	きょうごくちょう	Kyogoku-chō	01399

倶知安町	くっちゃんちょう	Kutchan-chō	01400
共和町	きょうわちょう	Kyowa-chō	01401
岩内町	いわないちょう	Iwanai-chō	01402
泊村	とまりむら	Tomari-mura	01403
神恵内村	かもえないむら	Kamoenai-mura	01404
積丹町	しゃこたんちょう	Shakotan-chō	01405
古平町	ふるびらちょう	Furubira-chō	01406
仁木町	にきちょう	Niki-chō	01407
余市町	よいちちょう	Yoichi-chō	01408
赤井川村	あかいがわむら	Akaigawa-mura	01409
南幌町	なんぽろちょう	Nanporo-chō	01423
奈井江町	ないえちょう	Naie-chō	01424
上砂川町	かみすながわちょう	Kamisunagawa-chō	01425
由仁町	ゆにちょう	Yuni-chō	01427
長沼町	ながぬまちょう	Naganuma-chō	01428
栗山町	くりやまちょう	Kuriyama-chō	01429
月形町	つきがたちょう	Tsukigata-chō	01430
浦臼町	うらうすちょう	Urausu-chō	01431
新十津川町	しんとつかわちょう	Shintotsukawa-chō	01432
妹背牛町	もせうしちょう	Moseushi-chō	01433
秩父別町	ちっぷべつちょう	Chippubetsu-chō	01434
雨竜町	うりゅうちょう	Uryu-chō	01436
北竜町	ほくりゅうちょう	Hokuryu-chō	01437
沼田町	ぬまたちょう	Numata-chō	01438
鷹栖町	たかすちょう	Takasu-chō	01452
東神楽町	ひがしかぐらちょう	Higashikagura-chō	01453
当麻町	とうまちょう	Tōma-chō	01454
比布町	ぴっぷちょう	Pippu-chō	01455
愛別町	あいべつちょう	Aibetsu-chō	01456
上川町	かみかわちょう	Kamikawa-chō	01457
東川町	ひがしかわちょう	Higashikawa-chō	01458
美瑛町	びえいちょう	Biei-chō	01459
上富良野町	かみふらのちょう	Kamifurano-chō	01460
中富良野町	なかふらのちょう	Nakafurano-chō	01461
南富良野町	みなみふらのちょう	Minamifurano-chō	01462
占冠村	しむかっぷむら	Shimukappu-mura	01463
和寒町	わっさむちょう	Wassamu-chō	01464
剣淵町	けんぶちちょう	Kenbuchi-chō	01465
下川町	しもかわちょう	Shimokawa-chō	01468
美深町	びふかちょう	Bifuka-chō	01469
音威子府村	おといねっぷむら	Otoineppu-mura	01470
中川町	なかがわちょう	Nakagawa-chō	01471
幌加内町	ほろかないちょう	Horokanai-chō	01472
増毛町	ましけちょう	Mashike-chō	01481
小平町	おびらちょう	Obira-chō	01482
苫前町	とままえちょう	Tomamae-chō	01483
羽幌町	はぼろちょう	Haboro-chō	01484
初山別村	しょさんべつむら	Shosanbetsu-mura	01485
遠別町	えんべつちょう	Enbetsu-chō	01486
天塩町	てしおちょう	Teshio-chō	01487
猿払村	さるふつむら	Sarufutsu-mura	01511
浜頓別町	はまとんべつちょう	Hamatonbetsu-chō	01512
中頓別町	なかとんべつちょう	Nakatonbetsu-chō	01513
枝幸町	えさしちょう	Esashi-chō	01514
豊富町	とよとみちょう	Toyotomi-chō	01516
礼文町	れぶんちょう	Rebun-chō	01517

利尻町	りしりちょう	Rishiri-chō	01518
利尻富士町	りしりふじちょう	Rishirifuji-chō	01519
幌延町	ほろのべちょう	Horonobe-chō	01520
美幌町	びほろちょう	Bihoro-chō	01543
津別町	つべつちょう	Tsubetsu-chō	01544
斜里町	しゃりちょう	Shari-chō	01545
清里町	きよさとちょう	Kiyosato-chō	01546
小清水町	こしみずちょう	Koshimizu-chō	01547
訓子府町	くんねっぷちょう	Kunneppu-chō	01549
置戸町	おけとちょう	Oketo-chō	01550
佐呂間町	さろまちょう	Saroma-chō	01552
遠軽町	えんがるちょう	Engaru-chō	01555
湧別町	ゆうべつちょう	Yūbetsu-chō	01559
滝上町	たきのうえちょう	Takinoue-chō	01560
興部町	おこっぺちょう	Okoppe-chō	01561
西興部村	にしおこっぺむら	Nishiokoppe-mura	01562
雄武町	おうむちょう	Ōmu-chō	01563
大空町	おおぞらちょう	Ōzora-chō	01564
豊浦町	とようらちょう	Toyoura-chō	01571
壮瞥町	そうべつちょう	Sōbetsu-chō	01575
白老町	しらおいちょう	Shiraoi-chō	01578
厚真町	あつまちょう	Atsuma-chō	01581
洞爺湖町	とうやこちょう	Tōyako-chō	01584
安平町	あびらちょう	Abira-chō	01585
むかわ町	むかわちょう	Mukawa-chō	01586
日高町	ひだかちょう	Hidaka-chō	01601
平取町	びらとりちょう	Biratori-chō	01602
新冠町	にいかっぷちょう	Niikappu-chō	01604
浦河町	うらかわちょう	Urakawa-chō	01607
様似町	さまにちょう	Samani-chō	01608
えりも町	えりもちょう	Erimo-chō	01609
新ひだか町	しんひだかちょう	Shinhidaka-chō	01610
音更町	おとふけちょう	Otofuke-chō	01631
士幌町	しほろちょう	Shihoro-chō	01632
上士幌町	かみしほろちょう	Kamishihoro-chō	01633
鹿追町	しかおいちょう	Shikaoi-chō	01634
新得町	しんとくちょう	Shintoku-chō	01635
清水町	しみずちょう	Shimizu-chō	01636
芽室町	めむろちょう	Memuro-chō	01637
中札内村	なかさつないむら	Nakasatsunai-mura	01638
更別村	さらべつむら	Sarabetsu-mura	01639
大樹町	たいきちょう	Taiki-chō	01641
広尾町	ひろおちょう	Hiroo-chō	01642
幕別町	まくべつちょう	Makubetsu-chō	01643
池田町	いけだちょう	Ikeda-chō	01644
豊頃町	とよころちょう	Toyokoro-chō	01645
本別町	ほんべつちょう	Honbetsu-chō	01646
足寄町	あしょろちょう	Ashoro-chō	01647
陸別町	りくべつちょう	Rikubetsu-chō	01648
浦幌町	うらほろちょう	Urahoro-chō	01649
釧路町	くしろちょう	Kushiro-chō	01661
厚岸町	あっけしちょう	Akkeshi-chō	01662
浜中町	はまなかちょう	Hamanaka-chō	01663
標茶町	しべちゃちょう	Shibecha-chō	01664
弟子屈町	てしかがちょう	Teshikaga-chō	01665
鶴居村	つるいむら	Tsurui-mura	01667

白糠町	しらぬかちょう	Shiranuka-chō	01668	標津町	しべつちょう	Shibetsu-chō	01693
別海町	べつかいちょう	Betsukai-chō	01691	羅臼町	らうすちょう	Rausu-chō	01694
中標津町	なかしべつちょう	Nakashibetsu-chō	01692				

Source: adapted from Japanese Government Statistics, n.d.

The climate of this Prefecture is affected by the position of the island, slightly differing from the rest of Japan: the main traits pertain to the Continental type, and even though it is possible to recognise four main seasons, similarly to the other Japanese Prefectures, there is not a rainy season and in the coldest months heavy snowing events might happen, especially on the western side (MLIT, n.d.-d). On the contrary, Hokkaidō displays the same peculiar morphological features of Japan: the territory is dominated by mountains and volcanoes, some of which are active, that align along a North-South direction and relegate the plains to the areas near the coasts (Encyclopaedia Britannica, n.d.). Similarly, the rivers that cross the region stretch from the higher areas towards the shores, in an articulated net spread throughout the territory. As a consequence, the development of Hokkaidō in the centuries has naturally integrated water bodies, their dynamics and their surrounding environments (MLIT, n.d.-e). Rivers are acknowledged to pose a menace, but also to represent a resource and a sustenance for local communities, both human and not (MLIT, n.d.-e). Hence, the strategies to promote a harmonious coexistence with water systems enhance a broader perspective, one that could encompass the rivers all along their course, from springs to estuaries, and all along the natural setting, encompassing the ecological communities. In this perspective, floods are considered part of the natural processes that characterise the territory as well. During the Meiji Era (late 19th-early 20th century), the newly established Government resolved to promote Hokkaidō as a critical node for the progress of Japan as a whole, hence public infrastructures and private activities begun to flourish along with a steady and relevant increase of the local population (MLIT, n.d.-f). Around the same time, management activities concerning water-related hazards were prompted to secure the growing and expanding assets from the recurrent threats that flood posed during the decades (MLIT, n.d.-g). This is especially relevant when the expansion of social and productive structures as well as infrastructures are concentrated in the lowland areas of riverine plains and the subsequent impact of a flood might be particularly severe. Indeed, in recent years Hokkaidō has severely suffered from flood events (Fig. 6.3), often originated from particularly dreadful typhoons.

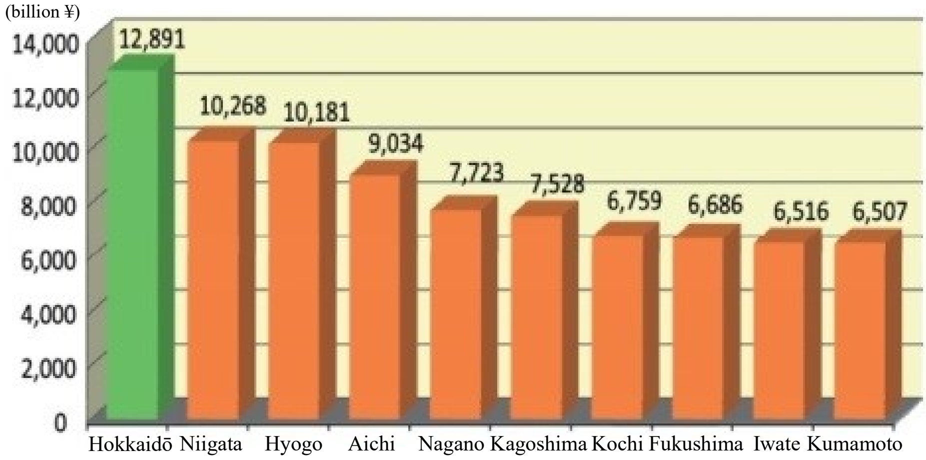


Figure 6.3 — Total flood damages in recent years (1981-2016).Values are referred to the year of the events. Source: adapted from MLIT, n.d.-c.

A recent flood event that took place in 2016 adhered to a similar outline, although the specific characteristics of this event were much worse than those recalled in the recent history. Between August 17 and 23, three different typhoons (n° 7, 9, 11) landed on Hokkaidō and just a week later an other typhoon (n° 10), combining with the local conditions, induced further heavy rains on the island (MLIT, n.d.-k). This resulted in an unprecedented event, even for the statistics of the Japan Meteorological Agency: for instance, three typhoons landing on Hokkaidō were never recorded before, in some places the amount of precipitation corresponded to annual values (MLIT, n.d.-c). The overall consequences were dire. Lives were lost and severely affected, along with a heavy toll in terms of damages to private assets and public infrastructures, such as river embankments, bridges and roadways (MLIT, n.d.-k). Such dreadful impacts affected the island as a whole, extending the effects also to the economic activities. In particular, since the Meiji Era Hokkaidō prompted the development of agriculture and the flourishment of such activities was planned to benefit all Japan (MLIT, n.d.-k). As a consequence, the events of August 2016 caused vast damages to the primary sector of Hokkaidō and spilled over the whole Country. As crops could not be harvested or planted, factories could not carry on their activities, products could not be transported, food processing lines suffered stagnation, leaving Japan without one of the most important Prefectures for food supplies (MLIT, n.d.-k). Similar cascade effects involved also the other economic sectors (MLIT, n.d.-k), remarking the seriousness and extension of the disaster. A further consequence of these events was the raising and consolidating awareness of the threat posed by floods, a menace that could only grow worse in the future, due to climate changes. Extreme rainfall and flooding events are expected to worsen in the decades to come, in Japan and especially in Hokkaidō, hence it is endorsed the need to enhance further mitigation measures, combined with innovative adaptation strategies, both structural and non-structural (MLIT, n.d.-c).

In a few words, the unfortunate happenings of 2016 have left behind negative consequences, as well as positive resolutions, that will possibly affect Hokkaidō in the long term.

Coming back to the perspective of adopting this area as a case study, it might be beneficial to summarise the most relevant features of this Prefecture. Hokkaidō presents a territory wrinkled by mountains and crossed by a manifold of water bodies: combined with the exposure to typhoons and other heavy rainfall events, possibly worsened by the ongoing environmental changes, it comes naturally that floods are a recurrent and significant feature for this region. This island is geographically detached from the other parts of Japan, has matured a peculiar history and holds the autonomy granted to Japanese Prefectures, yet its characteristics are somehow homogeneous within its territory. In light of these facts, Hokkaidō can be assumed as a Social-Ecological System (SES), composed of 179 Municipalities that provide the *sub-units* of the analysis. In this case, the temporal dimension extends over the year 2016, especially referring to the events happened in August, because of the extensive effects that Hokkaidō as a whole suffered, from a social, economic and environmental point of view. In particular the time period considered spans from 2015 to 2017, in order to catch the changes and mark the characteristics that concern the above-mentioned events.

6.4 The two case studies face to face

Once that the two case studies have been introduced, it might be interesting to recollect the major features that assimilate or differentiate them (Table 6.8).

Table 6.8 — Main characteristics of Marche Region and mountains and Hokkaidō case studies.

FEATURE	MARCHE REGION	HOKKAIDŌ
POSITION	central Italy (mainland)	North Japan (island)
AREA EXTENSION (in km^2)	9 401	83 424
POPULATION (people)	1 525 271	5 286 000
TOPOGRAPHY	mountains and hills predominate, valleys limited to coastal areas; torrential regime of rivers	mountains and hills predominate, valleys limited to coastal areas; torrential regime of rivers
ADMINISTRATIVE STATUS	Region	Prefecture
NUMBER OF MUNICIPALITIES	229	179
TIME PERIOD	2008-2018	2015-2017
FLOOD PERIOD	2011-2015	2016
NUMBER OF EVENTS	5	4

It appears that, even though the case studies are rather different in extension of their area and of their population, they share some important traits. First of all, the complex geography of territory, characterised by mountains that descend (either from West to East or from the centre towards the borders) towards the Sea or the Ocean. This morphology affects the characteristics of the water bodies, and in particular of rivers. Flood events have always been part of the development of these areas, and the recent years make no exception. Nonetheless, as for Marche Region, the area of impact is relatively narrow, while the extraordinary series of events happened in Hokkaidō caused significant consequences all over the Prefecture at once. Nonetheless, the natural characteristics of the areas are especially valuable: indeed, national and regional parks as well as other natural protection initiatives have been prompted in both Marche Region and Hokkaidō. Also, the case studies show similar climates, where between the four distinct seasons, the coldest ones suffer most from significant rainfall and snowfall events. The two case studies present rather homogenous features also in social and economic terms, while sharing some traits: for instance, agriculture plays a prominent role in the development of the territories along with tourism, although SMEs (Small and Medium Enterprises) and tertiary services are the cores of the economic activities (respectively for Marche Region and Hokkaidō).

In light of these factors, it seems appropriate to apply the proposed methodology to these case studies: Marche Region and Hokkaidō share features similar enough to allow for a comparison of the outcome of the analysis, and yet they differ enough to suggest that it might be possible to unveil some local peculiarities that might determine a specific behaviour or hamper the applied analysis.

6.5 Tailoring the proposed methodology to the case studies

Once the spatial and the temporal frames are set, it is possible to commence handling data that will allow to perform the analysis. One of the preliminary operations concerns collecting data: as it was previously mentioned, the methodology proposed for this research study centres on indicators as the basis for the analytical processes. Consequently, the first focus should be posed on the indicators themselves. It is true that in the previous discussions (see Ch. 5) the overarching framework was exposed, exploring the reasons behind the *attributes* and the *dimensions* of the two *cores*, resilience and sustainability (see Table 5.3). At the same time, it was suggested that these features appear to be relevant in conceptual terms, a little bit less in operative terms. That is, *attributes* and *dimensions* are fundamental to ground and guide the development of the methodology, but when it comes to carry on the process operatively, it is necessary to look for indicators, related to *attributes* and *dimensions*. As a consequence, at this point, where the case studies have been identified and the time span has been bounded, it is necessary to identify and search for quantitative indicators to employ in the two phases of the proposed methodology. In the following lines, the indicators adopted for the two case studies will be presented and discussed, for each phase of the methodology. It might be relevant to bear in mind that when considering what kind of proxies should be selected, two further principles were introduced along with the other requisites. First, the indicators had to respond as far as possible to the features already evidenced as significant in their respective field, that is to the related *core*. Indeed, it would be inappropriate to disregard previous research endeavours that already proved the relevance of specific themes. Second, indicators had to grant a adequate easiness of collecting such information. In other words, the aim was to opt for indicators that implied a straightforward process to gather them. The overarching assumption of the present methodology is to assist and ease the assessment of resilience and of sustainability: focusing on indicators hard to populate would turn into a contradiction. Nonetheless, it should be anticipated here that the collection of data was hindered by the availability of information. As a consequence, for instance, some indicators might not be the optimal choice, because of the restraints that the search incurred in, although in some other cases different versions of the same indicator were collected in order to identify the most suitable one. Another issue concerns the comparability of the information between the case studies. Provided the need to tailor the collected information to the case being studied in order to take into account features that could effectively hold a significant meaning for the specific case, it would be interesting to maintain the indicators as similar as possible, in order to compare the different relevance that the variables acquire possibly due to the specific local characteristics. In spite of this premise, in some cases the choice was nonetheless forced by the local availability.

In any case, the extended list of the explored indicators, including all the temporal references along with the related sources, for both *cores* and both case studies, might be consulted in the Appendices I and II. The Appendices (I and II) provide also the quantification of those indicators progressively selected in order to proceed through the analytical processes.

6.5.1 Marche Region

The following tables (Table 6.9 and 6.10) show the indicators that were adopted and tested for the Marche Region in order to fulfil the double-fold methodology implemented here.

The indicators associated to the *attributes* (Table 6.9), as mentioned earlier, come into play when approaching the first phase of the methodology. This is the phase where previous examples of application are less in number and in strictness; in addition, this is the phase designed to be most flexible, especially adapting the indicators to the risk scenario enhanced. Hence, at this point it is particularly relevant to lay out the reasons behind the choices in order to make the process as transparent as possible. Lastly, this aspect might become meaningful in order to address the requisite of replicability, simply being a reference also among case studies. The rationale that supports such indicators relies on the requisite that they should represent how resilience and sustainability manifested during occurred events. In the present case, the indicators should be related to flood risk and in general to proxies that tackle critical conditions or conditions that could evolve into critical situations.

In particular, referring to the resilience *core*, the learn *attribute* is intended to trace whether the community has learnt from the flood events, for instance, gradually leaving the flooding areas and resettling elsewhere. On the other hand, the aim of the indicator related to the absorb *attribute* intends to quantify the grants requested (and in particular those conceded) to cope with the suffered damages: it is assumed that the less the amount of grants, the less the damages hence the higher ability to face the flood events. Lastly, the aim of the indicator for the recover *attribute* is to evaluate if it was possible at least to restore the economic conditions of the community after the flood events.

The sustainability *core* followed a slightly different perspective, especially focusing on alterations that could hamper the ability of the environment to perform the natural processes. The conversion of natural land into urbanised and industrialised areas, related to the functions *attribute*, intends to echo the alteration of natural landscapes, hence the loss of the ability to manage (absorbing and draining) water. The services *attribute* is represented by a proxy of the increasing impact of human activities on natural sources and dynamics, where collecting natural water might hinder both spring and water courses. Lastly, the integrity *attribute* aims to report the state of the environment through the species that have particularly suffered from human processes, thus mirroring an expanding and degrading influence over natural systems.

Table 6.9 — Indicators of the cores per each attribute, related to their source for the Marche Region case study.

CORE	*ATTRIBUTE*	INDICATOR
resilience	learn	variation of population exposed to flood hazard
	absorb	grants for extraordinary and emergency interventions
	recover	ratio of tax revenue after 2 years and on the year of the last flood event
sustainability	functions	variation of land take
	services	variation of water intake
	integrity	number of species in inadequate or bad conservation status

Coming to the second phase of analysis, other indicators are needed, some that are related to the *dimensions* of the *cores* (Table 6.10). In this phase, the aim of the indicators is to depict the overall characteristics of the Social-Ecological System and of the *sub-units* in particular. The objective is to pinpoint the features that most efficiently discriminate the differences in disaster behaviour. In line with this perspective, when possible, more than one indicator was tried to represent a same *dimension*, in order to identify the most suitable one. In general terms, this phase of the methodology might benefit the most from the previous research endeavours. As suggested above, a wealth of indicators have been proposed to represent resilience and sustainability, as well as themes related to these *cores*. Consequently, the indicators presented here aim to follow as far as possible the path already laid out by previous efforts (see Table 4.7 and 4.8).

Concerning the resilience core, some indicators represent the basic characteristics of a community, along with some factors that have been suggested to influence its resilience, because of either their intrinsic fragilities (presence of elderlies and of women, population density) or their lack of familiarity with the area (presence of non-native people). At the same time, the cohesion of the community has received high attention, both from a private (involvement in local organisations) and a public (support of local organisations) perspectives, including the possibility to be connected to each other (internet access). In some other cases, the indicators try to capture some capitals, either non-material (level of education) or material (status of employment, income) that should enhance the ability to cope with extreme events. Similarly, public efforts to sustain fragile situations (investments to alleviate poverty and critical conditions) have been often considered, along with a picture of their effects on the area (difference between people living and only residing in the area, hence working elsewhere). The relevance of the health and emergency systems emerges particularly evident during an extreme event, hence maintaining their performance to the highest levels is indeed critical (structure of the health system, care of fragile people, quick activation of first respondents). At the same time, a community lives within an engineered space: its safety (support of mitigation efforts, year of construction), efficacy (extension of roadways) and efficiency (wasted water after abduction) shape everyday life, but they might as well enhance a prompt response in case of a disaster.

In the meanwhile, indicators related to the sustainability *core* are to be collected. This is the step that suffered most from the complexity of retrieving information. Therefore, unfortunately, it was not possible to collect as much indicators as for the resilience *core*. In this case, the aim is to keep trace of significant alterations of the pristine state of the natural environment (conditions of the environment, presence of quasi-natural areas, presence of environmentally valuable areas) and of the health of ecosystems (support of the production of raw materials and valuable products). At the same time, it appeared relevant to evaluate the permanence of physical features (variation in air quality and in water quantity during extreme events), as well as the evident impacts of human activities (areas converted for agricultural purposes, expansion of livestock, induced fragmentation of natural areas).

Table 6.10 — Indicators of the cores per each dimension, related to their source for the Marche Region case study.

CORE	*DIMENSION*	INDICATOR
resilience	demographic	immigrants
		population over 65 y.o. population over 80 y.o.
		female population
		population density
	social	population with higher education
		territory with UWB internet access
		volunteers in no-profit organisations dealing with social welfare and civil protection
		public revenues of no-profit organisations dealing with social welfare and civil protection volunteer expenditure of no-profit organisations dealing with social welfare and civil protection
	economic	employment unemployment
		taxable income
		social expenditure for social welfare
		present population difference in present and resident population
	health	mental health discharges residence facilities for the elderly beds in residence facilities for the elderly welfare facilities (non-residence) for the elderly total welfare facilities for the elderly
		hospital staff
		hospital beds
		average time of arrival on place average time of arrival on place over the past 5 years
	infrastructural	local expenditure for mitigation
		extension of municipal roads extension of non-municipal roads
		wasted drink water
		average building construction year
sustainability	ecosystems integrity	habitats in inadequate/bad status
		grassland and pasture woods owned by farms
		geobotanical value
	ecosystem benefits	forests for woods
		D.O.C. and I.G.P. producers
	physical processes state	flood discharge variation
		PM_{10} average value

		PM_{10} average difference PM_{10} average value in most populated cell PM_{10} average difference in most populated cell
	external pressures	agricultural area
		heads of livestock heads of cattle
		urban-transport fragmentation pressure

6.5.2 Hokkaidō

The rationale that guided the choice of the indicators for the Hokkaidō case study (Table 6.11 and 6.12) closely follows the concepts discussed for the Marche Region case study. Consequently, it seems that a further examination of these terms would not fruitfully contribute to the present discourse. On the other hand, it might be worthwhile to give some attention to the differences among the indicators and to the meaning that they carry within the adopted methodology.

Concerning the first phase (Table 6.9 and 6.11) of the analytical process, the major aim was to keep the indicators as similar as possible. In this way, the disaster behaviour would be evaluated through the same lens and whether some differences would be seen, they could be ascribed to the differences in specific local features of the case studies.

The data collection for the Marche Region allowed to highlight in advance the encouraging performance of the selected combination of indicators, hence the focus shifted on replicating this result for Hokkaidō. In spite of this objective, retrieving this kind of data resulted rather complex, hence other indicators were included, in order to test their suitability as substitutes. The results and their discussion will follow later, but this is an anticipation of the reason behind the presence of a multiplicity of indicators associated with the learn *attribute* of resilience here. The conceptual nucleus of the learn *attribute* lies on the alteration of a certain socio-economic trend after the influence of an event: in addition to evaluating the tendency to resettle elsewhere from hazardous areas, the extension of the area that suffered from the flood intended to represent the tendency to expose assets to hazardous conditions, while the distance from the water body was assumed to increase with the raise of awareness of flood risk. On the other hand, the other *attributes* received indicators rather similar among the case studies: the differences are merely formal, while the underlying meaning and content is comparable.

The sustainability *core* presents much wider discrepancies. Unfortunately, in this case data availability played a critical role, preventing the adoption of the same indicators. Consequently, its focus shifted towards maintaining their meaning as close as possible and assuring the performance of the analysis as high as possible. This is the reason why also in this case some *attributes* are associated with more than one indicator here. In particular, the variation in land use was traced through the financial transactions related to lands and through the vegetation that was altered throughout the recent years (functions *attribute*). Conversely, the alteration of the physical benefits was related to the extension of the assets related to the power supply, rather than the quantity of abducted water (services *attribute*). Lastly, rather that quantifying the wildlife species in critical conditions, the integrity of the environment was investigated through the distribution of an especially problematic species, that is the raccoon (洗熊 or 浣熊 rōmaji: *araiguma*): this alien species should not be confused with the Japanese raccoon dog (狸 rōmaji: *tanuki*), a local species that has suffered the spread of the *araiguma* raccoon since its artificial introduction started in the late ‘80s. The concern is significant to the point of issuing legislative countermeasures, although damages to agriculture and ecosystems are already severe (Ikeda et al., 2004) and especially relevant for a region like Hokkaidō, relying on the flourishing of the primary sector.

Table 6.11 — Indicators of the cores per each attribute, related to their source for the Hokkaidō case study.

CORE	*ATTRIBUTE*	INDICATOR
resilience	learn	total affected area
		distance from the nearest water body
		population exposed to flood hazard
	absorb	flood damages
	recover	percentual difference in income after 2 years and on the year of the last flood event
sustainability	functions	land transaction
		altered vegetation
	services	number of establishments
		employees in power supply
	integrity	distribution of raccoon (浣熊 rōmaji: *araiguma*)

Inevitably, differences among indicators persist also for those devoted to the second phase of the analysis (Table 6.10 and 6.12). Actually, in this case some discrepancies should not be discouraged: this phase aims to portray the peculiarities of a Social-Ecological System, hence it would make little sense to force a standard over different case studies, that are related to different social, economic and environmental conditions.

Nonetheless, the representation of the demographic *dimension* still maintains a homogeneity, as the same major variables have been evaluated throughout previous studies, in spite of the geographic focus. On the other hand, the social *dimension* recognises some alternative indicators, although this is mainly due to their availability: the aim to trace the interconnection within the community is still considered, even though through a different proxy (related to television rather than internet connection); similarly, the possibility to interact with each other and the public support to aggregation initiatives are assessed (presence and dimension of public facilities). The evaluation of the educational level is perfectly comparable, but it should be bore in mind that the Italian and Japanese educational systems are slightly different, for instance concerning the compulsory period, which ends one year earlier for Japan (15 years old) compared to Italy. In a similar fashion, the conceptual assumption supporting the economic *dimension* is consistent with the other case study, though it is possible more easily to trace the incoming external population, while the health *dimension* captures the investment rather than the (supposedly) subsequent efficacy of first responders (whereas other differences are merely formal). Lastly, the infrastructure *dimension* shows the only relevant variation when assessing public infrastructures: rather than their efficacy, the focus is posed on the availability, as septic tanks are adopted when households cannot rely on then public sewerage system.

Also in this case, possibly even more, the collection of information concerning the sustainability *core* was hampered by the complexity of retrieving data. In this case, the integrity of the ecosystems was depicted through the extension of natural and quasi-natural areas (forests, shrubs, grasslands, pastures), whereas the retrieved benefits are related to raw materials (such as wood) as well as wildlife catches and breeding (in this case related to fishery). The abduction of natural water is here employed as a proxy for the induced alteration of the physical processes, while the primary sector (agriculture and farming, especially cattle) is assumed as a representation of the human pressure exerted on the natural environment.

Table 6.12 —Indicators of the cores per each attribute, related to their source for the Hokkaidō case study.

CORE	*DIMENSION*	INDICATOR
resilience	demographic	immigrants
		population over 65 y.o. population over 75 y.o. population over 80 y.o.
		female population
		population density
	social	population with compelled education population with university education
		tv subscriptions satellite subscriptions
		public halls public halls and similar infrastructures personnel of public halls and similar infrastructures
		sport facilities personnel of sport facilities

	economic	employment
		taxable income
		social welfare expenses
		in-migrants from other Municipalities inflow of population from the same Prefecture inflow of population from a different Prefecture total inflow of population
	health	welfare facilities for the elderly nursing care facilities for the elderly
		medical facility doctors
		hospital with medical beds hospital beds beds in general clinics
		firefighting expenses
	infrastructural	disaster recovery expenses
		extension of roadways
		population served by septic tank
		average building construction year
sustainability	ecosystems integrity	forest and grassland forests grasslands
		wildlife sanctuary
	ecosystem benefits	private forests
		fisheries and aquaculture entities
	physical processes state	water intake of water supply businesses
		difference from optimal pH value in river water
	external pressures	cultivated land area
		revenue from livestock revenue from beef cattle

Finally, a significant difference between the data retrieved for the two case studies resides in the temporal reference implemented. In the context of the Marche Region, the spans from 2008 to 2018 (Table 6.8), hence indicators are preferably referred to 2018. Nonetheless, in some cases data availability imposes different temporal limits (for instance, information concerning education dates back to 2011, data on livestock to 2010). In addition, some indicators are related to variations, hence the time span responds to the specific requisites (e.g. the variation of taxable revenue depends on the year of the last event suffered by the municipality). In a similar vein, Hokkaidō was evaluated for the period 2015-2017 (Table 6.8), therefore the reference is set on 2017. Nevertheless, some information necessarily belongs to different years (e.g. data on energy system is available for 2014-2016), thus, especially for the indicators aiming to describe the overall characteristics of the Social-Ecological System (that is, through the *dimensions*), information was collected considering the year 2015 as far as possible, in order to capture the conditions preceding the flood event of 2016 and enhance as much as possible the consistency among data.

6.5.3 Methodological issues

As previously mentioned, the indicators were selected in order to keep their collection as straightforward and replicable as possible. Consequently, sources of information that could be easy accessed and that provided official data were preferred, such as the Italian National Institute of Statistics (ISTAT) (ISTAT, n.d.-c) or the Japanese Government Statistics (Japanese Government Statistics, n.d.-b). In spite of this overarching intention, some indicators indeed required a specific pre-processing in order to be employed. Hence, it might be relevant to report here such exceptions, in order to make the process the most transparent that is possible (see Table 6.9, 6.10, 6.11 and 6.12). Furthermore, some processes required a Geographic Information System (GIS) tool: in such cases, it was employed the opensource software QGIS 3.4 *Madeira* and later QGIS 3.10 *A Coruña* (QGIS, n.d.). These versions were preferred over the others, even the more recent ones, because they were the latest available Long Term Release (LTR) versions, hence they prove more stable and reliable.

Marche Region

It might be interesting to note that over the years some variations have occurred in the administrative boundaries of the municipalities, especially through merges and subsequent changes in local toponymy. This results in some issues when making use of data referred to different years: in other words, it might happen that information is related to municipalities that do not exist anymore. Consequently, it is often necessary to merge the scattered data and a reference for the occurred changes was indeed beneficial (Table 6.13).

Table 6.13 — Municipalities of the Marche Region before and after the merges occurred in the period 2008-2018.

FORMER MUNICIPALITY	MUNICIPALITY RESULTING AFTER MERGE	YEAR
Colbordolo Sant'Angelo in Lizzola	Vallefoglia	2014
Castel Colonna Monterado Ripe	Trecastelli	2014
Montemaggiore al Metauro Saltara Serrungarina	Colli al Metauro	2017

Acquacanina Fiastra	Fiastra	2017
Barchi Orciano di Pesaro Piagge San Giorgio di Pesaro	Terre Roveresche	2017
Fiordimonte Pievebovigliana	Valfornace	2017
Auditore Sassocorvaro	Sassocorvaro Auditore	2019

In order to perform spatial analysis in GIS environment, it was necessary to preliminary retrieve the official representation of the geographical features of the Marche Region. In particular, administrative boundaries were collected from the Italian National Institute of Statistics (ISTAT) for the year 2018 (ISTAT, n.d.-b). The information is available as a *shapefile* for three administrative levels: Region, Province and Municipality, comprising the overall national territory. Thus, it was necessary to *select* and isolate the elements pertaining specifically to the Marche Region, in order to hold a geospatial representation of its local administrative boundaries and respective identifying codes. The Coordinate Reference System (CRS) is WGS84 UTM32N, identified as EPSG: 32632 (ISTAT, n.d.-b). Afterwards, taking into account that this is also one of the most widely used CRS (QGIS Documentation, n.d.) and that it represents a global geographical standard, it was assumed appropriate to adopt it for all the following geographical data processing concerning the Marche Region (in the case of Hokkaidō, the WGS84 was still employed, but adapting it to Japan by choosing the UTM zone 54N, identified as EPSG:32654). A further preliminary data collection was performed, in order to retrieve a basic statistical information: the quantification of population pertaining to each Municipality was indeed the base for several following calculations. The Italian National Institute of Statistics (ISTAT) provides population data for the recent years (ISTAT, n.d.-c), hence in this case information was retrieved accordingly to the time reference of the following data processing.

First phase

- **variation of population exposed to flood hazard**

  The Italian Institute for Environmental Protection and Research (ISPRA) compiles reports to describe the condition of risk of the Italian territory. In this case the available reports are for year 2015 and 2018, hence their Appendices were consulted to retrieve information concerning the population exposed to flood risk (Trigila et al., 2018, 2015). The Italian legislative regulation recognises three level of hazardousness related to flood, depending on the probability of the event to happen, quantified through the return period (*D. Lgs. 49/2010 "Attuazione Della Direttiva 2007/60/CE Relativa Alla Valutazione e Alla Gestione Dei Rischi Di Alluvioni,"* 2010). Unfortunately, for the Marche Region it is possible to consult only data related to the intermediate level, that is medium probability of occurrence. As a consequence, that is the level adopted in the present case. After the collection, the variation in population exposed in 2018 compared to 2015 is calculated through the equation (Eq. 5):

$$\frac{pop_{2018} - pop_{2015}}{pop_{2015}} = \Delta pop_{2015-2018} \tag{5}$$

where pop_{2015} and pop_{2018} represent the population exposed to flood hazard as retrieved from the reports of 2015 and 2018, respectively. However, it should be noted that sometimes pop_{2015} equals 0, hence causing mathematical issues to the computation. In such cases, both pop_{2015} and pop_{2018} are added 1, so that the difference remains the same, but it is possible to evaluate the occurred variation. It is acknowledged here that this hampers the assessment, because in this way a variation from 0 to n is the same as a variation from 1 to n. Nonetheless, it is assumed as an acceptable approximation: even though the cases concerned with this procedure is only relatively low (49 sub-units out of 229, 21.40%), the majority (39 sub-units out of 229, 79.59%) resolves in an invariance of the conditions, hence eventually only a minority of the total cases (10 sub-units out of 229, 4.37%) is affected by this limitation.

- **grants for extraordinary and emergency interventions**

  When flood events are violent to the point of calling for the declaration of the state of emergency, the public contributions to alleviate the damages suffered by the population can be traced through official documents and transactions. In this case, the information was collected searching for and consulting each available document and decree in the online legislative archive of the Marche Region, for every event along the time span considered (Regione Marche, n.d.-e). The grants are considered only if referred to Municipalities (hence excluding those for the Provinces) and at the point of closure of the payment. They include, among other public interventions, the contributions to displaced population, assistance to population and support to local companies. It is acknowledged here that at the moment of last consultation (July 2019) the documents might be incomplete, since the reimbursement procedures might last up to 6 years after the event, limiting the availability of data for the present study. Nonetheless, to the knowledge of the author, unfortunately this aspect can not be avoided nor compensated, hence it is accepted as an inherent issue.

- **ratio of tax revenue after 2 years and on the year of the last flood event**

  The conceptual foundation of this indicator lies in evaluating the strength to recover from a disastrous event. In this perspective, the variation in the personal economic condition was targeted through the taxable income. To begin with, it is necessary to assess the time span for each municipality. In particular, the year of the last impacting flood should be identified for each sub-unit. At the time of retrieving data (2019), the latest available information on the website of the Ministry of Economy and Finance (Ministero dell'Economia e delle Finanze, n.d.) refers to 2018, that is the fiscal year 2017. As a consequence, since the last severe flood considered here dates back to 2015, it follows that the longest time span possible is 2 years. Thus, for each sub-unit the 2-year delay is identified. Nonetheless, as previously mentioned (Table 6.5), a minority of the sub-units (2.62%) resulted in not being affected by any flood event. With regards to these cases, it was assumed that the event of November-December 2013 involved such a large portion (79.91%) of the municipalities (see Table 6.4), that some effects might reasonably have spilled over all the Marche Region. Hence, the period 2013-2015 is associated to those particular cases, although it represents an artificial construct. At this point, the taxable income for each pertaining year is collected per each sub-unit, and the variation is computed as a percentual difference (Eq. 6):

$$\frac{\left(taxinc_{event+2years} - taxinc_{event}\right) \cdot 100}{taxinc_{event}} = \Delta taxinc_{event\,-\,event+2years} \qquad (6)$$

  where $taxinc_{event}$ and $taxinc_{event+2years}$ represent the taxable income on the year and after two years from the latest flood event.

- **land take**

  One evident alteration of the natural environment consists in the anthropogenic transformation from pristine areas into urbanised and industrialised settlements. This variation directly affects the processes that the ecosystems perform: as their extension is progressively reduced, the functions that they operate are also declining. A possible indicator of this alteration is the degree of land take, that depicts the amount of territory converted from natural and semi-natural areas for artificial land uses (EEA, 2019c). Data on land take for the Italian territory can be publicly accessed thanks to the Italian Institute for Environmental Protection and Research (ISPRA) (SINAnet - ISPRA, 2019). At the moment of the collection, data was published for the time period 2012-2018. Although fitting with the present temporal scale, by the moment of publication the administrative boundaries had changed for a Municipality (Table 6.13), hence in this case the total amount was distributed on the base of the proportional areas of the two former Municipalities, disjoined until 2018. Among the manifold of information, data concerning the extent and the percentage of areas affected by land take was considered, for 2012 and 2018. Then, the variations were calculated and adopted as indicators.

- **variation of water intake**

  The growing intensity of human activities might be related to a higher request for water, since this natural source is employed in a multitude of fields, from industrial purposes to common daily lives. Nonetheless, the greater the request, the more severe the impact on the water cycle, and in general on the natural equilibria. In this perspective, data was collected from Italian National Institute of Statistics (ISTAT) from the available period of 2012-2015. Also in this case, data is affected by the changes occurred in the Municipalities (Table 6.13), hence some aggregations were necessary before calculating the differential variation.

- **biodiversity**

  As previously mentioned, biodiversity might be well assumed as a sign of the status of a natural ecosystem, especially when considering the distribution of both flora and fauna. Here, attention is focused on the distribution of species that are in an unfavourable conservation status, with the aim of investigating on eventual critical conditions of the environment. With regard to this issue, the Habitats Directive (*Council Directive 92/43/EEC*, 1992) provides specific guidelines for the European Countries in order to evaluate the conservation status of habitats and species. Such assessment is performed through a series of parameters (for species: range, population, habitat of species and future prospects) that allow to identify the status of conservation, which might be “favourable”, “unfavourable-inadequate” or “unfavourable-bad” (Eionet - EEA, n.d.). Here, two categories are considered: “inadequate”, that represents species which need a change in the management strategies, but are not critically endangered, and “bad”, that represents species near the extinction, at least locally (SINAnet - ISPRA, n.d.-a). The 3rd Italian report (Genovesi et al., 2014) was consulted in order to identify the relevant species for the Italian territory, then summarising such information in an Excel table, identifying those responding to the criteria adopted in this case (that is, being in an unfavourable condition), so that it could be later exported in QGIS. In the meanwhile, the species distribution was retrieved from the data provided by the Italian national report as a *shapefile*, accessible from the SINAnet database (SINAnet - ISPRA, n.d.-b). In QGIS, such files were firstly *joined*, then *cut* and *merged* to the Municipal boundaries: in this way, the *attribute table* presents all species in unfavourable conditions for all Municipalities. After exporting it in Excel, it was possible to assess the number of species in unfavourable conditions per each Municipality. It is acknowledged here that the species whose spatial distribution was 50x50 km^2 were not included in the evaluation, because such a coarse resolution significantly affected the reliability of the representation (for instance, the species *caretta caretta* resulted mentioned in Municipalities far from the coast, clearly unreasonable). Hence, the general resolution of the species distribution adopted here is limited to 10x10 km^2.

Second phase

- **%territory with ultrabroadband internet access**
  Internet access was assumed as a proxy to verify the interconnection of people with the wider social network and thence the possibility to be reached by information and eventually warnings from the local authorities. Data is available at the website of the Ministry of Economic Development (INVITALIA - Ministero dello Sviluppo Economico, n.d.). The information is related to the status of implementation of the strategy to advance the distribution of the ultrabroadband throughout the Italian territory. In particular, it is here employed the diffusion of NGA (Next Generation Access) networks, that should allow a download speed of at least 30 Mb/s. A further datum is available, concerning faster connections called NGA-VHCN (Very High Capacity Networks), but given the general critical situation of internet connection, NGA-VHCN appeared to be limiting in representing the differences among the Municipalities, as they would probably all show very low shares in the distribution of this advanced infrastructure. In order to retrieve the NGA data, the above-mentioned website is consulted per each Municipality, reporting the information available from 2018 onwards for the earliest viable year.
- **% employment**
  % unemployment
  The quantification of the status of employment was particularly affected by the changes in administrative boundaries that occurred over the years (see Table 6.13). Consequently, two different sources came into play: Italian National Institute of Statistics (ISTAT) provides

most of the information through the 2011 census in terms of both employment and unemployment (ISTAT, n.d.-a), although the Marche Region Statistical Informative System (SIS, *Sistema Informativo Statistico*) was consulted to retrieve data per each Municipality not considered in the former source (Sistema Informativo Statistico - Regione Marche, n.d.-c). Unfortunately, it is possible to access only data referred to 2011, that is the year of the last census, hence the choice of data is limited, given that more recent information is available only at a Province level.

- **hospital staff/pop**

  It was not possible to retrieve the number of hospital staff associated to each Municipality. This might be at least partly due to the organisation of the local Health System, based on *Aree Vaste* rather than Municipalities. In particular, an *Area Vasta* encompasses a territory broadly corresponding to a Province, hence there are 5 *Aree Vaste* in the Marche Region. Consequently, here data is elaborated for each *Area Vasta* and then associated as it is to the Municipalities, since the population of each Municipality might rely on all the hospital staff available for the pertaining *Area Vasta*. Nonetheless, it is necessary to depend on indirect information that can be consulted on the website of the Regional Health Agency (ASUR), in the form of information concerning bonuses distributed among the personnel (Azienda sanitaria unica regionale, n.d.). Documents are available per each *Area Vasta*: excluding directors (assumed not to perform operative roles), the hospital staff might be quantified and the value associated to each Municipality, based on the pertaining *Area Vasta* reported on the Regional SIS website (Sistema Informativo Statistico - Regione Marche, n.d.-b).

- **hospital beds/pop**

  At the time of collecting information (July 2019), a Regional deliberation had recently been approved to redistribute the number of hospital beds among the *Aree Vaste* (*D.G.R. 639/2018 Ridefinizione Della Dotazione Dei Posti Letto Della Rete Ospedaliera Marchigiana*, 2018). Hence, likewise the previous indicator, data is necessarily referred to that scale, rather than to the Municipality. In any case, in order to grasp the effective availability of hospital beds to the local population, the value is referred to 1000 inhabitants of the pertaining *Area Vasta*: in this case, the data is retrieved from the Marche Region Statistical Informative System (Sistema Informativo Statistico - Regione Marche, n.d.-a).

- **average time of arrival on place**

  average time of arrival on place over the past 5 years

The time needed to reach the place of intervention is assumed as a proxy for the efficacy of first responders. Furthermore, when considering the variation of this indicator throughout the years, it might be possible to catch the attention devoted to this emergency service: more public investments would suggest an improvement of their performance, hence progressively less time to arrive on place. In this case, information was retrieved from the latest available version (at the time of data collection, July 2018) of the Firefighters Statistical Yearbook (Signoretti & Vertola, 2018). It should be noted that in this case the territory of the Province of Fermo is under the jurisdiction of the provincial command of Ascoli Piceno, consequently it was not possible to disaggregate the information for the two Provinces.

- **local expenditure per capita for mitigation**

  When dealing with hazards that allow a certain level of preparation and prevention, it is relevant to comprehend how local authorities deal with them. In particular, it might be interesting to trace their efforts in mitigating their impacts, for instance through structural activities devoted to weakening the threat posed by specific conditions. In this perspective, the investments in flood risk mitigation are included. Information can be retrieved from the online legislative archive of the Marche Region (Regione Marche, n.d.-e), through a search with the keyword "*rischio idr*", then selecting all and only the documents referred to "*rischio idraulico*" (that is flood risk in Italian), hence distinguishing from landslide risk ("*rischo idrogeologico*" in Italian, that is partly similar to "*rischio idraulico*"). Afterwards, a validation was performed, in order to check for their consistency. In this case, it was verified either through the state of payment settlement or by consulting the website of the Marche Region devoted to local defence interventions (Paesaggio Territorio Urbanistica Genio Civile - Regione Marche, n.d.). In addition, the latter source was also accessed to record further projects that have been excluded. With a similar double objective, it was thought relevant to consult the website of ReNDiS ("*Repertorio Nazionale degli interventi per la Difesa del Suolo*"), a project promoted by the Italian Institute for Environmental Protection and Research (ISPRA) on the behalf of the Ministry of the Environment, Land and Sea to monitor the progress of local actions against flood and landslide risks (ReNDiS - ISPRA, n.d.-c). Data was extrapolated from the list of interventions, selecting "flood", "coastal" and "mixed" among the typologies (ReNDiS - ISPRA, n.d.-b) and additionally imposing "Marche Region" as a limiting criterion to visualise and thence to access each document available in the database related to regional decrees (ReNDiS - ISPRA, n.d.-a). Likewise, information was crosschecked referring to the OpenCUP database (OpenCUP -

DIPE, n.d.), that is a website where it is possible to verify the state of a project financed through public funds via its CUP ("*Codice Unico per conoscere gli investimenti pubblici*"). This initiative is promoted by the Department for the programming and coordination of economic policy (DIPE), part of the Prime Minister's Office. Lastly, some specific legislative documents where considered: D.G.R. 1554/2017 and "*3° Atto integrativo all'accordo di programma finalizzato alla programmazione e al finanziamento di interventi urgenti e prioritari per la mitigazione del rischio idrogeologico*" (*3° Atto Integrativo All'accordo Di Programma Finalizzato Alla Programmazione e Al Finanziamento Di Interventi Urgenti e Prioritari per La Mitigazione Del Rischio Idrogeologico*, n.d.). Even though the primary objective was to identify the specific public investment per each Municipality, it was not always possible to deduce it from the available documents, as the values might be referred to a set of Municipalities. In such cases, the adopted criterion consists in the proportion of coastline or of waterways among the concerned Municipalities. In order to estimate such proportions, the shape files were retrieved from official databases: the Italian National Institute of Statistics (ISTAT) provides the coastline (ISTAT, n.d.-d), while waterways are available at the Italian Institute for Environmental Protection and Research (ISPRA) through the service SINAnet ("*Rete del Sistema Informativo Nazionale Ambientale*"), devoted to collect data about the environment and natural phenomena (SINAnet - ISPRA, n.d.-c). With regards to waterways, among the available typologies, only courses identified as "*fiume*" (that is river in Italian) have been selected and *cut* within the borders of the pertaining Municipality; then their length was calculated through the specific function (*$length*) in the *Field calculator* instrument, available in QGIS 3.4. Proportions, both of coastlines and waterways, were all calculated in Excel.

- **municipal road km/pop**
  non-municipal road km/pop
  In order to enhance the picture of the infrastructures available to citizens and first responders, both in everyday life and in emergency conditions, the extension of the roadway networks is investigated. In this case, data is retrieved per each Municipality from the website of the Ministry of the Interior (Dipartimento per gli Affari Interni e Territoriali - Ministero Dell'Interno, n.d.). The information is available in the section "*Certificati Consuntivi*", selecting the sheets responding to the D.P.R. 194/1996. Unfortunately, this limits the availability of data: the latest source dates back to 2015. Nonetheless, the roadways are considered only as under the jurisdiction of the Municipalities, and their

quantification is specified in terms of roads both within and outside urbanised areas: the sum of these values is considered here, eventually related to the population of each Municipality (referred 1st January 2016).

- **%wasted drinking water**

  In the perspective of portraying the state of public infrastructures, the water supply system is considered especially relevant, as it addresses one of the basic human needs. Indeed, its efficacy is fundamental for the daily life of human communities. In this case, information could be retrieved from the Italian National Institute of Statistics (ISTAT), for the year 2015. Measures are available for both input and distributed water, hence their relative difference (Eq. 7) is here implemented.

$$\frac{\left(water_{input} - water_{output}\right) * 100}{water_{input}} = wastwat \tag{7}$$

  Here, $water_{input}$ and $water_{output}$ represent the quantity of water input in the water supply system and the quantity of water effectively distributed to users, respectively. Their relative difference informs on the ratio of natural water that is dispersed throughout the network: in other words, $wastwat$ depicts the quality of the water supply system and the efficacy of its preservation.

- **average building construction year**

  The status of the residential real estates erected on the Municipal territory is evaluated on the base of the information collected from the Italian National Institute of Statistics (ISTAT). The date of construction derives for the 2011 census and expresses the number of residential buildings per 9 time periods, spanning from “1918 and before” to “2006 and after”. In order to obtain a representative value that can be employed as an indicator, the mean value is calculate per each Municipality, eventually falling within one of the above-mentioned time periods. In the case of a merged Municipalities (as highlighted in Table 6.13), the assets of the former Municipalities are first associated to the merged Municipality and then the overall mean value is calculated. It is important to note that the result consists of a categorical variable, rather than a continuous variable as ideally requested to carry on a discriminant analysis. Unfortunately, this is the only approximation available to estimate the age of the local estates. In any case, the classes ideally cover an infinite time span, as the extremes (“1918 and before”, “2006 and after”) are limitless, hence they ideally extend to the infinite past and the infinite future: in other words, they might be approximated to continuous variables.

- **#habitats in inadequate/bad status**

  In order to depict the status of the ecosystems that host a variety of species, both flora and fauna, the Habitat Directive (*Council Directive 92/43/EEC*, 1992) guided once more the assessment, this time in terms of status of conservation of the habitats. This indicator embraces a wider perspective, as it does not just focus on living beings, but rather comprehends the environment as a whole. Information is disclosed by the European Environment Agency in an open access format (EEA, 2015a; EU Open Data Portal, 2019). The classification envisions a specific symbology that derives from the official reporting guidelines (EEA, 2015b), that includes a code for the status and a qualifier for the expected future trends. In this case, the status of conservation considered is “unfavourable” and “unknown” for any kind of qualifier, in order to grasp all possible present negative conditions (see Table 6.14). Such assumption revolves around the consideration that not only an unfavourable condition is negative, but even a lack of knowledge on the status of a specific habitat is undesirable, because it does not allow to eventually promote the enhancement of management options.

Table 6.14 — Symbology adopted when reporting under the Habitat Directive (92/43/EEC), including all the possible conservation status and trend.

	SYMBOL	MEANING
CONSERVATION STATUS	FV	Favourable
	U1	Unfavourable-Inadequate
	U2	Unfavourable-Bad
	XX	Unknown
QUALIFIER	+	improving
	=	stable
	-	declining

A further relevant aspect concerns the classification itself. The European Environment Agency (EEA) provides data referred to the European Union, composed of the 27 Member States (MS), and to each specific MS (EU Open Data Portal, 2019). Nonetheless, the status of conservation varies also depending on the geographical reference. Consequently, for instance, a habitat might result in a favourable status of conservation when considering the European Union, that turns into an unfavourable condition when considering a specific

State. At the same time, the present assessment concerns only one Italian Region: the comparisons that are intrinsic to the adopted methodology involve only the Municipalities within such Region. As a consequence, the minimum geographical scale is the preferred: the optimal choice would be a Regional reference, but as this is unreasonable, the best option is the national comparison. In this case, the *shapefile* employed is the one referred to the Member States. Once data could be visualised in QGIS, eventually the number of habitats for the unfavourable and unknown status could be counted and reported per each Municipality.

- **geobotanical value**

  In relation to the previous indicator, it might be interesting to include an investigation around the status of areas that have experienced a limited impact deriving from human activities. In 2013, the Marche Region founded the REM (*Rete Ecologica Marche*), meant to capitalise existing knowledge and instruments applied to regional natural ecosystems in order to promote an effective and integrated conservation management (Regione Marche, n.d.-h). Part of the enhanced activities is the evaluation of the "*valenza geobotanica*" (geobotanical value), that represents the environmental quality and vulnerability of a certain area, supporting the identification of the critical issues that lie within a territory, hence supporting the prioritising of conservative actions (Regione Marche, n.d.-g). In particular, it is possible to retrieve the map of geobotanical value (Regione Marche, n.d.-h) in pdf format: interpreted as a *raster* in QGIS, it can be *georeferred* and later used as a base *layer* for the Municipal boundaries, so that the highest and lowest class of *valenza geobotanica* could be identified and separately reported per each Municipality. It is acknowledged here that this is another example of categorical data that might not be especially suitable for a discriminant analysis. Nevertheless, the number of classes of geobotanical value is not pre-defined, but rather it is determined on the base of the local ecosystem characteristics, computing a series of variables: diffusion, vulnerability, fragmentation, floristic value (Regione Marche, n.d.-g). As a consequence, the number of classes might ideally span over a wide range of values, in a similar vein of a continuous variable. Even though in this case the number of classes is very low (3), the potential, unknown *a priori*, enabled its employment in the present case.

- **flood discharge variation**

  A variety of aspects of the processes related to the water cycle might be affected from external pressures, including the ongoing environmental changes. In present case, alterations of flood dynamics turn to be especially significant, in terms of both human safety and natural equilibria. The European Environment Agency (EEA) have quantified the trends in flood discharge over a period of 50 years: the results are available to be visualised and are also free to be accessed (EEA, 2019e). in particular, it is possible to utilise a *shapefile* with several points of measure distributed all over the European territory: working in QGIS environment, after *cutting* the point *layer* with that of the Municipal boundaries and then *merging* them, the resulting *layer* holds all the relevant characteristics for this assessment, since the *attribute table* returns the trends of flood discharge per each Municipality. At this point, it is just necessary to export the values, in percentual variation of the mean annual flood discharge per decade (EEA, 2019e), in an Excel *sheet* in order to average the eventual multiple measures associated to a Municipality and list the values to be later implemented as indicator.

- **PM_{10} average**
  PM_{10} difference average
  PM_{10} average for largest exposed population
  PM_{10} difference average for largest exposed population
  Along with water, clean air is a fundamental element for human, animal and vegetable life. Maintenance of air quality is also one of the fundamental regulating services performed by ecosystems (Millennium Ecosystem Assessment, 2003b), that might be disturbed whether ecosystem processes were hampered or excessively burdened. Air quality is a common metric adopted to assess and monitor the salubrity of human landscapes: several parameters might be considered, including the presence of particulate matter (PM). Fine particulate matter is especially relevant: when particles are small enough to penetrate lungs, they might cause severe health consequences (EEA, n.d.). PM_{10} represents a hazard of this kind, being composed of particles with an aerodynamic diameter equalling at most 10 µm (EEA, n.d.). Although this pollutant might have also natural sources, such as wildfires, its presence is highly affected by human activities: in Europe, the main anthropic contributors are related to commercial, households and institutional uses, industry and agriculture (EEA, 2019a). Information on the distribution and concentration of air pollutants, including PM_{10}, is fully available for the whole European territory (EEA, 2013). Data is provided interpolated over a 1 km- or 2 km-grid: the former was adopted in the present case, in order to raise at most the resolution, and data was retrieved for the year 2017, the latest available. Thus, it was possible to *cut* and *merge* such grid with the Municipal boundaries, so that the *attribute table* included all the relevant information, including not only the above mentioned PM_{10} values, but also the population residing in each grid cell. Consequently, among the several

values associated to each Municipality, the PM_{10} annual average values and the interannual difference in PM_{10} annual average were identified and selected following two criteria: the highest absolute values and the values corresponding to the grid cell with the largest human exposure (in terms of population), for a total of four possible indicators to be tested in the following discriminant analysis. The aim was to represent the most harmful conditions in general terms and specifically for human health.

- **urban-transport fragmentation pressure**

A relevant source of pressure for natural ecosystems is posed by the infrastructures, often roadways and urban structures, that physically interfere with the continuity of natural landscapes (EEA, 2019d). The resulting fragmentation reveals to be a serious concern, since the interruption of ecosystem connections might isolate natural populations and degrade habitats, increasing the overall vulnerability of the area and thus hampering the overall capacity to carry on ecosystem services (EEA, 2019d). Indeed, the Seventh Environment Action Programme (7th EAP) adopted by the European Union recognises that landscape fragmentation plays a relevant role in compromising natural ecosystems and human resilience: “The degradation, fragmentation and unsustainable use of land in the Union is jeopardising the provision of several key ecosystem services, threatening biodiversity and increasing Europe’s vulnerability to climate change and natural disasters” (Decision N° 1386/2013/EU on a General Union Environment Action Programme to 2020 “Living well, within the limits of our planet,” 2013, para. 23). In light of these considerations, it appeared significant to include this kind of information within the present framework. Data could be retrieved for the whole Europe in terms of fragmentation pressure caused by urban and transport infrastructure expansion (EEA, 2019b, 2019d). Values are presented as “seff value”, that is the number of fragmented meshes per 1 000 km^2, in other words a measure of density of fragmentation (EEA, 2019d). Such values might span from 0 to infinite: the higher the value, the higher the landscape fragmentation (EEA, 2019d). In order to produce a more intuitive map, values were categorised within classes associated with a different degree of fragmentation pressure (Table 6.15).

Table 6.15 — Correspondence of "seff values" and fragmentation classes

SEFF VALUES (NUMBER OF MESHES PER 1 000 KM^2)	FRAGMENTATION CLASS	FRAGMENTATION CLASS VALUE
0-1.5	Very low	1
1.5-10	Low	2
10-50	Medium	3
50-250	High	4
> 250 seffs	Very high	5

Source: adapted from (EEA, 2019d, 2019b)

The available data consists of a *shapefile* reporting the fragmentation class values for the European territory. Therefore, it was possible to use this *layer* as a base for the Municipal boundaries *layer* in the QGIS environment, thence identifying and exporting on a separate table the highest value per each Municipality. In this way, the most severe landscape disturbance posed by urban and transport infrastructure could be detected. It is here acknowledged that, even though the original "seff values" correspond to a continuous variable, the available information is limited to a class, hence a categorical variable: unfortunately, this is the best approximation that it was possible to retrieve, hence such a limitation was accepted in view of the utter relevance of the indicator.

Hokkaidō

Similarly to the case of Marche Region, first of all a working area in QGIS was created as a preliminary step for the processes that would follow. As previously mentioned, the Coordinate Reference System (CRS) was set as WGS84 UTM54N, that is EPSG:32654, suitable to represent Japan in this global CRS (epsg.io, n.d.). Also in this case, the basic *layer* is necessarily that of the Municipal boundaries. The Geospatial Information Authority of Japan (GSI) provides, free to be used, a series of geospatial products, including administrative, demographic and infrastructural information, lastly revised in 2016, hence consistent with the Municipal mergers occurred in 2015 (GSI, n.d.). In particular, it is possible to access data on the area contained within political boundaries, identified as "polbnda" among the available *shapefiles* (ISCGM, 2012). This is especially convenient, since the information comprises the *fields* of "*State/Province/Prefectural name*" ("*nam*"), "*local administrative area name*" ("*laa*") and "*administrative code*" ("*adm_code*") (ISCGM, 2012, p. 22): consequently, since the *shapefile* covers the whole Japanese territory, it was sufficient to *select* only the elements pertaining to "*Hokkai Do*" in order to obtain the geospatial representation of the Municipalities of this Prefecture. A relevant benefit of this process consists precisely in the inclusion of the identifying code per each Municipality, fundamental in case on homonymy, impossible to discern with only the *romaji* version of toponymies. A further basic information, fundamental several following processes, concerns the population pertaining to each Municipality. In this case, data could be retrieved for the most recent survey that comprehensively involved Municipalities and that was performed in 2015 (Japanese Government Statistics, n.d.-c).

First phase

- **distance from the nearest water body**

  As previously mentioned, the experience matured through the Marche case study suggested that investigating the extension of the population exposed to flood hazard might be rather beneficial for the overall success of the analysis. Nonetheless, also testing other indicators could provide further insights. In this perspective, other metrics were here included: the distance from water bodies is one of these. The rational justifying this indicator relies in the assumption that as the flood hazard becomes more manifest and the related awareness grows, the local population should aim to move further and further from the most evident source of threat, thence the distance of the urbanised area should increase. In this case, information was acquired in the GIS environment: data was retrieved from the Geospatial Information Authority of Japan (GSI, n.d.). The basic *layers* employed represented the Municipality boundaries, the build-up areas and the water bodies, these latter encompassing rivers, dams or any other inland water body (ISCGM, 2012). At this point, it was possible to estimate the distance of each urbanised area from the nearest water body employing *Measure Line*, a *tool* included in QGIS. During the process, any kind of water body was admitted, except for those seemingly representing springs, since it appeared unreasonable that they could trigger a serious flood. Then, data could be reported and associated to each Municipality.

- **%population exposed to flood hazard**

  Eventually, it was possible to include the estimation of the portion of the population directly exposed to the potential damages of river floods. This indicator was intended to grasp the possible influence of flood memory on the preference of choice in the development area for settlements. In order to enhance the comparability with the other case study, it would have been ideal to adopt the variation in such distribution. Although it was not possible to pursue such an aim, the estimation of the exposed population was referred to the actual population of the municipality, in order to take account for the inherent difference in the amount of residents per each municipality, similarly to the Marche Region case. The data collection moved in two different directions: information on the distribution of the population and extension of the flooding areas. The Japanese Government Statistics provides data on the population distribution in several geographic formats and spatial resolutions, covering the whole national territory: in this case, a 500m-grid was selected for the Hokkaidō area in the world geodetic latitude/longitude form (Japanese Government Statistics, 2010). The *shapefiles* were merged together in order to obtain a single mesh grid spanning throughout the Prefectural territory. Then, the focus shifted towards inundation areas. The Ministry of Land, Infrastructure, Transport and Tourism provides access to the maps elaborated after that the Flood Prevention Act was endorsed in 2015 (MLIT, n.d.-b). It is noteworthy that such maps do not encompass the whole Hokkaidō area, but rather they were shaped for the 13 major river systems, including a total of 60 rivers (MLIT, n.d.-b). For each river system, several alternatives are available, the most relevant being: "assumed maximum scale", "plan scale", "inundation duration" and other representation related to physical properties or induced damages of floods. In the present case, maps designed for the "plan scale" ("計画規模" in Japanese) were selected in order to adhere to development planning approach. Maps were retrieved in pdf format, hence they had to be preliminary *georeferred* to be employed in QGIS. *Ground Control Points* (GCP) were engaged to the features of rivers and municipal boundaries, even though when maps presented overlaps, the correspondence among such *rasters* was preferred in order to enhance a consistent representation of the local areas and to overcome the simplifications of the other *vector* features. An average of around 80 GCPs appeared to be generally sufficient to deliver an acceptable *georeferred* outcome. The adopted algorithms varied in order to optimise the transformation, although the *Polynomial 1* type and *nearest neighbour* or *linear* resampling method was often the most successful combination. Then, the yielded *rasters* served as basis to draw the *shapefiles*: these *vector layers* were composed of as many *polygons* as necessary to comprise all the flood inundation areas, represented through a coloured scale, from yellow to red (all shades were included). Eventually, all the *shapefiles* referring to different rivers but same river system were progressively *merged* together. At this point it was possible to overlay the Municipalities with the population distribution and the flood inundation areas. Per each Municipality, the *layer* of the flood inundation area was *cut* within the municipal borders and then used to *cut*, in turn, the *layer* of the population distribution. Consequently, it was possible to obtain the inhabited *mesh cells* included in a flooding area: the *attribute table* was then exported in Excel in order to calculate the total amount of exposed population per each Municipality. It might be relevant to bear in mind that in this way some Municipalities resulted without reported inhabitants residing in flooding areas. Although this might correspond to real flood risk conditions, it might also be due to the limited extension of the inundation maps. As mentioned, only the major rivers are envisioned, as well as coastal floods or other water-related flooding events are excluded from this estimation. Since this information is consistent throughout the Hokkaidō territory, it was assumed as an acceptable shortcoming for the present discussion. Nonetheless, this estimation should not be regarded as a flood risk assessment.

- **land transaction**

  The permanence of natural ecosystems relies on fragile equilibria that have been balanced throughout the centuries. As a result, the consequences of external disturbances might be highly detrimental for ecosystems and in particular for the functions that they perform. A significant alteration that might concern natural landscapes consists in the expansion of anthropic systems. In other words, the conversion of natural areas for urban and industrial purposes undoubtedly hampers the continuity of the functions of local natural ecosystems. At the same time, the change in land use and in general the transactions that concern Municipal territories might be assumed as an indicator of the restlessness affecting land and potentially the enclosed natural systems. In this case, it is possible to access data related to land transactions through the Ministry of Land, Infrastructure, Transport and Tourism (MLIT, n.d.-j). The law in force requires to submit specific notifications of such transactions when concerning urbanised areas as well as areas outside city boundaries, although with different minimum thresholds (MLIT, n.d.-h), hence alterations affecting the natural environment are here included, along with alteration of urban landscapes. The disclosed information employed here refers to the areal extension of land transactions, retrieved for year 2015 and 2016 (MLIT, n.d.-a): since every document includes the coded year and the two previous years, it was possible to aggregate data and calculate the ratio between the areal extension of land transactions for 2016 and 2014.
- **altered vegetation**

  As previously suggested, the performance of ecosystem functions might result highly affected by external disturbances, that often occur because of anthropic activities. Where land transactions directly concern areas occupied by humans, a further indicator of the induced changes to the natural environment might be the alteration affecting the distribution of vegetation. In this case, information is granted by the Biodiversity Center of Japan: it is possible to access data concerning the “植生調査(植生自然度調査)” (in English: “Vegetation survey (vegetation naturalness survey)”) (Biodiversity Center of Japan, n.d.-b). This kind of investigation has been cyclically iterated throughout the years: the last available reports refer to 1999 onwards (6th and 7th survey). Unfortunately, such research efforts portray the actual, but not the altered vegetation, hence, the 5th survey was employed in this case, referring to the period 1994-1998 (Biodiversity Center of Japan, n.d.-a, n.d.-b). In particular, among the available *shapefiles* only those referred to the areal representation of altered vegetation were here utilised: such *layers* are codified with the root “*vg5*” to recall the 5th vegetation survey followed by a progressive number for the different Prefectures and Local Branches (for Hokkaidō there are seven Branches, that are n°51 to 57), and the label “a” to differentiate from the linear representation (coded as “l”). At this point, all the *layers* were *merged* to cover the Prefectural territory and the area extension estimated through the *Field calculator* (function: *$area*); later, this *layer* was eventually merged, once more, with the Municipality boundary *layer*. It was then possible to extract the information and proceed to aggregate the area extensions per each Municipality. This allowed to verify that not all areas (represented as *polygons*) had been associated to a Municipality: coming back to the GIS environment, these polygons were identified and such association completely fulfilled, thence optimising the final quantitative aggregation. Eventually, the areal extension of the altered vegetation could be related to the overall extension of each Municipality.

- **distribution of raccoon**

  The concept of integrity suggests the image of a pristine condition: for instance, that of a natural environment which has not been affected by the invasion of alien species. This aspect is especially relevant because the introduction of plant and animals that do not originally belong to an ecosystem might alter the local equilibria, hampering the survivability of the overall natural system: the effects might reach the point of inducing the irreversible loss of native species as well as the degradation of local habitats (WWF, n.d.). Accordingly, human processes are not exempted from the potential negative impacts: for example, the activities that rely on natural systems, such as the primary sector, might severely suffer the consequences of the spread of invasive alien species. As previously mentioned, a scenario of this kind became a reality in Hokkaidō, after the introduction and the following diffusion of the *araiguma* raccoon (洗熊 or 浣熊) throughout the island. Hence, the presence of this species in the Municipalities was quantified. As suggested above, the Biodiversity Center of Japan provides a wealth of information of the state of the natural environment, including the results of the "要注意鳥獣(クマ等)生息分布調査" (in English: "Survey of habitat distribution for birds and beasts (bears, etc.)"): here, the distribution of the *araiguma* raccoon is available to be freely accessed (Biodiversity Center of Japan, n.d.-c). Data is provided as a *shapefile*, in particular as a mesh with a resolution of 5x5 km^2. After limiting the representation to the Hokkaidō territory, among the information displayed in the *attribute table* the *field* "*H29*" was employed, since it represents the "「平成 29 年度要注意鳥獣（クマ等）生息分布調査業務」において生息ありのメッシュ" (in English: "Inhabited mesh in "2017 bird and beast (bears, etc.) habitat distribution survey operations""), as reported in the enclosed explanatory notes. Hence, it was possible to identify the meshes that exhibited the presence of the *araiguma* raccoon and later *merge* them with the *layer* of the Municipalities. Then, the *Field calculator* allowed to estimate the area extension of the meshes (function: *$area*). When exporting the information and eventually aggregating the meshes per each Municipality, it was possible to obtain the number of meshes and the total extension of the area concerned by the diffusion of the *araiguma* raccoon, as well as the proportion of the territory affected. Afterwards, a visual check allowed to verify that not all relevant meshes were associated to the respective Municipality: this happened for the parts of meshes *cut* by the Municipal boundaries but falling outside, for instance in the sea. Nonetheless, a further check confirmed that the area pertaining to the land was indeed related to the respective Municipality, thus this issue was not considered as a limitation (after all, the *araiguma* raccoon is a terrestrial species). In addition, in two cases, Shakotan and Nanporo Municipalities, the proportion of the territory concerned by the diffusion of the the *araiguma* raccoon slightly exceeded the total (100.04% for both): clearly, this result is illogical. Nevertheless, it seems reasonable to assume that this error might be caused by succession of data processing, approximations and potential differences in Coordinate Reference Systems (CRS): consequently, the values were manually reduced to 100% and also in this case the inaccuracy was considered as acceptable.

Second phase

- **roadways m/pop**

  As previously mentioned, roadways represent a pivotal infrastructure, both for everyday life and in emergency situations: the transportation of products and travellers might turn into the delivery of first aids and responders in case of a disaster. Consequently, the efficacy of roadways in connecting the territory of a Municipality might be considered as a significant issue to properly enhance. In order to quantify the extension of such infrastructure, information was retrieved from the Geospatial Information Authority of Japan (GSI) website (GSI, n.d.). Indeed, it is possible to access to a *line shapefile* drawing the roads all over the Japanese territory. Hence, after selecting the elements pertaining to Hokkaidō in a separate *shapefile*, it was possible to associated it with the *layer* of the Municipalities. Then, an *analysis tool* of QGIS was employed, that automatically aggregates and calculates the lines contained within polygons (that is "*Sum Lines Lengths*"). The outcome consists in the extension and the number of segments per each polygon, in form of additional *attributes* to the polygon *shapefile*. In this case, the extension and number of roadways traits (*line layer*) were calculated and associated to the respective Municipality (*polygon layer*). The reported length measures are expressed in metres. At this point, the required information could be extracted and later reported to the local population, in order to evaluate the extension of roadways available per each Municipal citizen.

- **wildlife sanctuary**

  One of the first attempts to nurture natural systems and equilibria consisted in the institution of protected areas. The aim was to enclose portions of territories within boundaries that rigidly regulated anthropic activities, in order to limit the human pressures exerted on natural ecosystems, which could thence flourish, possibly undisturbed. In this vein, Wildlife Protection and Hunting Law and the Law for Conservation of Endangered Species of Wild Fauna and Flora promote in Japan the preservation of habitats, the protection of endangered species, the control of hunting and the contrast to illegal activities (Ministry of the Environment, n.d.-b). A means for protecting wildlife species was the establishment of Wildlife Special Protection Areas, where any anthropic activity, whether utilising water sources or cutting bamboo tress, require a specific permission from the Ministry of the Environment or the Prefectural Authorities (Ministry of the Environment, n.d.-b). In other words, this kind of wildlife sanctuary is a strictly regulated area where flora and fauna might prosper almost unaffected by human processes, here it might be a significant indicator of the awareness and consciousness towards the preservation of the natural environment. In this case, data was retrieved from the National Land Numerical Information, provided by the Ministry of Land, Infrastructure, Transport and Tourism as a *shapefile* for each Prefecture and two survey years, 2009 and 2015 (MLIT, n.d.-i). Consequently, the GIS environment was employed once more: the *layer* for Hokkaidō wildlife sanctuaries was first simplified, by *dissolving* all the geometries into one *polygon*, that later was *merged* to the *layer* of the Municipal boundaries. The *Field calculator* (function: *$area*) allowed to estimate the area extent of each polygon: in particular, at this point a polygon represented the portion of a wildlife sanctuary pertaining to a specific Municipality. Nonetheless, when examining the *attribute table*, it was possible to notice that one element was not associated: a check on the GIS map allowed to recognise a sea area that consequently did not fall into Municipal boundaries. In this case, the association was performed manually (the involved Municipality is Betsukai). It was then possible to aggregate some separated elements in spite of pertaining to the same Municipality (involved Municipalities: Nemuro, Date, Matsumae, Haboro, Akkeshi, Betsukai), hence obtaining the overall area extension. After being reported, the value was related to the area extension of the relative Municipality.

- **water intake**

  A fundamental component of natural ecosystems is water, in its numerous different forms: water systems sustain local species, as well as support anthropic activities. Consequently, ensuring that the quantity of water is sufficient to nourish all natural and human processes becomes pivotal. In this sense, if the quantity of water abducted for anthropic uses poses excessive pressure on the capacity of natural systems to provide this primary source, the effects might be detrimental for the environment. Consequently, quantifying the flow of water from natural to human systems might be a significant indicator of the conditions of natural physical processes. In order to perform this assessment, information was retrieved from the Hokkaidō Prefectural Government website, that provides reports on the local water supply system for the recent years (Environment and Life Department - Hokkaidō Prefectural Government, 2019). In this case, bearing in mind the temporal dimension of the analysis, the 2015 report was employed (Environment and Life Department - Hokkaidō Prefectural Government, 2017). In particular, the sections II-2 (*水道事業の概要,* in English: “Outline of water supply business”, p. 29) and II-7 (*簡易水道事業の取水状況*,

in English: "Water intake status of simple water supply business", p. 69) were especially informative. The implemented measures are those under the label "実績年間取水量 (m^3)" (in English: "Actual annual water intake (thousand m^3)") for section II-2, and under the label "合計 (m^3)" (in English: "total (m^3)") for section II-7. This double reference was necessary because depending of the dimension of the served community, the supply of clean water might depend on two different institutions. Nonetheless, it might happen that the same Municipality benefits from both services. In addition, in section II-2 some Municipalities were aggregated under one water supply business: in this case, the allocation of supplied water was based on the proportion of the concerned population. On the contrary, in section II-7 several local services crossed the same Municipality, hence in this case an aggregation was necessary, although this process was performed also for the Kitami in section II-2. At this point, it was possible to combine the values for all the Municipalities, summing the reported data, even though values from section II-2 were first converted in m^3 in order to match the dimensions of data from section II-7. In order to estimate the quantity of water available per each citizen, the values were later referred to the local population. It is acknowledged here that, given the data processing from section II-2, this value might lose some relevance for Municipalities that were originally aggregated. Nevertheless, this limitation is here accepted because it still might provide an estimate of the magnitude of water demand from those territories.

- **water quality**

  Along with quantity, another essential feature of water systems is their quality: a healthy ecosystem might not exist in case water sources and bodies were contaminated and severely altered. This issue is relevant not only for wildlife, but also for humans, considering that water is fundamental for the sustainment of wild species as well as of human activities, like domestic or industrial uses. Consequently, water quality is widely recognised as a relevant indicator to assess the state of the natural environment: in this case, the viewpoint stems from the induced alteration of natural processes under external pressures. Nonetheless, many parameters have been identified to assess water quality, in order to depict the complex essence of this issue. In the present case, the pH value was assumed as an indicator of water quality. Some considerations directed towards this choice: pH is a commonly accepted and implemented metric and its measurement is a rather basic operation, hence while its relevance is widely recognised, the facilitated assessment suggests a larger availability of data. It is acknowledged here that this is merely a partial representation of the quality of water bodies, far from being exhaustive. Nonetheless, it might be a significant piece of the overall representation of the status of the environment. The Hokkaidō Prefectural Government discloses information on water quality through a database and a webGIS, that are free to access (Hokkaidō Prefectural Government, n.d.). Data is available from 1971 to 2018 and includes a manifold of physical, chemical and biological parameters, evaluated in sampling points scattered all over the Prefecture. In this case, the year 2015 was selected, in order to represent the water conditions before the 2016 flood events. Skimming through the available information, pH values appear to be quantified most consistently throughout the sampling points, hence confirming the indicator assumption. A necessary preliminary operation consisted in associating each sampling point to the respective Municipality: consequently, each point was geolocalised employing different sources: for instance Google Maps webservice (Google Maps, n.d.), maps developed by local authorities (Ochiishi Marine Vision Council, n.d.), official documents (Tokachi River Basin Committee, 2008) and plans (Hokkaidō Development Bureau, 2018). Afterwards, per each sampling point, the pH value with the larger deviation from a common reference was identified and reported on a separated list. Clearly, at this point a reference value needed to be assumed. Different authorities and institutions have set optimal ranges and values for this parameter, concerning freshwater bodies (Table 6.16).

Table 6.16 — References for water quality standards.

RECOMMENDED pH VALUE	MEAN VALUE	WATER SOURCE	FOCUS	REFERENCE
6.5-8.5 or 6.0-8.5 (depending on the use of water)	7.5 or 7.2	rivers	conservation of the living environment	(Ministry of the Environment, n.d.-a)
around 7.5	7.5	drinking water supply	water quality management	(Wakayama, 2010)
6.5-8.5	7.5	surface water	surface water quality for abstraction of drinking water	(Council Directive 75/440/EEC Concerning the quality of surface water intended for the abstraction of drinking water in Member States, n.d.)
6-9	7.5	fresh waters	support of fish life	(European Economic Community, 1978)
5-9	7	domestic water supplies	reference for water quality criteria	(United States Environmental Protection Agency (USEPA), 1986)
6.5-9.0	7.75	freshwater aquatic life		
6.5-9	7.75	fresh water	support of fish communities	(Enderlein et al., 1997)

After considering the extension and evaluating the mean value of the proposed intervals, the reference was here set on $pH = 7.5$. Hence, it was possible to associate each Municipality with a set of values, those with the larger distance from 7.5, in order to capture the worst condition per each sampling point and thence Municipality. Eventually, the deviation from the reference value was calculated and employed, rather than the pH value. The reason behind this preference stems from the fact that the core of the quality issue lies in being part of an optimal range: whether towards acid or basic extremes, moving from the reference value results in a worsening of water conditions in any case. In other words, what is relevant is not the direction of such deviation, but rather its magnitude: therefore, the deviation from the reference value is more suitable than the pH value itself in addressing such dimension. This question arises also in some practical concerns: it might happen that for a Municipality, the two extreme values are equally distant from the reference value; in this case, it would be difficult to decide whether acid or basic conditions would be worse, while, by adopting the deviation from the reference value as indicator, the problem is immediately solved because the deviation would be the same for both extreme values. It is acknowledged here that since the pH develops on a logarithmic scale, calculating a simple mean value might be inaccurate. Nonetheless, the purpose of this elaboration is merely to identify a common reference to carry on a comparison, hence it is assumed as an acceptable limitation.

7. Results

Along the above lines the discussion concerning the issue of disaster resilience and environmental sustainability was delved through the lens of a theoretical framework that led to the design of an operative research methodology in order to address the outlined research questions. Once the viable case studies were selected, such methodology could be eventually applied. In the following paragraphs the results of that application will be presented. The discussion will proceed through each case study at a time.

7.1 Marche Region

7.1.1 First phase – classification

As previously mentioned (see Ch. 5), the methodology proposed for this research study encompasses two main phases. In particular, the first phase aims at identifying the level of resilience and of sustainability per each *sub-unit*, in this case per each Municipality. In order to achieve this classification, the methodology employs a cluster analysis. In this way, the comparison among the Municipalities allows to separate groups based of different behaviour. Such behaviour is distinctly described in terms of both disaster resilience and environmental sustainability through selected indicators. Three indicators per each *core* (see Table 6.9) were selected, each representing a different *attribute*.

The analytical steps were symmetrical for the resilience and the sustainability assessments. The processes envisioned a first cluster analysis adopting the Ward's method. Here, the STATGRAPHICS Centurion 18 (v. 18.1.12) software allowed to use standardised indicators (z-values), select Euclidean distance and request three final clusters. The desired outcome consisted in the centroids of the clusters, that would be saved in a separate file. The following step consisted of a further cluster analysis, in this case employing the k-means method. Here, the SPSS Statistics (v. 19) software allowed to select once more the z-values and request three clusters, while opting for "*iterate and classify*" technique and enabling the input of the initial centroids from those obtained through the previous step. In addition, the procedure in SPSS performs a set of statistical tests: in this case, the ANOVA table was selected. At the end of the procedure, the belonging to a specific cluster was saved per each Municipality. In the following lines the results for each *core* will be throughout discussed.

Resilience

The resilience *core* was described through indicators related to the social exposure to flood hazard, the entity of flood damages and the economic effects of the last flood (Table 7.1).

Table 7.1 — Indicators and their codes per each attribute *of the resilience* core.

CORE	*ATTRIBUTE*	INDICATOR	CODE
resilience	learn	variation of population exposed to flood hazard	POP_FLOOD
	absorb	grants for extraordinary and emergency interventions	EMERG_GRANT
	recover	ratio of tax revenue after 2 years and on the year of the last flood event	IRPEF_VAR

The cluster analysis carried on following the Ward's method resulted in the centroids per each of the requested clusters (Table 7.2).

Table 7.2 — Initial centroids per each cluster and each indicator of resilience.

INDICATOR	CLUSTER		
	1	2	3
POP_FLOOD	-0.11582	-0.22801	1.54249
EMERG_GRANT	-0.22176	-0.20902	2.15162
IRPEF_VAR	0.54852	-0.78761	-0.72468

The centres of the clusters appear to be rather differentiated, each centroid belonging to a different quarter of the ideal space defined by the three indicators, although the values are not particularly dissimilar in absolute terms for the first two clusters.

These centroids were then employed as the starting points to perform the cluster analysis following the k-means method. The process required three iterations to stabilise over the final centroids, that remained well differentiated (Table 7.3 and 7.4).

Table 7.3 — Variation in the position of the centroids per each iteration.

ITERATION	CHANGES IN THE CENTROIDS		
	1	2	3
1	0.116	0.204	0.555
2	0.031	0.043	0.000
3	0.000	0.000	0.000

Table 7.4 — Final centroids per each cluster and each indicator of resilience.

INDICATOR	CLUSTER		
	1	2	3
POP_FLOOD	-0.15104	-0.14285	1.96669
EMERG_GRANT	-0.32130	0.01562	2.46632
IRPEF_VAR	0.64446	-0.78535	-0.89411

The trend of the final centroids could be then represented in a bar chart, in order to visualise and differentiate each cluster (Fig. 7.1).

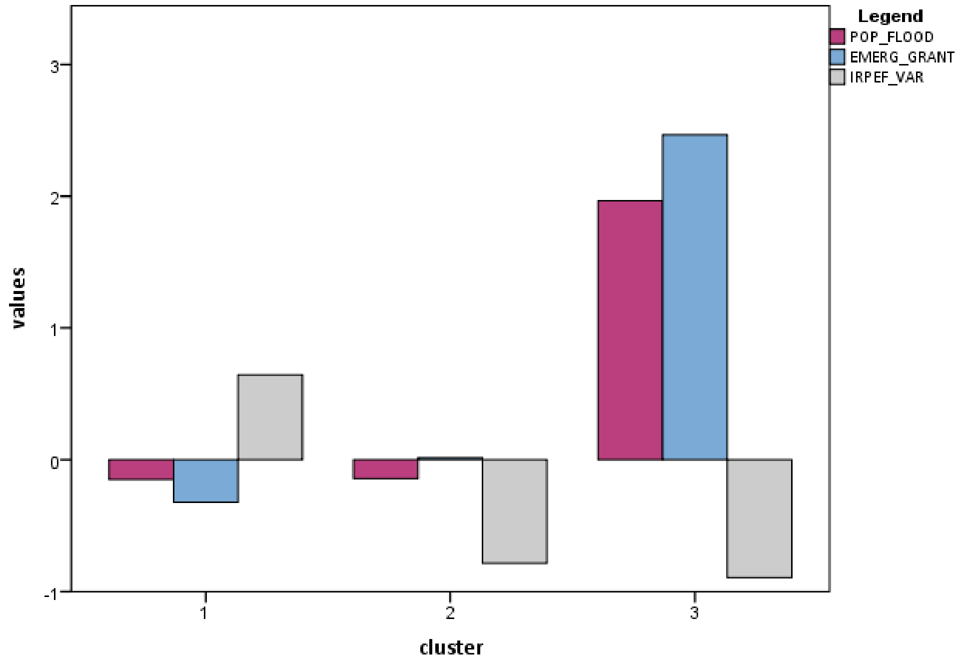


Figure 7.1 — Bar graph of the final centroids per each cluster and each indicator of resilience.

The SPSS procedure provides some statistical tests, in this case the ANOVA table was adopted to assess the effectiveness of the performed analysis (Table 7.5). In particular, it was possible to verify that all the indicators were statistically significant (Sig. < 0.001, per each indicator) in determining the differentiation in clusters of the Municipalities. In addition, IRPEF_VAR and EMERG_GRANT appeared to hold the highest and most comparable weights (F = 122.460 and F = 106.185, respectively).

Table 7.5 — ANOVA table.

INDICATOR	CLUSTER		ERROR		F	Sig.
	Mean Square	df	Mean Square	df		
POP_FLOOD	33.269	2	0.714	226	46.567	0.000
EMERG_GRANT	55.228	2	0.520	226	106.185	0.000
IRPEF_VAR	59.290	2	0.484	226	122.460	0.000

Eventually, the collected information allowed for the sorting of all the Municipalities, although the clusters were unevenly populated: the largest portion of the Municipalities belongs to cluster 1 (127), followed by cluster 2 (87) and 3 (16) (Table 7.6).

Table 7.6 — Number of cases (Municipalities) per each cluster of resilience.

CLUSTER	1	127
	2	86
	3	16
CASES	VALID	229
	MISSING	0

Sustainability

The sustainability *core* was investigated through a similar procedure. Also in this case three indicators were selected, but some variations were tested in order to achieve the optimal combination (Table 7.7). In the present case, reporting the results of all the attempts might lack of interest, hence only the two most significant outputs will be provided, that are also the most different combinations.

Table 7.7 — Indicators, their codes and their combinations per each attribute of the sustainability core.

CORE	*ATTRIBUTE*	INDICATOR	CODE	COMBINATION	
				C_1	C_2
sustainability	functions	variation of land take	LAND_TAKE_ABS	X	
		variation of land take compared to total areal extension	LAND_TAKE		x
	services	variation of water intake	CLEAN_WATER_ABS	X	
		percentual variation of water intake	CLEAN_WATER		X
	integrity	number of species in inadequate or bad conservation status	SPECIES_INADBAD	X	X

Concerning combination 1, the initial centroids provided by the Ward's method appear to be well differentiated, each belonging to a different quarter of the space defined by the indicators (Table 7.8).

Table 7.8 — Initial centroids per each cluster and each indicator of combination 1 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
LAND_TAKE_ABS	-0.21364	1.55569	-0.43624
CLEAN_WATER_ABS	1.12176	0.08222	-0.61745
SPECIES_INADBAD	0.32703	-0.32876	-0.05568

Then, four iterations were necessary in order to stabilise the final centroids. Even though their position actually changed, they still appeared well differentiated (Table 7.9 and 7.10), as can be visualised in a bar graph (Fig. 7.2).

Table 7.9 — Variation in the position of the centroids of combination 1 per each iteration.

ITERATION	CHANGES IN THE CENTROIDS		
	1	2	3
1	0.759	0.740	0.540
2	0.412	0.271	0.189
3	0.146	0.124	0.097
4	0.000	0.000	0.000

Table 7.10 — Final centroids per each cluster and each indicator of combination 1 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
LAND_TAKE_ABS	-,19547	1,79617	-,37623
CLEAN_WATER_ABS	,39608	-,66108	,00693
SPECIES_INADBAD	1,28276	,10709	-,54770

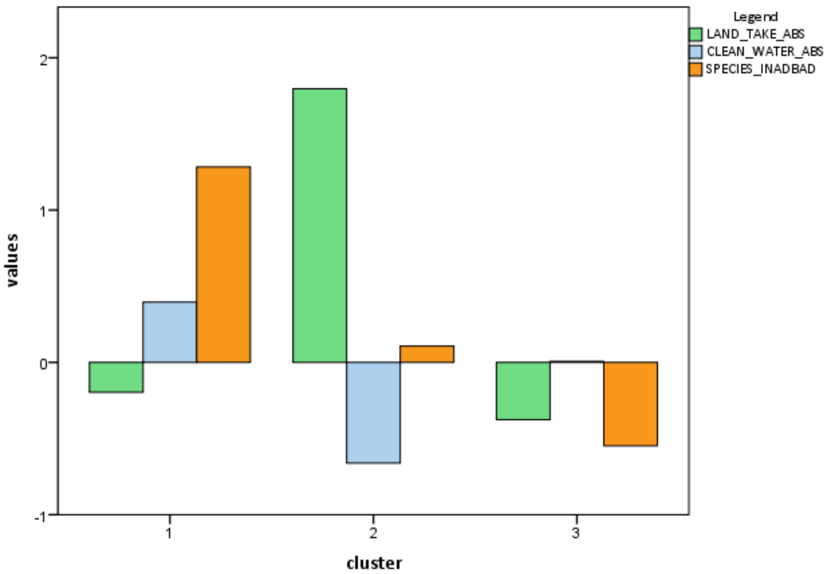


Figure 7.2 — Bar graph of the final centroids per each cluster and each indicator of combination 1 of sustainability.

Thence, the ANOVA table informed on the relevance of this outcome (Table 7.11). The indicators show a high statistical significance in the clustering process (all sig. < 0.001). nonetheless, their weights are somehow comparable for metrics related to land take and species in dangerous conditions (162.822 and 160.925), whereas the differentiating power of water intake appears extremely weak (13.349).

Table 7.11 — ANOVA table for combination 1.

INDICATOR	CLUSTER		ERROR		F	Sig.
	Mean Square	df	Mean Square	df		
LAND_TAKE_ABS	67.296	2	0.413	226	162.822	0.000
CLEAN_WATER_ABS	12.044	2	0.902	226	13.349	0.000
SPECIES_INADBAD	66.973	2	0.416	226	160.925	0.000

Also in this case, the clusters presented a high difference in the number of associated Municipalities, with the higher portion (138) pertaining to cluster 3 (Table 7.12).

Table 7.12 — Number of cases (Municipalities) per each cluster of combination 1 of sustainability.

CLUSTER	1	56
	2	35
	3	138
CASES	VALID	229
	MISSING	0

In a similar vein, the analytical process was performed for combination 2. Hence, first the initial centroids were derived through the Ward's method and also in this case the different position in the space was promptly evident (Table 7.13).

Table 7.13 — Initial centroids per each cluster and each indicator of combination 2 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
LAND_TAKE	-0.22040	-0.52605	2.15834
CLEAN_WATER	-0.14408	0.71540	-0.35451
SPECIES_INADBAD	-0.40258	1.48746	-0.13816

Following was the k-means procedure. Here, the centroids stabilised in few iterations and their positions were not much altered (Table 7.14 and 7.15), remaining substantially as before. The related bar graph shows their different values (Fig. 7.3).

Table 7.14 — Variation in the position of the centroids of combination 2 per each iteration.

ITERATION	CHANGES IN THE CENTROIDS		
	1	2	3
1	0.069	0.112	0.142
2	0.010	0.033	0.000
3	0.000	0.000	0.000

Table 7.15 — Final centroids per each cluster and each indicator of combination 2 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
LAND_TAKE	-0.26430	-0.44121	2.11559
CLEAN_WATER	-0.20706	0.80621	-0.24915
SPECIES_INADBAD	-0.40778	1.42621	-0.22329

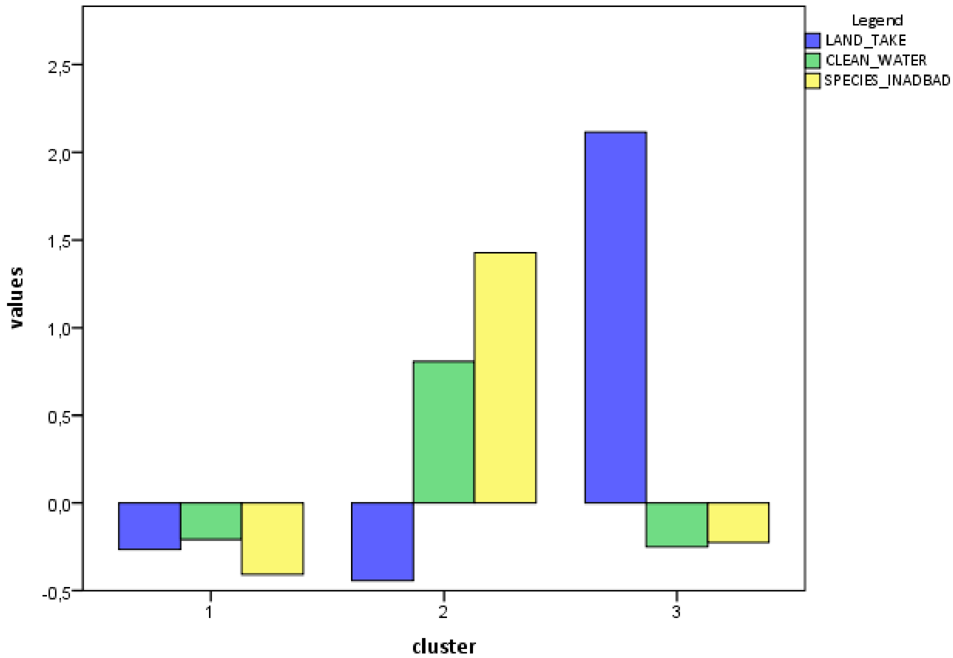


Figure 7.3 — Bar graph of the final centroids per each cluster and each indicator of combination 2 of sustainability.

Eventually, the ANOVA table provided the information on the relevance of the outputs. Once more, the high significance equates all the indicators (all sig. < 0.001), while the weights evidently differ (Table 7.16). The variation of land take appears to hold the highest power (216.286), followed by species in dangerous conditions (135.584) and water intake (23.691).

Table 7.16 — ANOVA table for combination 2.

INDICATOR	CLUSTER		ERROR		F	Sig.
	Mean Square	df	Mean Square	df		
LAND_TAKE	74.879	2	0.346	226	216.286	0.000
CLEAN_WATER	19.758	2	0.834	226	23.691	0.000
SPECIES_INADBAD	62.178	2	0.459	226	135.584	0.000

The process led to an inhomogeneous distribution of the Municipalities throughout the clusters, the first one being the most populated (152) of the three (Table 7.17).

Table 7.17 — Number of cases (Municipalities) per each cluster of combination 2 of sustainability.

CLUSTER	1	152
	2	48
	3	29
CASES	VALID	229
	MISSING	0

Comparing the two combinations, it appears that the initial centroids were rather different and that combination 1 proceeded through a higher rate of iterations before stabilising, whereas combination 2 required less cycles. In addition, the centroids of combination 2 were affected by smaller changes before achieving their final positions, while combination 1 saw a more significant alteration in the position of the centroids. Qualitatively, in terms of positions of the centroids, the clusters 1 and 3 from combination 1 somehow resemble the clusters 2 and 1, respectively, of combination 2, although the remaining clusters show higher differences, hence it might not be appropriate to straightforwardly superimpose the two set of clusters: it might be necessary a thorough discussion on the meaning of each cluster. In any case, the ANOVA tables show the most evident differences. Although in both cases all the indicators play a significant role in grouping the cases (Municipalities) and the indicators related to the same *attribute* hold the most meaningful clustering power, combination 2 shows the highest values, especially for the weaker indicator. It might also be interesting to observe that assuming the previously mentioned overlay of clusters between the combinations is valid, the allocation of the Municipalities is rather comparable, with only 14 out of 229 Municipalities differently distributed among the groups. In light of the above considerations, combination 2 appeared more reliable and the following analytical procedures adopted that set of indicators.

7.1.2 Second phase – characterisation

The second phase of the proposed methodology involves a discriminant analysis. In this case, the grouping of the previous clustering processes is adopted as a basis to identify the variables that play the most significant role in differentiating among the groups. Thence, the analytical process commenced from the previous allocation of each Municipality to a specific cluster. Also in this case, the SPSS Statistics (v. 19) software was employed to carry on the main process.

Resilience

In order to perform a discriminant analysis, a dependent variable and a set of independent variables both are required. Since the former was already set through the previous analysis, it was necessary to introduce a further collection of indicators. In order to optimise to outcome, a series of possible combinations (C_n) were tested (Table 7.18).

Table 7.18 — Indicators and their combinations per each dimension of the resilience core.

DIMENSION	INDICATOR	COMBINATION											
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
demographic	immigrants												x
	percentage of immigrants	x	x	x	x	x	x	x	x	x	x	x	
	population over 65 y.o.												x
	percentage of population over 65 y.o.	x			x	x	x	x	x	x	x	x	
	percentage of population over 80 y.o.		x	x									
	female population												x
	percentage of female population	x	x	x	x	x	x	x	x	x	x	x	
	population density	x	x	x	x	x	x	x	x	x	x	x	x
social	population with higher education												x
	percentage of population with higher education	x	x	x	x	x	x	x	x	x	x	x	
	percentage of territory covered by UWB internet access	x	x	x	x	x	x	x	x	x	x	x	x
	volunteers in no-profit organisations												x
	volunteers in no-profit organisations dealing with social welfare and civil protection	x	x	x	x	x	x	x	x	x	x	x	
	percentage of volunteers in no-profit organisations dealing with social welfare and civil protection												
	public revenues of no-profit organisations dealing with social welfare and civil protection expenditure of no-profit organisations dealing with social welfare and civil protection	x	x	x	 x	x	x	x	x	x	x x	x x	x x
economic	percentage of employment	x	x		x	x	x	x	x	x	x	x	x
	percentage of unemployment			x									
	taxable income	x	x	x	x	x	x	x	x	x	x	x	x
	expenditure for social welfare	x	x	x	x	x	x	x	x	x	x	x	x
	present population	x	x	x	x								
	percentual difference in present and resident population					x	x	x	x	x	x	x	x
health	percentual mental health discharges	x	x	x	x	x					x	x	x
	residence facilities for the elderly												
	beds in residence facilities for the elderly						x						
	welfare facilities (non-residence) for the elderly							x	x	x	x	x	
	total welfare facilities for the elderly												x
	hospital staff												x

	hospital staff/population	x	x	x	x	x	x	x	x	x	x	x	
	hospital beds												x
	hospital beds/population	x	x	x	x	x	x	x	x	x	x	x	
	average time of arrival on place	x	x	x	x	x	x	x					
	average time of arrival on place over the past 5 years								x	x	x	x	x
infrastructural	local expenditure per capita for mitigation	x	x	x	x	x	x	x	x	x	x	x	x
	extension of municipal roads												x
	extension of municipal roads/population	x	x	x	x	x	x	x	x		x	x	
	extension of non-municipal roads												x
	extension of non-municipal roads/population									x			
	percentage of wasted drink water	x	x	x	x	x	x	x	x	x	x	x	x
	average building construction year	x	x	x	x	x	x	x	x	x	x	x	x

The SPSS procedure includes some statistical tests, in particular those related to eigenvalues and Wilks' lambda. Here, the inclusion of the complete tables for all the combinations might contribute much to the discussion, hence only the values related to most encouraging discriminant function in terms of canonical correlation referred to the eigenvalues and significance referred to Wilks' lambda will be presented (Table 7.19).

Table 7.19 — Main statistical tests for each combination of indicators for resilience.

STATISTICS	COMBINATION											
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
canonical correlation (eigenvalue)	0.427	0.422	0.409	0.427	0.440	0.439	0.439	0.446	0.445	0.448	0.448	0.469
Sig. (Wilks' lambda)	0.017	0.021	0.059	0.018	0.004	0.004	0.004	0.004	0.007	0.007	0.007	0.004

The examination of those statistics allowed to realise that the initial approach might not have been appropriate. In fact, although it aimed at adopting indicators related to the features of each Municipality as far as possible in order to normalise the data and enhance the comparison among the outcomes, it was only after shifting to absolute values that the results achieved the highest significance. In fact, the canonical correlation progressed from a minimum of 0.409 (C_3) towards 0.469 (C_{12}), along with the significance of the function that lowered from a maximum of 0.059 (C_3) towards 0.004 (C_5, C_6, C_7, C_8, C_9, C_{12}). While the canonical correlation informs on the discriminant power of the function, the significance grants for the statistical validity of that function. It might be noteworthy that in all combinations (except C_3) the functions were actually statistically significant with a 95% of confidence, since sig. < 0.05 for all the combinations (except C_3). Nevertheless, considering both metrics at the same time, it appears that the last combination (C_{12}) showed the better performance in explaining the difference among the clusters. Consequently, this combination was preferred over the others (Table 7.20). Hence, it might be interesting to include here the complete tables referred to the eigenvalues (Table 7.21) and Wilks' Lambda for C_{12} (Table 7.22).

Table 7.20 — Indicators and their codes for combination 12 per each dimension of the resilience core.

DIMENSION	INDICATOR	CODE
demographic	immigrants	IMMIGR
	population over 65 y.o.	POP_over65
	female population	POP_FEM
	pop density	DENSPOP
social	population with higher education	HIGH_EDU
	percentage of territory covered by UWB internet access	UWB_ACCESS
	volunteers in no-profit organisations	VOLUNT
	public revenues of no-profit organisations dealing with social welfare and civil protection expenditure of no-profit organisations dealing with social welfare and civil protection	PUBL_REV_CPASS EXP_CPASS
economic	percentage of employment	EMPL_PERC
	taxable income	TAX_INCOME
	social expenditure for social welfare	SOC_EXP
	percentual difference in present and resident population	PRESRES_POP
health	percentual mental health discharges total welfare facilities for the elderly	MENT_DISCH ELDWELF_FAC
	hospital staff	HOSP_STAFF
	hospital beds	HOSP_BED
	average time of arrival on place over the past 5 years	ARR_TIME
infrastructural	local expenditure per capita for mitigation	MITIG_EXP
	extension of municipal roads	MUN_ROAD
	percentage of wasted drink water	WAST_WAT
	average building construction year	BUILD_AGE

Table 7.21 — Eigenvalue statistics for the combination 12 of indicators for resilience.

FUNCTION	EIGENVALUE	PERCENTAGE OF VARIANCE	CUMULATIVE PERCENTAGE	CANONICAL CORRELATION
1	0.281	73.5	73.5	0.469
2	0.102	26.5	100.0	0.304

Table 7.22 — Wilks' lambda statistics for the combination 12 of indicators for resilience.

TEST OF FUNCTION(S)	WILKS' LAMBDA	CHI-SQUARE	DF	SIG.
1 through 2	0.708	73.266	44	0.004
2	0.908	20.569	21	0.486

The discriminant analysis provides a number of discriminant functions equal to the number of initial groups minus one. Hence, in this case, the procedure provided two discriminant functions, as the preliminary groups were three. The eigenvalues for both functions are not particularly high, although the difference is sensible anyway. The first function is able to explain the 73.5% of the variation, hence it holds a more significant relevance compared to the other function. Indeed, the canonical correlation is similarly higher (0.469 compared to 0.304). In particular, the squared canonical correlation might offer an estimation of the discriminant power of the function: in this case, $0.469^2 = 0.21996$, hence Function 1 is able to explain around 22% of the variations among the clusters. It might be interesting to note that the statistical significance of Function 1 is rather high (0.004), whereas Function 2 is statistically not significant (0.486 > 0.05).

Eventually, the process allowed to retrieve the explicit discriminant function. In this case, the equation for the standardised function 1 is (Eq. 8):

$$\begin{aligned}F = {} & 0.628 * \mathrm{IMMIGR} - 6.320 * \mathbf{POP\_over65} + 7.463 * \mathbf{POP\_FEM} - 0.115 * \mathrm{DENSPOP} - 0.453 * \mathrm{HIGH\_EDU} - 0.262 * \\ & \mathrm{UWB\_ACCESS} - 1.306 * \mathbf{VOLUNT} + 0.451 * \mathrm{PUB\_REV\_PCASS} - 0.301 * \mathrm{EXP\_CPASS} + 0.287 * \mathrm{EMPL\_PER} + 0.680 * \\ & \mathrm{TAX\_INCOME} + 0.075 * \mathrm{SOC\_EXP} + 0.280 * \mathrm{PRERES\_POP} - 0.617 * \mathrm{MENT\_DISCH} + 0.252 * \mathrm{ELDWELF\_FAC} - 0.718 * \\ & \mathrm{HOSP\_STAFF} + 0.952 * \mathrm{HOSP\_BED} - 0.061 * ARR\_TIME - 0.293 * \mathrm{MITIG\_EXP} - 0.336 * \mathrm{MUN\_ROAD} + 0.058 * \\ & WAST\_WAT - 0.004 * BUILD\_AGE\end{aligned} \tag{8}$$

In Eq. 8 the indicators holding the largest weight are evidenced in bold. Within the combination of indicators enhanced to compose Function 1, women, elderly and volunteers in no-profit organisations appear to hold the highest discriminant power (weights: 7.463, 6.320, 1.306 respectively), whereas the average building age, the amount of wasted water and the average arrival time of first respondents, in italics, appear not to play a particular influence on the process (weights: 0.004, 0.058 and 0.061, respectively).

At this point it might be interesting to evaluate the effectiveness of the discriminant function. In particular, it is possible to compare the clusters assigned to the Municipalities at the end of the previous cluster analysis and the clusters that can be predicted as a final step of the discriminant analysis (Table 7.23).

Table 7.23 — Clusters assigned after the cluster analysis and predicted after the discriminant analysis of resilience.

MUNICIPALITY		CLUSTER OF RESILIENCE	
NAME	ID	ASSIGNED	PREDICTED
Acqualagna	41001	1	1
Apecchio	41002	1	2
Auditore	41003	2	2
Belforte all'Isauro	41005	2	2
Borgo Pace	41006	1	3
Cagli	41007	1	2
Cantiano	41008	3	2
Carpegna	41009	1	1
Cartoceto	41010	2	1
Fano	41013	1	1
Fermignano	41014	1	1
Fossombrone	41015	1	2
Fratte Rosa	41016	2	2
Frontino	41017	3	3
Frontone	41018	1	2
Gabicce Mare	41019	2	3
Gradara	41020	1	1
Isola del Piano	41021	1	1

Lunano	41022	1	1
Macerata Feltria	41023	2	2
Mercatello sul Metauro	41025	1	1
Mercatino Conca	41026	1	1
Mombaroccio	41027	2	1
Mondavio	41028	1	1
Mondolfo	41029	1	1
Montecalvo in Foglia	41030	1	1
Monte Cerignone	41031	1	1
Monteciccardo	41032	1	1
Montecopiolo	41033	1	3
Montefelcino	41034	1	1
Monte Grimano Terme	41035	2	2
Montelabbate	41036	1	1
Monte Porzio	41038	1	1
Peglio	41041	1	1
Pergola	41043	2	2
Pesaro	41044	1	1
Petriano	41045	1	1
Piandimeleto	41047	2	1
Pietrarubbia	41048	1	1
Piobbico	41049	2	2
San Costanzo	41051	2	1
San Lorenzo in Campo	41054	2	2
Sant'Angelo in Vado	41057	1	1
Sant'Ippolito	41058	2	1
Sassocorvaro	41059	2	2
Sassofeltrio	41060	1	1
Serra Sant'Abbondio	41061	1	1
Tavoleto	41064	2	1
Tavullia	41065	1	1
Urbania	41066	1	2
Urbino	41067	2	1
Vallefoglia	41068	1	1
Colli al Metauro	41069	1	1
Terre Roveresche	41070	2	1
Agugliano	42001	1	1
Ancona	42002	1	1
Arcevia	42003	2	2
Barbara	42004	1	1
Belvedere Ostrense	42005	1	2
Camerano	42006	1	1
Camerata Picena	42007	1	1
Castelbellino	42008	1	1
Castelfidardo	42010	1	1
Castelleone di Suasa	42011	1	2
Castelplanio	42012	1	1
Cerreto d'Esi	42013	2	2
Chiaravalle	42014	1	3
Corinaldo	42015	2	1
Cupramontana	42016	2	2
Fabriano	42017	2	2
Falconara Marittima	42018	2	2
Filottrano	42019	1	2
Genga	42020	3	3
Jesi	42021	1	1
Loreto	42022	1	3
Maiolati Spontini	42023	1	1
Mergo	42024	2	2
Monsano	42025	1	1
Montecarotto	42026	2	2
Montemarciano	42027	1	1
Monte Roberto	42029	1	1
Monte San Vito	42030	1	1
Morro d'Alba	42031	1	2
Numana	42032	1	1
Offagna	42033	1	1
Osimo	42034	1	3
Ostra	42035	3	3
Ostra Vetere	42036	2	2
Poggio San Marcello	42037	2	3
Polverigi	42038	1	1
Rosora	42040	2	1
San Marcello	42041	2	1
San Paolo di Jesi	42042	1	2
Santa Maria Nuova	42043	1	1
Sassoferrato	42044	2	2
Senigallia	42045	3	3
Serra de' Conti	42046	1	1
Serra San Quirico	42047	1	2
Sirolo	42048	1	1
Staffolo	42049	1	2
Trecastelli	42050	2	1
Apiro	43002	1	1
Appignano	43003	1	1
Belforte del Chienti	43004	1	1
Bolognola	43005	1	1
Caldarola	43006	2	2
Camerino	43007	2	2
Camporotondo di Fiastrone	43008	2	
Castelraimondo	43009	2	2
Castelsantangelo sul Nera	43010	2	2
Cessapalombo	43011	2	3
Cingoli	43012	1	1
Civitanova Marche	43013	1	1
Colmurano	43014	2	2
Corridonia	43015	1	1
Esanatoglia	43016	2	2

Fiastra	43017	1	3
Fiuminata	43019	1	3
Gagliole	43020	1	2
Gualdo	43021	2	2
Loro Piceno	43022	1	2
Macerata	43023	2	1
Matelica	43024	1	1
Mogliano	43025	1	2
Montecassiano	43026	2	2
Monte Cavallo	43027	1	1
Montecosaro	43028	1	1
Montefano	43029	1	1
Montelupone	43030	1	1
Monte San Giusto	43031	2	2
Monte San Martino	43032	3	3
Morrovalle	43033	3	1
Muccia	43034	2	2
Penna San Giovanni	43035	2	2
Petriolo	43036	1	1
Pieve Torina	43038	2	2
Pioraco	43039	1	2
Poggio San Vicino	43040	2	3
Pollenza	43041	1	1
Porto Recanati	43042	1	1
Potenza Picena	43043	1	1
Recanati	43044	1	2
Ripe San Ginesio	43045	2	1
San Ginesio	43046	2	2
San Severino Marche	43047	1	2
Sant'Angelo in Pontano	43048	2	2
Sarnano	43049	2	2
Sefro	43050	2	3
Serrapetrona	43051	2	2
Serravalle di Chienti	43052	2	2
Tolentino	43053	2	2
Treia	43054	1	1
Urbisaglia	43055	2	2
Ussita	43056	2	2
Visso	43057	2	2
Valfornace	43058	3	
Acquasanta Terme	44001	2	3
Acquaviva Picena	44002	1	1
Appignano del Tronto	44005	1	2
Arquata del Tronto	44006	2	3
Ascoli Piceno	44007	2	2
Carassai	44010	2	2
Castel di Lama	44011	1	1
Castignano	44012	2	2
Castorano	44013	1	3

Colli del Tronto	44014	1	1
Comunanza	44015	2	2
Cossignano	44016	2	2
Cupra Marittima	44017	1	2
Folignano	44020	1	1
Force	44021	2	3
Grottammare	44023	1	1
Maltignano	44027	2	3
Massignano	44029	2	1
Monsampolo del Tronto	44031	1	1
Montalto delle Marche	44032	2	2
Montedinove	44034	1	1
Montefiore dell'Aso	44036	1	2
Montegallo	44038	3	3
Montemonaco	44044	3	3
Monteprandone	44045	1	1
Offida	44054	1	2
Palmiano	44056	3	3
Ripatransone	44063	2	1
Roccafluvione	44064	2	3
Rotella	44065	3	3
San Benedetto del Tronto	44066	1	1
Spinetoli	44071	1	2
Venarotta	44073	1	3
Altidona	109001	1	1
Amandola	109002	2	1
Belmonte Piceno	109003	1	1
Campofilone	109004	1	1
Falerone	109005	1	1
Fermo	109006	1	1
Francavilla d'Ete	109007	1	1
Grottazzolina	109008	1	1
Lapedona	109009	1	1
Magliano di Tenna	109010	1	1
Massa Fermana	109011	2	2
Monsampietro Morico	109012	2	3
Montappone	109013	1	2
Montefalcone Appennino	109014	3	
Montefortino	109015	2	3
Monte Giberto	109016	2	2
Montegiorgio	109017	1	1
Montegranaro	109018	2	1
Monteleone di Fermo	109019	1	3
Montelparo	109020	2	2
Monte Rinaldo	109021	1	2
Monterubbiano	109022	3	2
Monte San Pietrangeli	109023	2	1
Monte Urano	109024	2	1
Monte Vidon Combatte	109025	1	2

Monte Vidon Corrado	109026	1	2
Montottone	109027	2	2
Moresco	109028	1	1
Ortezzano	109029	1	1
Pedaso	109030	2	2
Petritoli	109031	1	2
Ponzano di Fermo	109032	1	1
Porto San Giorgio	109033	3	3
Porto Sant'Elpidio	109034	1	1
Rapagnano	109035	2	1
Santa Vittoria in Matenano	109036	1	3
Sant'Elpidio a Mare	109037	1	1
Servigliano	109038	2	2
Smerillo	109039	3	3
Torre San Patrizio	109040	2	1

In this case it is possible to observe that 150 out of 226 Municipalities (66%) were associated the same cluster by the two analytical processes. That is, the discriminant function was able to provide an outcome that almost resembles that of the cluster analysis. In might be noteworthy that the function could not associate a cluster to some of the Municipalities (3 are missing) because one of the indicators (number of volunteers) related to the *dimensions* of the resilience *core* was not quantified, hence the analysis could not be performed.

Sustainability

A specular process was developed for the sustainability *core*. In this case, the set of indicators was reduced, due to the complexity in retrieving relevant information at an appropriate scale for themes related to the environment and the occurring changes. Nevertheless, it was possible to test a series of combinations (C_n), with the aim of identifying the most promising outcome (Table 7.24).

Table 7.24 — Indicators and their combinations per each dimension of the sustainability core.

DIMENSION	INDICATOR	COMBINATION											
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
ecosystems integrity	habitats in inadequate/bad status	x	x	x	x	x	x	x	x	x	x	x	x
	grassland and pasture	x	x	x	x	x	x	x	x	x	x	x	x
	woods owned by farms	x	x	x	x	x	x	x	x	x	x	x	x
	high geobotanical value	x	x	x	x	x							x
	low geobotanical value						x	x	x	x	x	x	x
ecosystem benefits	forests for woods	x	x	x	x	x	x	x	x	x	x	x	x
	D.O.C. and I.G.P. producers	x	x	x	x	x	x	x	x	x	x	x	x
physical processes state	flood discharge variation	x	x	x	x	x	x	x	x	x	x	x	x
	PM_{10} average value	x				x	x		x				x
	PM_{10} average difference		x					x		x			
	PM_{10} average value in most populated cell			x							x		
	PM_{10} average difference in most populated cell				x							x	
external pressures	agricultural area	x	x	x	x	x	x	x	x	x	x	x	x
	heads of livestock	x	x	x	x		x	x			x	x	x

	heads of cattle					x			x	x			
	urban-transport fragmentation pressure	x	x	x	x	x	x	x	x	x	x	x	x

A rapid examination at the basic statistics (Table 7.25) related to the combinations allowed to observe the common high significance (sig. < 0.001 for all combinations) and the overall high discriminant power of the functions (canonical correlation minimum = 0.710 for C_5), hence it appears that this set of indicators is generally appropriate to explain the differences among the levels of sustainability. In particular, combinations 6 and 12 seem to deliver to most desirable outcome, hence it might be noteworthy to examine more in depth their characteristics.

Table 7.25 — Main statistical tests for each combination of indicators for sustainability.

STATISTICS	COMBINATION											
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
canonical correlation (eigenvalue)	0.729	0.726	0.720	0.714	0.710	0.730	0.728	0.722	0.720	0.715	0.717	0.730
Sig. (Wilks' lambda)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

In general terms, combination 12 closely resembles combination 6 (Table 7.26), except for the addition of one indicator. Indeed, combination 12 includes both metrics concerning the geobotanical value of the local landscape. It might be significant to note that these values are mutually independent, as they represent the highest and lowest rates that could be observed on the territory, hence the requirement of independence of the discriminant variables is granted. At the same time, it might be significant to comprise both the most positive and the most negative estimations in a representation of the local sustainability, as they would draw a more comprehensive picture of the local features and issues.

Table 7.26 — Indicators and their codes for combinations 6 and 12 per each dimension of the sustainability.

DIMENSION	INDICATOR	CODE	C_6	C_{12}
ecosystems integrity	habitats in inadequate/bad status	HABITAT_INADEG	x	x
	grassland and pasture	GRASS_PAST	x	x
	woods owned by farms	WOOD_FARM	x	x
	high geobotanical value	GEOBOTVAL_HIGH		x
	low geobotanical value	GEOBOTVAL_LOW	x	x
ecosystem benefits	forests for woods	FOR_WOODS	x	x
	D.O.C. and I.G.P. producers	QUAL_PROD	x	x
physical processes state	flood discharge variation	TREND_FLOOD	x	x
	PM_{10} average value	PM10_AVG	x	x
external pressures	agricultural area	AGR_AREA	x	x
	heads of livestock	LIVESTOCK	x	x
	urban-transport fragmentation pressure	FRAGM_PRESS	x	x

In terms of statistical characteristics, both combinations show a promising performance. As well as in the resilience case, the discriminant analysis provided two discriminant functions per each combination. Although for both combinations the first function is evidently more significant than the other, combination 12 seems to be thoroughly more consistent, as the effectiveness of the second function is higher than for combination 6, since all the statistics are stronger than those of the second function elaborated for combination 6 (Table 7.27 and 7.29). In any case, the main focus of interest is the first function. In this case, the eigenvalue for combination 12 is higher than that for combination 6 (1.143 > 1.141), though the canonical correlation is equal among the combinations, as previously mentioned. Hence, it is possible to estimate the discriminant power of both. In particular, these functions are able to explain more than half (53.29%) of the variability within the clusters of sustainability (indeed, $0.73^2 = 0.5329$). At the same time, function 1 for combination 6 holds a stronger relevance compared to function 2, as it is able to explain the 85.7% of the variability (for combination 6) compared to a 84.1% for combination 12, but this might be due to the overall larger reliability of combination 12. Meanwhile, function 1 for combination 12 shows a higher chi-square value (134.587 compared to 131.989), though the Wilks' lambda is slightly smaller (0.384 compared to 0.392). Furthermore, in this case all functions are significant (sig. < 0.05 for all functions of both combinations), although function 2 for combination 12 is slightly more statistically significant than function 2 for combination 12 (0.004 < 0.006) (Table 7.28 and 7.30).

Table 7.27 — Eigenvalue statistics for the combination 6 of indicators for sustainability.

FUNCTION	EIGENVALUE	PERCENTAGE OF VARIANCE	CUMULATIVE PERCENTAGE	CANONICAL CORRELATION
1	1.141	85.7	85.7	0.730
2	0.191	14.3	100.0	0.401

Table 7.28 — Wilks' lambda statistics for the combination 6 of indicators for sustainability.

TEST OF FUNCTION(S)	WILKS' LAMBDA	CHI-SQUARE	DF	SIG.
1 through 2	0.392	131.989	22	0.000
2	0.840	24.657	10	0.006

Table 7.29 — Eigenvalue statistics for the combination 12 of indicators for sustainability.

FUNCTION	EIGENVALUE	PERCENTAGE OF VARIANCE	CUMULATIVE PERCENTAGE	CANONICAL CORRELATION
1	1.143	84.1	84.1	0.730
2	0.216	15.9	100.0	0.422

Table 7.30 — Wilks' lambda statistics for the combination 12 of indicators for sustainability.

TEST OF FUNCTION(S)	WILKS' LAMBDA	CHI-SQUARE	DF	SIG.
1 through 2	0.384	134.587	24	0.000
2	0.822	27.508	11	0.004

In light of the above considerations, combination 12 appears overall more reliable than combination 6. Hence, combination 12 was selected to proceed to the final step of the analysis aimed at expliciting the discriminant function. In this case, the standardised function 1 is (Eq. 9):

$$\mathrm{F} = 0.287 * \mathrm{HABITAT\_INADEG} + 0.166 * \mathrm{GRASS\_PAST} + 0.569 * \mathbf{WOOD\_FARM} - 0.047 * \mathit{GEOBOTVAL\_HIGH} + 0.112 * \mathit{GEOBOTVAL\_LOW} - 0.139 * \mathrm{FOR\_WOODS} + 0.500 * \mathrm{QUAL\_PROD} + 0.525 * \mathbf{TREND\_FLOOD} - 0.440 * \mathrm{PM10\_AVG} - 0.510 * \mathbf{AGR\_AREA} + 0.266 * \mathrm{LIVESTOCK} + 0.013 * \mathit{FRAGM\_PRESS} \quad (9)$$

In Eq. 9 it is possible to compare the weight of each indicator of the discriminant function. In particular, the indicators associated with the larger weights are evidenced in bold, whereas those associated to the smaller weights are in italics. Metrics related to the forests associated to farmers (0.569), to the variations of flood discharges (0.525) and to the extension of the agricultural areas (0.510) appear to have the wider discriminant weights among the other indicators. On the opposite side, the pressure exerted by anthropic infrastructures (0.013) and both the geobotanical values (0.047 for high and 0.112 for low) seem not to play a significant role in discriminating among the clusters. This might be particularly interesting, considering the significant enhancement of the statistical features of combination 12 achieved after the inclusion of these values.

At this point, it is possible to draw the predicted clusters of sustainability following the identification of the discriminant function (Table 7.31).

Table 7.31 — Clusters assigned after the cluster analysis and predicted after the discriminant analysis of sustainability.

MUNICIPALITY		CLUSTER OF SUSTAINABILITY	
NAME	ID	ASSIGNED	PREDICTED
Acqualagna	41001	1	2
Apecchio	41002	2	2
Auditore	41003	2	1
Belforte all'Isauro	41005	2	2
Borgo Pace	41006	2	2
Cagli	41007	2	2
Cantiano	41008	2	2
Carpegna	41009	2	
Cartoceto	41010	3	3
Fano	41013	3	3
Fermignano	41014	1	3
Fossombrone	41015	2	2
Fratte Rosa	41016	1	
Frontino	41017	2	2
Frontone	41018	2	
Gabicce Mare	41019	1	
Gradara	41020	3	3

Isola del Piano	41021	1	2
Lunano	41022	1	
Macerata Feltria	41023	1	
Mercatello sul Metauro	41025	2	2
Mercatino Conca	41026	2	
Mombaroccio	41027	3	1
Mondavio	41028	1	3
Mondolfo	41029	3	3
Montecalvo in Foglia	41030	1	
Monte Cerignone	41031	2	
Monteciccardo	41032	1	1
Montecopiolo	41033	2	2
Montefelcino	41034	1	1
Monte Grimano Terme	41035	2	
Montelabbate	41036	3	
Monte Porzio	41038	1	
Peglio	41041	1	
Pergola	41043	2	2
Pesaro	41044	1	3
Petriano	41045	1	
Piandimeleto	41047	2	
Pietrarubbia	41048	1	2
Piobbico	41049	2	
San Costanzo	41051	1	1
San Lorenzo in Campo	41054	3	
Sant'Angelo in Vado	41057	1	2
Sant'Ippolito	41058	1	
Sassocorvaro	41059	2	2
Sassofeltrio	41060	2	
Serra Sant'Abbondio	41061	2	
Tavoleto	41064	2	
Tavullia	41065	3	3
Urbania	41066	2	2
Urbino	41067	2	2
Vallefoglia	41068	3	3
Colli al Metauro	41069	1	3
Terre Roveresche	41070	1	3
Agugliano	42001	1	
Ancona	42002	1	3
Arcevia	42003	1	1
Barbara	42004	1	3
Belvedere Ostrense	42005	1	1
Camerano	42006	3	3
Camerata Picena	42007	3	

Castelbellino	42008	3	
Castelfidardo	42010	3	3
Castelleone di Suasa	42011	3	
Castelplanio	42012	3	3
Cerreto d'Esi	42013	3	1
Chiaravalle	42014	3	
Corinaldo	42015	1	1
Cupramontana	42016	2	3
Fabriano	42017	2	2
Falconara Marittima	42018	3	
Filottrano	42019	1	1
Genga	42020	2	2
Jesi	42021	1	1
Loreto	42022	1	3
Maiolati Spontini	42023	3	3
Mergo	42024	2	
Monsano	42025	1	3
Montecarotto	42026	1	1
Montemarciano	42027	1	3
Monte Roberto	42029	1	
Monte San Vito	42030	1	3
Morro d'Alba	42031	1	1
Numana	42032	1	
Offagna	42033	1	3
Osimo	42034	1	1
Ostra	42035	1	3
Ostra Vetere	42036	1	3
Poggio San Marcello	42037	1	
Polverigi	42038	1	1
Rosora	42040	1	3
San Marcello	42041	1	1
San Paolo di Jesi	42042	1	1
Santa Maria Nuova	42043	1	
Sassoferrato	42044	2	2
Senigallia	42045	1	1
Serra de' Conti	42046	1	1
Serra San Quirico	42047	2	2
Sirolo	42048	1	
Staffolo	42049	1	1
Trecastelli	42050	1	
Apiro	43002	2	2
Appignano	43003	1	1
Belforte del Chienti	43004	1	1
Bolognola	43005	1	

Caldarola	43006	1	
Camerino	43007	1	2
Camporotondo di Fiastrone	43008	1	
Castelraimondo	43009	2	
Castelsantangelo sul Nera	43010	1	2
Cessapalombo	43011	1	
Cingoli	43012	1	1
Civitanova Marche	43013	1	3
Colmurano	43014	1	
Corridonia	43015	1	1
Esanatoglia	43016	2	2
Fiastra	43017	1	2
Fiuminata	43019	2	
Gagliole	43020	2	
Gualdo	43021	1	1
Loro Piceno	43022	1	1
Macerata	43023	1	1
Matelica	43024	2	2
Mogliano	43025	1	
Montecassiano	43026	1	1
Monte Cavallo	43027	1	
Montecosaro	43028	3	
Montefano	43029	1	1
Montelupone	43030	1	1
Monte San Giusto	43031	1	1
Monte San Martino	43032	1	1
Morrovalle	43033	1	1
Muccia	43034	1	
Penna San Giovanni	43035	1	1
Petriolo	43036	1	3
Pieve Torina	43038	1	2
Pioraco	43039	1	1
Poggio San Vicino	43040	3	
Pollenza	43041	1	1
Porto Recanati	43042	1	3
Potenza Picena	43043	1	3
Recanati	43044	1	1
Ripe San Ginesio	43045	1	
San Ginesio	43046	2	2
San Severino Marche	43047	1	1
Sant'Angelo in Pontano	43048	1	1
Sarnano	43049	2	2
Sefro	43050	2	
Serrapetrona	43051	1	3

Serravalle di Chienti	43052	2	2
Tolentino	43053	1	1
Treia	43054	1	1
Urbisaglia	43055	1	
Ussita	43056	2	
Visso	43057	2	2
Valfornace	43058	1	1
Acquasanta Terme	44001	2	2
Acquaviva Picena	44002	1	
Appignano del Tronto	44005	1	1
Arquata del Tronto	44006	2	2
Ascoli Piceno	44007	1	1
Carassai	44010	1	1
Castel di Lama	44011	1	3
Castignano	44012	1	1
Castorano	44013	1	
Colli del Tronto	44014	1	
Comunanza	44015	1	3
Cossignano	44016	1	
Cupra Marittima	44017	1	1
Folignano	44020	3	3
Force	44021	1	1
Grottammare	44023	1	3
Maltignano	44027	3	
Massignano	44029	1	1
Monsampolo del Tronto	44031	3	3
Montalto delle Marche	44032	1	1
Montedinove	44034	1	
Montefiore dell'Aso	44036	1	1
Montegallo	44038	2	
Montemonaco	44044	2	2
Monteprandone	44045	3	3
Offida	44054	3	1
Palmiano	44056	1	
Ripatransone	44063	1	1
Roccafluvione	44064	1	1
Rotella	44065	1	1
San Benedetto del Tronto	44066	1	
Spinetoli	44071	3	3
Venarotta	44073	1	
Altidona	109001	1	3
Amandola	109002	2	1
Belmonte Piceno	109003	1	
Campofilone	109004	1	

Falerone	109005	1	1
Fermo	109006	1	1
Francavilla d'Ete	109007	1	
Grottazzolina	109008	1	
Lapedona	109009	1	3
Magliano di Tenna	109010	1	
Massa Fermana	109011	1	
Monsampietro Morico	109012	1	
Montappone	109013	1	
Montefalcone Appennino	109014	1	1
Montefortino	109015	2	3
Monte Giberto	109016	1	1
Montegiorgio	109017	1	1
Montegranaro	109018	1	1
Monteleone di Fermo	109019	1	
Montelparo	109020	1	
Monte Rinaldo	109021	1	1
Monterubbiano	109022	1	1
Monte San Pietrangeli	109023	1	1
Monte Urano	109024	1	3
Monte Vidon Combatte	109025	1	1
Monte Vidon Corrado	109026	1	
Montottone	109027	1	1
Moresco	109028	3	
Ortezzano	109029	1	
Pedaso	109030	3	
Petritoli	109031	1	
Ponzano di Fermo	109032	1	1
Porto San Giorgio	109033	1	
Porto Sant'Elpidio	109034	1	
Rapagnano	109035	1	
Santa Vittoria in Matenano	109036	1	1
Sant'Elpidio a Mare	109037	1	1
Servigliano	109038	1	1
Smerillo	109039	1	
Torre San Patrizio	109040	1	1

In this case, incomplete information prevented from assigning a cluster to 80 of the 229 Municipalities, that are thence missing. In particular, the dataset was missing measure concerning grassland and pastures, as well as woods owned by farmers and the variation of floods. Nonetheless, the outcome evidence that 72% of the remaining *sub-units* (149 put of 229) were equally grouped by the cluster and the discriminant analysis.

At this point, the first and second phases of the proposed methodology were completed. Before discussing the meaning of the delivered outcomes, it might be interesting to present the application of this analytical procedure to the other case study.

7.2 Hokkaidō

7.1.1 First phase – classification

The analytical process performed on the indicators related to the Municipalities of Hokkaidō perfectly mirrored that previously introduced for the Marche Region case. Nonetheless, the indicators necessarily slightly differed, in order to account for the local peculiarities in terms of specific features and available information. Also in this case, when possible, a range of different combinations were tested, in order to seek for the most reliable outcome.

Resilience

The resilience *core* could be described arranging several sets of indicators, both in absolute and relative terms. In particular, although conceptually the same, metrics related to affected area, population exposed and flood damages were tested both in absolute and in relative dimensions. Nonetheless, presenting all the results might not particularly enhance the present discussion, hence only the most significant outcomes will be displayed, those that introduce all different indicators maintaining consistent their form that is absolute rather than relative metrics (Table 7.32).

Table 7.32 — Indicators, their codes and their combinations per each attribute of the resilience core.

CORE	*ATTRIBUTE*	INDICATOR	CODE	COMBINATION		
				C_1	C_2	C_3
resilience	learn	total affected area	AREA_DAMAGED	x		
		distance from the nearest water body	DIST_WATBOD		x	
		population exposed to flood hazard	EXP_POP			x
	absorb	flood damages	FLOOD_DAMAGE	x	x	x
	recover	percentual difference in income after 2 years and on the year of the last flood event	TAXINCOME_1715	x	x	x

It might be interesting to observe that all the most significant combinations involved absolute values rather than metrics related to the population or other normalising references. This might be due to the fact that absolute values might be more efficient in evidencing different behaviours rather than relative metrics. In any case, the procedure started from STATGRAPGICS in order to collect the initial centroids to prompt the further analysis to be completed in SPSS. Such steps were followed per each tested combination.

The initial centroids of combination 1 were distributed in the space defined by the indicators (Table 7.33), even after undergoing several and significant changes in their positions (Table 7.34 and 7.35), that led to a distinctive representation in the bar graph (Fig. 7.4).

Table 7.33 — Initial centroids per each indicator and each cluster of combination 1 resilience.

INDICATOR	CLUSTER		
	1	2	3
AREA_DAMAGED	-0.23153	1.44107	-0.23761
FLOOD_DAMAGE	-0.20188	1.38782	-0.26099
TAXINCOME_1715	-0.48436	0.34771	0.59594

Table 7.34 — Variation in the position of the centroids per each iteration for combination 1.

ITERATION	CHANGES IN THE CENTROIDS		
	1	2	3
1	0.088	1.235	0.356
2	0.050	0.314	0.179
3	0.060	0.779	0.135
4	0.025	0.000	0.113
5	0.028	0.000	0.160
6	0.012	0.000	0.076
7	0.006	0.000	0.040
8	0.013	0.000	0.088
9	0.000	0.000	0.000

Table 7.35 — Final centroids per each cluster and each indicator of combination 1 of resilience.

INDICATOR	CLUSTER		
	1	2	3
AREA_DAMAGED	-0.12486	2.63496	-0.23800
FLOOD_DAMAGE	-0.17356	3.22466	-0.15159
TAXINCOME_1715	-0.25162	-0.05518	1.71527

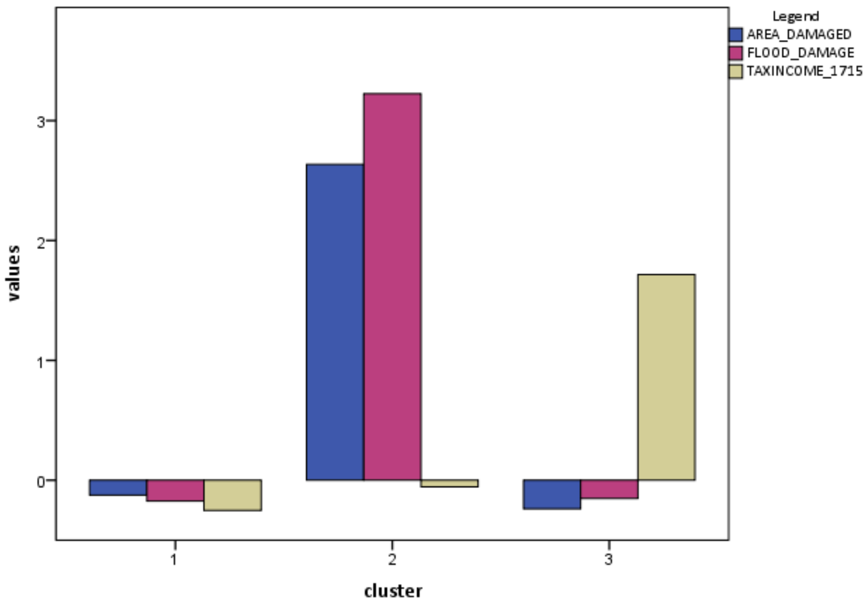


Figure 7.4 — Bar graph of the final centroids per each cluster and each indicator of combination 1 of resilience.

The statistical significance of all the indicators is rather high (sig. < 0.001 for all indicators), while in terms of differentiating power one indicator, that related to suffered damages, overcomes the others (F = 109.155), that in turn have comparable wights (Table 7.36).

Table 7.36 — ANOVA table for combination 1.

INDICATOR	CLUSTER		ERROR		F	SIG.
	Mean Square	df	Mean Square	df		
AREA_DAMAGED	33.020	2	0.636	176	51.908	0.000
FLOOD_DAMAGE	49.275	2	0.451	176	109.155	0.000
TAXINCOME_1715	37.062	2	0.590	176	62.796	0.000

Eventually, the Municipality were arranged in inhomogeneous clusters, with cluster 1 resulting the most densely populated, with 148 cases out of 179 (Table 7.37).

Table 7.37 — Number of cases (Municipalities) per each cluster of combination 1 of resilience.

CLUSTER	1	148
	2	9
	3	22
CASES	VALID	179
	MISSING	0

Even though the cycle of iterations adjusting the centroids of combination 2 resulted to be shorter than that of combination 1 (Table 7.39), the positions of the centroids were rather different, especially for cluster 3, that eventually belonged to a different quarter (Table 7.38 and 7.40).

Table 7.38— Initial centroids per each indicator and each cluster of combination 2 of resilience.

INDICATOR	CLUSTER		
	1	2	3
DIST_WATBOD	-0.22855	1.51178	-0.21124
FLOOD_DAMAGE	-0.20171	1.38866	-0.21098
TAXINCOME_1715	-0.42162	-0.06134	0.89570

Table 7.39 — Variation in the position of the centroids per each iteration for combination 2.

ITERATION	CHANGES IN THE CENTROIDS		
	1	2	3
1	0.082	0.450	0.206
2	0.040	0.100	0.169
3	0.041	0.000	0.213
4	0.030	0.000	0.202
5	0.014	0.000	0.098
6	0.007	0.000	0.053
7	0.000	0.000	0.000

Table 7.40 — Final centroids per each cluster and each indicator of combination 2 of resilience.

INDICATOR	CLUSTER		
	1	2	3
DIST_WATBOD	-0.29611	2.05021	0.12509
FLOOD_DAMAGE	-0.15158	1.31362	-0.18687
TAXINCOME_1715	-0.25012	0.00265	1.74831

In spite of this change, the all cluster were easily distinguishable when visualised through a bar graph (Fig. 7.5).

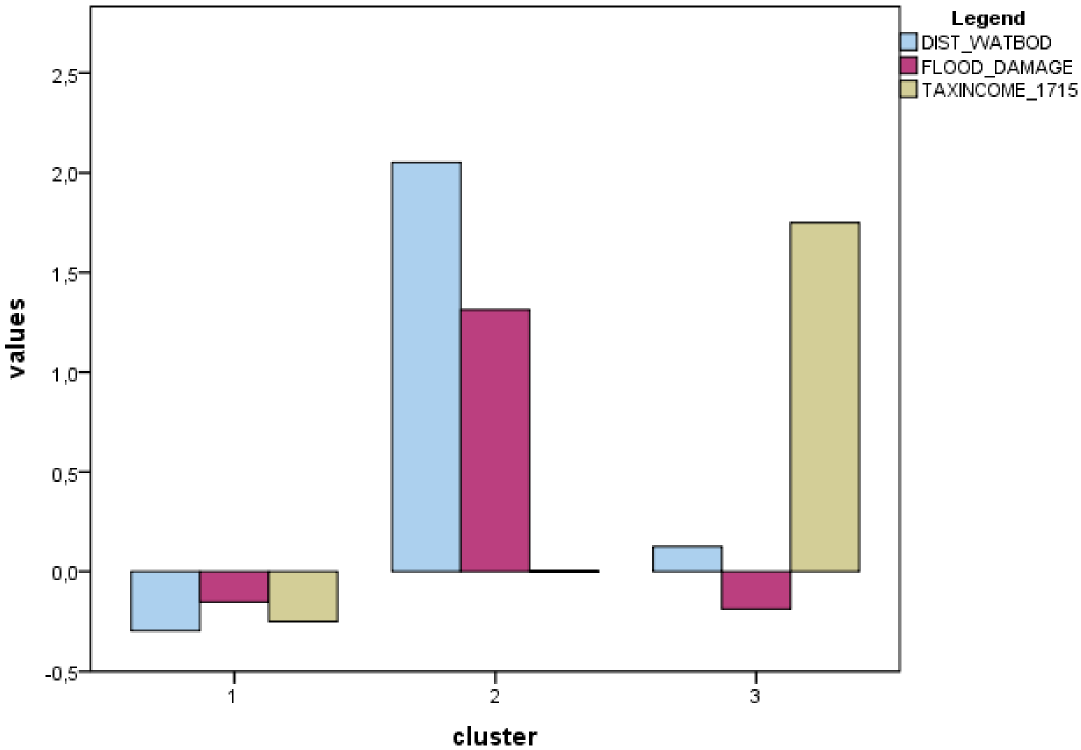


Figure 7.5 — Bar graph of the final centroids per each cluster and each indicator of combination 2 of resilience.

Also in this case, all indicators were statistically significant (sig. < 0.001 for all) and even their power was comparable, although this resulted in weights not particularly high, the highest of which (F = 95.104) related to the estimated distance of the built area from the nearest water body (Table 7.41).

Table 7.41 — ANOVA table for combination 2.

INDICATOR	CLUSTER		ERROR		F	SIG.
	Mean Square	df	Mean Square	df		
DIST_WATBOD	46.226	2	0.486	176	95.104	0.000
FLOOD_DAMAGE	18.351	2	0.803	176	22.857	0.000
TAXINCOME_1715	34.945	2	0.614	176	56.889	0.000

In this case, the majority of the Municipalities were allocated in cluster 1 (140 out of 179), while the remaining were almost equally distributed between cluster 2 and 3 (Table 7.42).

Table 7.42 — Number of cases (Municipalities) per each cluster of combination 2 of resilience.

CLUSTER	1	140
	2	19
	3	20
CASES	VALID	179
	MISSING	0

Combination 3 encompasses the set of indicators for the Hokkaidō case most closely comparable to the combination adopted for the Marche case study, hence it was especially relevant to include it in this presentation (Table 7.31 and 7.32). Once more, the centroids belonged to different quarters of the space, that remained substantially the same, even after the adjustments, that were not less than in the other cases (Table 7.43, 7.44 and 7.45).

Table 7.43 — Initial centroids per each indicator and each cluster of combination 3 of resilience.

INDICATOR	CLUSTER		
	1	2	3
EXP_POP	1.20256	-0.07556	-0.13888
FLOOD_DAMAGE	2.50344	-0.22082	-0.20072
TAXINCOME_1715	0.05096	-0.48871	0.66960

Table 7.44 — Variation in the position of the centroids per each iteration for combination 3.

ITERATION	CHANGES IN THE CENTROIDS		
	1	2	3
1	0.587	0.078	0.248
2	0.743	0.062	0.203
3	0.000	0.030	0.135
4	0.000	0.025	0.113
5	0.000	0.028	0.159
6	0.000	0.012	0.076
7	0.000	0.012	0.083
8	0.000	0.006	0.046
9	0.000	0.000	0.000

Table 7.45 — Final centroids per each cluster and each indicator of combination 3 of resilience.

INDICATOR	CLUSTER		
	1	2	3
EXP_POP	2.06219	-0.08964	-0.14280
FLOOD_DAMAGE	3.50201	-0.16565	-0.15159
TAXINCOME_1715	-0.07531	-0.24922	1.71527

Indeed, the three clusters were easily distinguishable in the graphic representation (Fig. 7.6).

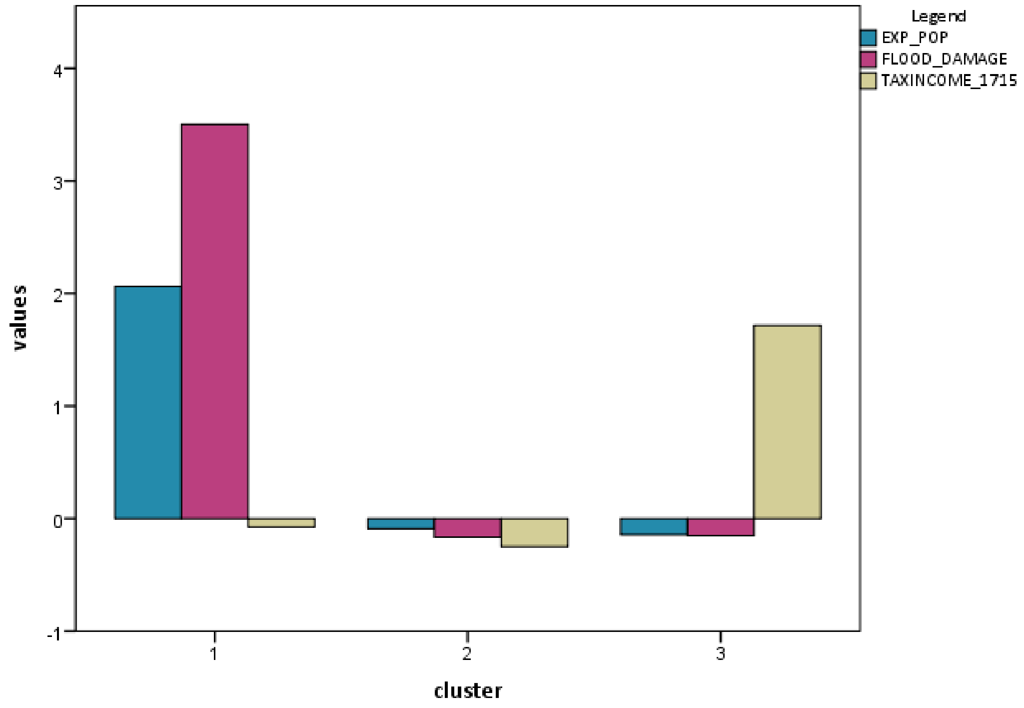


Figure 7.6 — Bar graph of the final centroids per each cluster and each indicator of combination 3 of resilience.

The statistical significance of the indicators was confirmed also in this case (sig. < 0.001 for all indicators), whereas the differentiating power of the indicators was not homogeneously distributed, being the indicator related to flood damages the most relevant (120.039) between the others (Table 7.46).

Table 7.46 — ANOVA table for combination 3.

INDICATOR	CLUSTER		ERROR		F	SIG.
	Mean Square	df	Mean Square	df		
EXP_POP	17.833	2	0.809	176	22.052	0.000
FLOOD_DAMAGE	51.353	2	0.428	176	120.039	0.000
TAXINCOME_1715	37.014	2	0.591	176	62.655	0.000

Eventually, the composition of the cluster was revealed to be uneven, with cluster 2 holding the wider portion (149 out of 179) of the Municipalities (Table 7.47).

Table 7.47 — Number of cases (Municipalities) per each cluster of combination 3 of resilience.

CLUSTER	1	8
	2	149
	3	22
CASES	VALID	179
	MISSING	0

The three combinations differed for the indicator employed to represent the learn *attribute*, that was mirrored in the different outcomes presented above. As it might be expected, the centroids belonged to different positions, although qualitatively those of combination 1 and 3 are visually the most comparable and their adjustment required the same amount of iterations. Similarly, clusters from combination 1 and 3 might be almost superimposed, with cluster 1, 2 and 3 of combination 1 possibly corresponding to clusters 2, 1 and 3 of combination 3, respectively. Indeed, the distribution of Municipalities between the clusters is rather analogous, with only 1 case differently allocated. On the other hand, combination 2 showed a slightly higher stability, as less iterations were cycled in order to achieve the final centroids, although changes were significant and are less comparable to the others. In a similar vein, clusters were differently populated compared to the other combinations, especially the smaller ones. Additionally, the set of indicators employed in combination 2 showed the most limited power in differentiating among the clusters, whereas combination 1 and 3 showed higher weights, even though the effectiveness was more unevenly distributed. Anyhow, combination 3 delivered the most robust set. It might be noteworthy that the indicator related the recover *attribute* was always significant and the second most powerful. On the contrary, the absorb *attribute* emerged as the most important for combination 1 and 3, shifting to learn *attribute* for combination 2.

In light of the above considerations, combination 3 seemed the most promising to sustain the further analytical steps. In particular, the consistency with the other combinations suggested the higher robustness of the delivered partition in clusters, whereas the indicators appeared as the most effective, even though none was overwhelming compared to the others. it might be relevant to consider that although combination 1 was closely comparable, it included two indicators related to flood damages: those indicators were conceptually different and operatively distinct, but such a potential overlay was completely absent in the set employed for combination 3. As a consequence, combination 3 was preferred over the others to provide a base for the following discriminant analysis.

Sustainability

The sustainability *core* was associated with a variety of indicators, some of which were also further differentiated in terms of absolute and relative metrics (Table 7.48). This allowed to arrange a series of combinations. Nonetheless, discussing all the possible arrangements might not contribute much in informing the present examination, hence the three most significant combinations will be described here, with the aim to investigate the consequences of introducing only one different indicator or, conversely, maintaining the same indicator while adopting absolute or relative metrics.

Table 7.48 — Indicators, their codes and their combinations per each attribute of the sustainability core.

CORE	*ATTRIBUTE*	INDICATOR		CODE	COMBINATION		
					C_1	C_2	C_3
sustainability	functions	land transaction		LAND_TRANS	X		
		altered vegetation	area extension	ALT_VEG		x	
			area percentage	ALT_VEG_PERC			x
	services	number of establishments		POW_NUM	x	x	
		employees in power supply		POW_EMP			x
	integrity	distribution of raccoon (浣熊 rōmaji: *araiguma*)	area extension	ARAIG_AREA	x	x	
			area percentage	ARAIG_PERC			x

The centroids of combination 1 were well differentiated between the quarters of the space (Table 7.51) and even though several iterations were required to adjust their position, the variations mainly affected the first cluster (Table 7.49 and 7.50).

Table 7.49 — Initial centroids per each cluster and each indicator of combination 1 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
LAND_TRANS	0.07222	-0.02998	-0.09997
POW_NUM	-0.55141	-0.07551	1.67653
ARAIG_AREA	0.76096	-0.62043	-0.13976

Table 7.50 — Variation in the position of the centroids of combination 1 per each iteration.

ITERATION	CHANGES IN THE CENTROIDS		
	1	2	3
1	0.336	0.112	2.177E-6
2	0.127	0.044	0.000
3	0.076	0.030	0.000
4	0.023	0.009	0.000

5	0.048	0.018	0.000
6	0.025	0.009	0.000
7	0.000	0.000	0.000

Table 7.51 — Final centroids per each cluster and each indicator of combination 1 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
LAND_TRANS	0.21754	-0.05360	-0.09997
POW_NUM	-0.58235	-0.19618	1.67653
ARAIG_AREA	1.36239	-0.45288	-0.13976

Eventually, the clusters exhibited clearly distinct features and were thus easily recognisable also in a bar graph (Fig. 7.7).

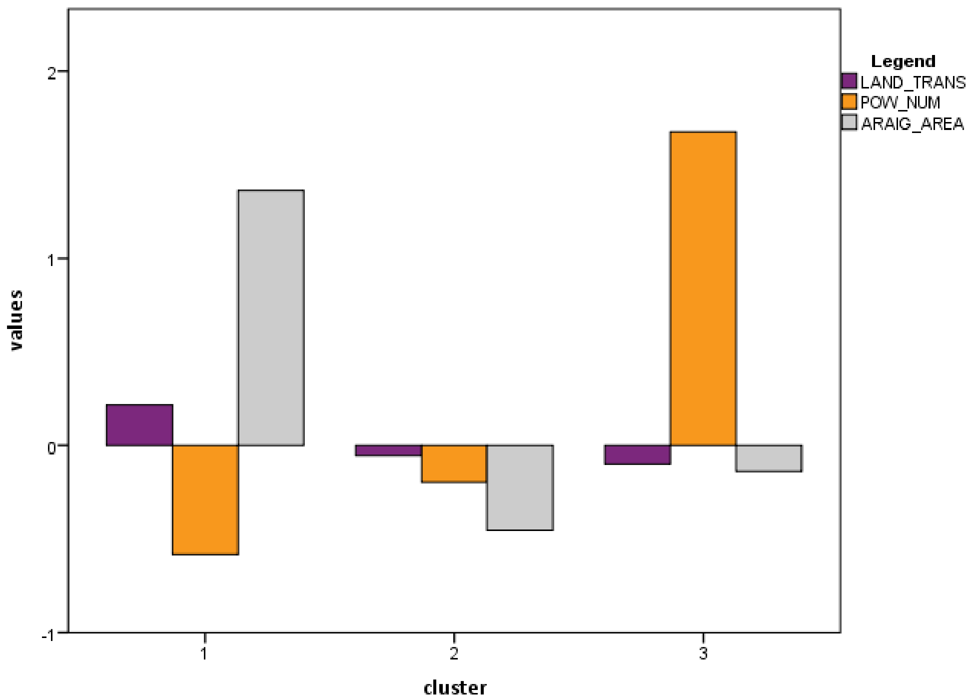


Figure 7.7 — Bar graph of the final centroids per each cluster and each indicator of combination 1 of sustainability.

Although the statistical significance of all the indicators was granted (sig. < 0.001 for all indicators), one of them displayed a rather low power (F = 1.246) in differentiating between the cluster (Table 7.52).

Table 7.52 — ANOVA table for combination 1.

INDICATOR	CLUSTER		ERROR		F	SIG.
	Mean Square	df	Mean Square	df		
LAND_TRANS	1.242	2	0.997	176	1.246	0.290
POW_NUM	46.883	2	0.479	176	97.958	0.000
ARAIG_AREA	48.871	2	0.456	176	107.171	0.000

The final clusters were unevenly populated, with the majority of the Municipalities (112 out of 179) allocated in cluster 2 (Table 7.53).

Table 7.53 — Number of cases (Municipalities) per each cluster of combination 1 of sustainability.

CLUSTER	1	40
	2	112
	3	27
CASES	VALID	179
	MISSING	0

Combination 2 underwent a shorter cycle of iterations in order to stabilise its clusters (Table 7.55), that did not affect much the distribution of the centroids in the space (Table 7.54 and 7.56).

Table 7.54 — Initial centroids per each cluster and each indicator of combination 2 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
ALT_VEG	0.57629	-0.44328	0.60255
POW_NUM	-0.49600	-0.22126	1.40277
ARAIG_AREA	1.27687	-0.49087	-0.23097

Table 7.55 — Variation in the position of the centroids of combination 2 per each iteration.

ITERATION	CHANGES IN THE CENTROIDS		
	1	2	3
1	0.378	0.086	2.449E-6
2	0.231	0.051	0.000
3	0.094	0.021	0.000
4	0.000	0.000	0.000

Table 7.56 — Final centroids per each cluster and each indicator of combination 2 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
ALT_VEG	1.09080	-0.41869	0.60255
POW_NUM	-0.55821	-0.24587	1.40277
ARAIG_AREA	1.72754	-0.34437	-0.23097

Indeed, the centroids and thus the clusters were easily distinguishable even in a graphic representation (Fig. 7.8).

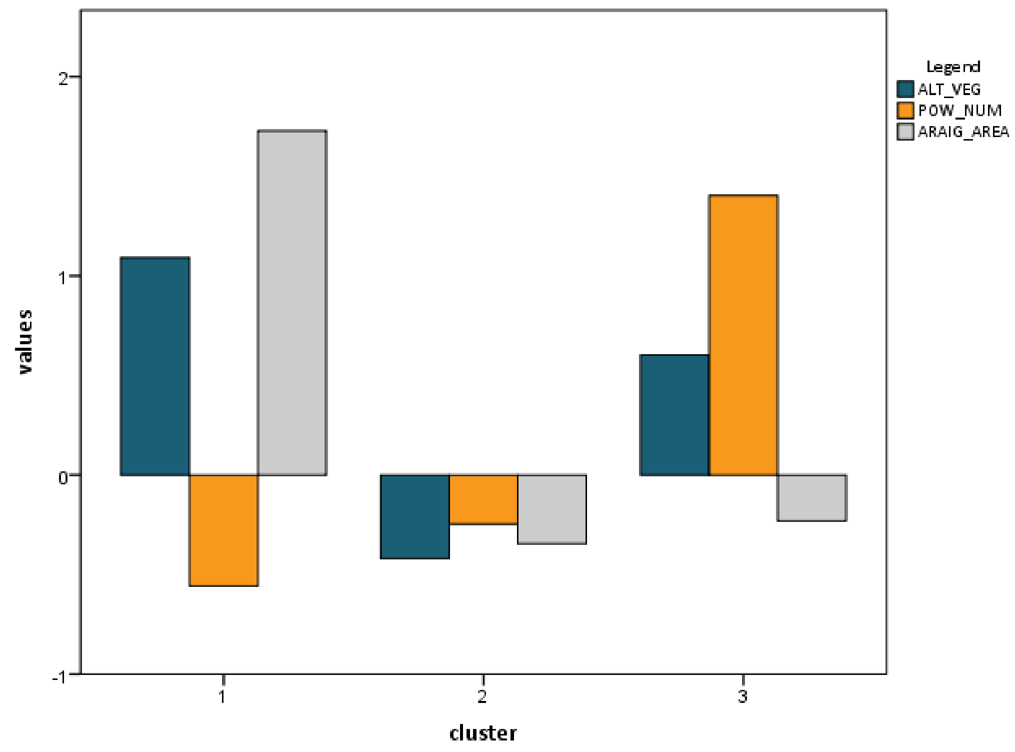


Figure 7.8 — Bar graph of the final centroids per each cluster and each indicator of combination 2 of sustainability.

All the indicators resulted statistically significant in drawing the clusters (sig. < 0.001 for all indicators) and their potential is relatively high, with the maximum value (111.244) associated to the distribution of alien species on the territory (Table 7.57).

Table 7.57 — ANOVA table for combination 2.

INDICATOR	CLUSTER		ERROR		F	SIG.
	Mean Square	df	Mean Square	df		
ALT_VEG	32.897	2	0.638	176	51.601	0.000
POW_NUM	39.444	2	0.563	176	70.042	0.000
ARAIG_AREA	49.691	2	0.447	176	111.244	0.000

Eventually, the Municipalities were mainly allocated in the second cluster (119 out of 179), although the remaining were almost evenly distributed between the two other clusters (Table 7.58).

Table 7.58 — Number of cases (Municipalities) per each cluster of combination 2 of sustainability.

CLUSTER	1	28
	2	119
	3	32
CASES	VALID	179
	MISSING	0

The centroids identified for combination 3 required a relatively long cycle of iterations (Table 7.60) in order to stabilise over the final positions, even though the belonged quarter did not change after the adjustments (Table 7.59 and 7.61) and the three clusters were easily distinguishable even in a visual representation (Fig. 7.9).

Table 7.59 — Initial centroids per each cluster and each indicator of combination 3 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
ALT_VEG_PERC	-0.33298	1.24088	-0.70988
POW_EMP	-0.00340	-0.04911	0.04720
ARAIG_PERC	0.57165	0.30105	-0.92418

Table 7.60 — Variation in the position of the centroids of combination 3 per each iteration.

ITERATION	CHANGES IN THE CENTROIDS		
	1	2	3
1	0.331	0.121	0.168
2	0.173	0.089	0.086
3	0.087	0.051	0.035
4	0.060	0.000	0.035
5	0.063	0.038	0.022
6	0.034	0.055	0.017
7	0.020	0.000	0.011
8	0.000	0.000	0.000

Table 7.61 — Final centroids per each cluster and each indicator of combination 3 of sustainability.

INDICATOR	CLUSTER		
	1	2	3
ALT_VEG_PERC	-0.10074	1.41541	-0.57954
POW_EMP	-0.24407	-0.11464	0.18864
ARAIG_PERC	1.21667	0.06383	-0.71221

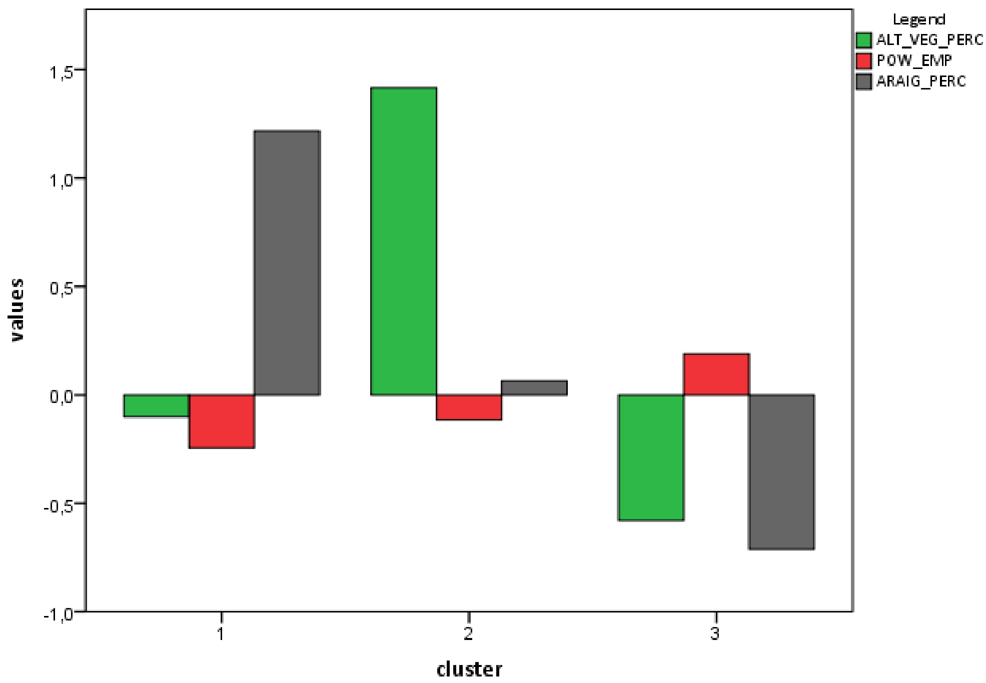


Figure 7.9 — Bar graph of the final centroids per each cluster and each indicator of combination 3 of sustainability.

From a statistical standpoint, all indicators appear to be significant, although the metric related to the employees in the power supply sector almost reaches the critical threshold (sig. = 0.035 < 0.05). Furthermore, the differentiating power of that indicator is rather low (F = 3.427), almost negligible especially if compared to the others (Table 7.62).

Table 7.62 — ANOVA table for combination 3.

INDICATOR	CLUSTER		ERROR		F	SIG.
	Mean Square	df	Mean Square	df		
ALT_VEG_PERC	55267	2	0.383	176	144.179	0.000
POW_EMP	3.336	2	0.973	176	3.427	0.035
ARAIG_PERC	59.661	2	0.333	176	178.951	0.000

All the final clusters are consistently populated, with none of them overwhelming the others, even though the third still gathers the main portion (89 out of 179) of the Municipalities (Table 7.63).

Table 7.63 — Number of cases (Municipalities) per each cluster of combination 3 of sustainability.

CLUSTER	1	50
	2	40
	3	89
CASES	VALID	179
	MISSING	0

Overall, combinations 1 and 3 resulted more instable than combination 2, although the final clusters of combination 1 were qualitatively more resembling those of combination 2. In any case a straightforward overlay could be possible, as the centroids exhibited significant differences in arranging the groupings. This held true even though conceptually different indicators were employed: the meaning of their trends, that is the intuitive correspondence of their increase or decrease to higher or lower levels of sustainability, was the same, hence the visualisation could have been somehow comparable. Concerning the indicators, combination 1 and 3 presented metrics with very low potential in explaining the differences between the clusters, whereas the indicators for combination 2 were more balanced and reliable in these terms. The distribution of the Municipalities among the groups was once more inhomogeneous between the combinations, although combination 1 and 2 provided a more comparable conclusion. In light of these considerations, combination 2 appeared to deliver a more consistent representation of the levels of sustainability, hence this combination was chosen to proceed through the further analytical steps.

7.1.2 Second phase – characterisation

Similarly to the previous case, the second phase of the present adopted methodology employed a discriminant analysis that was developed by means of SPSS tools. The grouping outlined in the previous phase served as a starting point for the process of identifying the relation among some further indicators in characterising the different clusters.

Resilience

The resilience *core* could be described through a set of indicators that allowed to arrange several combinations, C_n (Table 7.64). As a consequence, the discriminant analysis was run repeatedly in order to identify the most reliable assortment of indicators.

Table 7.64 — Indicators and their combinations per each dimension of the resilience core.

DIMENSION	INDICATOR	COMBINATION														
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
demographic	immigrants	x														
	percentage of immigrants		x	x	x	x	x	x	x	x	x	x	x	x	x	x
	population over 65 y.o.	x														
	percentage of population over 65 y.o.		x	x	x	x	x			x	x	x	x	x	x	x
	percentage of population over 75 y.o.								x							
	percentage of population over 80 y.o.							x								
	female population	x														
	percentage of female population		x	x	x	x	x	x	x	x	x	x	x	x	x	x
	population density	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

social	population with compelled education	x														
	percentage of population with compelled education		x	x	x	x	x				x	x	x	x	x	x
	percentage of people with university or graduate education							x	x	x						
	TV broadcast subscription	x														
	TV broadcast subscription per 1000 people		x	x	x		x	x	x	x	x	x	x	x	x	x
	satellite broadcast subscription per 1000 people					x	x	x	x	x	x	x	x	x	x	x
	public halls and similar facilities	x														
	public halls and similar facilities per person		x	x	x	x	x	x	x	x	x			x	x	x
	personnel of public halls and similar facilities											x	x			
	public and private sport facilities	x	x	x						x	x			x	x	x
	personnel of public and private sport facilities				x	x	x	x	x			x	x			
economic	employed population	x														
	percentage of employment		x	x	x	x	x	x	x	x	x	x	x	x	x	x
	taxable income	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	expenditure for social welfare	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	in-migrants from other Municipalities	x														
	percentage of in-migrants from other Municipalities		x	x	x											
	inflow population living in the same Prefecture													x		
	inflow population living in another Prefecture													x		
	percentage of inflow population living in the same or another Prefecture					x	x	x	x	x	x	x	x		x	x
health	welfare facilities for the elderly	x	x													
	nursing care facilities for the elderly			x	x	x	x	x	x	x	x	x	x	x	x	x
	hospitals with medical beds	x														
	hospitals with medical beds per 1000 people		x		x	x	x				x				x	
	hospital beds per 1000 people			x				x		x				x		x
	beds in general clinic												x			
	beds in general clinic per 1000 people								x			x				
	doctors in medical facilities	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	firefighting expenses (municipal finance) in 1000 yen	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
infrastructural	disaster recovery expenses in 1000 yen	x											x			
	disaster recovery expenses per person in yen		x	x	x	x	x	x	x	x	x	x		x	x	x
	extension of municipal roads	x											x			
	extension of municipal roads/population		x	x	x	x	x	x	x	x	x	x		x	x	x
	percentage of population served by septic tank	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	average building construction year	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

As expected, given the initial three clusters, the analytical procedure delivered two discriminant functions. The selection of the most promising combinations was based on the statistical characteristics of the soundest function per each arrangement (Table 7.65). In particular, the statistical significance was homogeneous throughout the tests (sig. ≤ 0.001 for all with a 95% of confidence), while combinations 7, 9 and 15 exhibited the strongest discriminant potential (canonical correlation = 0.902, hence $0.902^2 = 0.814$), that could be estimated as an ability to explain the 81.4% of the variation between the clusters of resilience. Nevertheless, it might be interesting to observe how shifting from absolute (C_1) to relative metrics (the other combinations in general) significantly increased the discriminant potential of the arranged indicators, as the canonical correlation progressed from 0.684 (C_1) to 0.902 (C_7, C_9, C_{15}). Overall, this statistical metrics remained rather high throughout the combinations, hence the employed indicators appeared generally appropriate to characterise the resilient behaviour of the Municipalities.

Table 7.65 — Main statistical tests for each combination of indicators for resilience

STATISTICS	COMBINATION														
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
canonical correlation (eigenvalue)	0.684	0.882	0.893	0.892	0.901	0.901	0.902	0.886	0.902	0.897	0.891	0.898	0.853	0.897	0.902
Sig. (Wilks' lambda)	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

In order to progress through the analytical process, it appeared especially significant to examine more in detail these combinations 7, 9 and 15. It might be noteworthy that a high portion of indicators was shared between these combinations, while the main differences related to the age of the elderlies, the level of education and the metric associated to sport facilities (Table 7.66).

Table 7.66 — Indicators and their codes for combination 7, 9 and 15 per each dimension of the resilience core.

DIMENSION	INDICATOR	CODE	COMBINATION		
			C_7	C_9	C_{15}
demographic	percentage of immigrants	IMMIGR_PERC	x	x	x
	percentage of population over 65 y.o.	POP_OVER65_PERC		x	x
	percentage of population over 80 y.o.	POP_OVER80_PERC	x		
	percentage of female population	POP_FEM_PERC	x	x	x
	population density	POP_DENS	x	x	x
social	percentage of population with compelled education	COMPEL_EDU_PERC			x
	percentage of people with university or graduate education	GRADUATE_EDU_PERC	x	x	
	TV broadcast subscription per 1000 people	TV_SUBSCRIPT_POP	x	x	x
	satellite broadcast subscription per 1000 people	SAT_SUBSCRIPT_POP	x	x	x
	public halls and similar facilities per person	PUBL_HALL_POP	x	x	x
	public and private sport facilities	SPORT_FAC		x	x
	personnel of public and private sport facilities	SPORT_FAC_PERS	x		
economic	percentage of employment	EMPLOYED_POP_PERC	x	x	x
	taxable income	TAX_INCOME	x	x	x
	expenditure for social welfare	SOC_EXPENSE	x	x	x
	percentage of inflow population living in the same or another Prefecture	INFLOW_TOT_PERC	x	x	x
health	nursing care facilities for the elderly	NURS_FAC	x	x	x
	hospital beds per 1000 people	HOSP_BEDS_POP	x	x	x
	doctors in medical facilities	MEDFAC_DOCT	x	x	x
	firefighting expenses (municipal finance) in 1000 yen	FIREFIGHT_EXPENSE	x	x	x
infrastructural	disaster recovery expenses per person in yen	DISREC_EXP_PROCAP	x	x	x
	extension of municipal roads/population	ROAD_LENGHT_POP	x	x	x
	percentage of population served by septic tank	SEPTTANK_PERC	x	x	x
	average building construction year	AVG_BUILD_AGE	x	x	x

As mentioned, the canonical correlation for the first discriminant function was equal between the combinations. Nonetheless, it might be significant that also the second function of all combinations held a relevant discriminant potential, with common comparable values of canonical correlation (Table 7.67, 7.69 and 7.71). Anyhow, the first functions were predominant in explaining the differences in the clusters, as their cumulative percentage was always around 76-77%, thence overwhelming the metric related to the second functions (Table 7.67, 7.69 and 7.71). The eigenvalues were generally rather high for all the first functions, although the highest value (4.368) could be observed for combination 15 (Table 7.71). The statistical significance was indeed granted for all functions (sig. < 0.05), although the first functions appeared more reliable due to the lowest values (Table 7.68, 7.70 and 7.72). At the same time, the Wilks' lambda of the first functions approximated 0.08 for all first functions, showing a promising low value (Table 7.68, 7.70 and 7.72). Among the Chi-square metric of the first functions, combination 7 exhibited the highest one (96.132) closely followed by combination 15 (95.334) (Table 7.68, 7.70 and 7.72).

Table 7.67 — Eigenvalue statistics for the combination 7 of indicators for resilience.

FUNCTION	EIGENVALUE	PERCENTAGE OF VARIANCE	CUMULATIVE PERCENTAGE	CANONICAL CORRELATION
1	4.355	76.4	76.4	0.902
2	1.344	23.6	100.0	0.757

Table 7.68 — Wilks' lambda statistics for the combination 7 of indicators for resilience.

TEST OF FUNCTION(S)	WILKS' LAMBDA	CHI-SQUARE	DF	SIG.
1 through 2	0.080	96.132	42	0.000
2	0.427	32.364	20	0.040

Table 7.69 — Eigenvalue statistics for the combination 9 of indicators for resilience.

FUNCTION	EIGENVALUE	PERCENTAGE OF VARIANCE	CUMULATIVE PERCENTAGE	CANONICAL CORRELATION
1	4.346	77.1	77.1	0.902
2	1.293	22.9	100.0	0.751

Table 7.70 — Wilks' lambda statistics for the combination 9 of indicators for resilience.

TEST OF FUNCTION(S)	WILKS' LAMBDA	CHI-SQUARE	DF	SIG.
1 through 2	0.082	95.231	42	0.000
2	0.436	31.531	20	0.049

Table 7.71 — Eigenvalue statistics for the combination 15 of indicators for resilience.

FUNCTION	EIGENVALUE	PERCENTAGE OF VARIANCE	CUMULATIVE PERCENTAGE	CANONICAL CORRELATION
1	4.368	77.2	77.2	0.902
2	1.290	22.8	100.0	0.751

Table 7.72 — Wilks' lambda statistics for the combination 15 of indicators for resilience.

TEST OF FUNCTION(S)	WILKS' LAMBDA	CHI-SQUARE	DF	SIG.
1 through 2	0.081	95.334	42	0.000
2	0.437	31.480	20	0.049

In light of the above examination, combination 15 appeared the best compromise in terms of reliability, compared to the other combinations. Indeed, the eigenvalue was the highest, whereas the Wilks's lambda was comparable to the others and the Chi-square value was not particularly distant from the highest value. Consequently, combination 15 was selected to proceed towards the conclusion of the analysis and produce the discriminant function. In particular, the standardised discriminant function 1 is (Eq. 10):

$$F = 0.081 * \mathrm{IMMIGR\_PERC} - 0.195 * \mathrm{POP\_OVER65\_PERC} + 0.578 * \mathrm{POP\_FEM\_PERC} - 1.106 * \mathrm{POP\_DENS} - 0.306 * \mathrm{COMPEL\_EDU\_PERC} + 0.004 * \mathit{TV\_SUBSCRIPT\_POP} - 0.207 * \mathrm{SAT\_SUBSCRIPT\_POP} - 0.393 * \mathrm{PUBL\_HALL\_POP} + 0.694 * \mathrm{SPORT\_FAC} - 0.602 * \mathrm{EMPLOYED\_POP\_PERC} + 0.908 * \mathrm{TAX\_INCOME} - 24.234 * \mathbf{SOC\_EXPENSE} + 0.422 * \mathrm{INFLOW\_TOT\_PERC} + 2.412 * \mathrm{NURS\_FAC} - 0.410 * \mathrm{HOSP\_BEDS\_POP} + 18.369 * \mathbf{MEDFAC\_DOCT} + 3.815 * \mathbf{FIREFIGHT\_EXPENSE} + 0.051 * \mathit{DISREC\_EXP\_PROCAP} + 0.056 * \mathit{ROAD\_LENGHT\_POP} + 0.498 * \mathrm{SEPTTANK\_PERC} + 0.253 * \mathrm{AVG\_BUILD\_AGE} \tag{10}$$

In Eq. 10 the indicators that hold the most significant discriminating power are highlighted in bold, whereas those that contributed the least to the description of the clusters are evidenced in italics. Hence, it is possible to observe how the investments on social welfare, the presence of doctors and the expenses devoted to first respondents held a pivotal role in terms of discrimination (coefficients equal 24.234, 18.369 and 3.815, respectively). On the opposite side, subscriptions to TV broadcasting services, the expenses allocated for disaster recovery and the extension of road infrastructure were not particularly significant (weights: 0.004, 0.051 and 0.056, respectively).

At this point, it was eventually possible to compare the cluster of resilience assigned by the previous cluster analysis to those that could be predicted at the end of this phase by means of the selected discriminant function (Table 7.73).

Table 7.73 — Clusters assigned after the cluster analysis and predicted after the discriminant analysis of resilience.

MUNICIPALITY		CLUSTER OF RESILIENCE	
RŌMAJI	ID	ASSIGNED	PREDICTED
Sapporo-shi	1100	1	1
Hakodate-shi	1202	2	2
Otaru-shi	1203	2	2
Asahikawa-shi	1204	1	1
Muroran-shi	1205	2	2
Kushiro-shi	1206	2	2
Obihiro-shi	1207	1	1
Kitami-shi	1208	2	2
Yubari-shi	1209	2	2
Iwamizawa-shi	1210	2	2
Abashiri-shi	1211	2	2
Rumoi-shi	1212	2	2

Tomakomai-shi	1213	2	2
Wakkanai-shi	1214	2	2
Bibai-shi	1215	2	2
Ashibetsu-shi	1216	2	2
Ebetsu-shi	1217	2	2
Akabira-shi	1218	2	2
Monbetsu-shi	1219	2	2
Shibetsu-shi	1220	2	2
Nayoro-shi	1221	2	2
Mikasa-shi	1222	2	2
Nemuro-shi	1223	2	2
Chitose-shi	1224	2	2
Takikawa-shi	1225	2	2
Sunagawa-shi	1226	2	2
Utashinai-shi	1227	2	2
Fukagawa-shi	1228	2	2
Furano-shi	1229	2	2
Noboribetsu-shi	1230	2	2
Eniwa-shi	1231	2	2
Date-shi	1233	2	2
Kitahiroshima-shi	1234	2	2
Ishikari-shi	1235	2	2
Hokuto-shi	1236	2	2
Tobetsu-cho	1303	2	2
Shinshinotsu-mura	1304	3	
Matsumae-cho	1331	2	
Fukushima-cho	1332	2	
Shiriuchi-cho	1333	2	
Kikonai-cho	1334	2	
Nanae-cho	1337	2	2
Shikabe-cho	1343	2	
Mori-machi	1345	2	2
Yakumo-cho	1346	2	2
Oshamambe-cho	1347	2	
Esashi-cho	1361	2	
Kaminokuni-cho	1362	2	
Assabu-cho	1363	2	
Otobe-cho	1364	2	
Okushiri-cho	1367	2	
Imakane-cho	1370	2	
Setana-cho	1371	2	
Shimamaki-mura	1391	2	
Suttsu-cho	1392	2	
Kuromatsunai-cho	1393	2	
Rankoshi-cho	1394	2	
Niseko-cho	1395	3	
Makkari-mura	1396	3	
Rusutsu-mura	1397	3	
Kimobetsu-cho	1398	2	

Kyogoku-cho	1399	2	
Kutchan-cho	1400	3	3
Kyowa-cho	1401	2	
Iwanai-cho	1402	2	
Tomari-mura	1403	2	
Kamoenai-mura	1404	3	
Shakotan-cho	1405	3	
Furubira-cho	1406	2	
Niki-cho	1407	2	
Yoichi-cho	1408	2	2
Akaigawa-mura	1409	2	
Nanporo-cho	1423	2	
Naie-cho	1424	2	
Kamisunagawa-cho	1425	2	
Yuni-cho	1427	2	
Naganuma-cho	1428	2	
Kuriyama-cho	1429	2	
Tsukigata-cho	1430	2	
Urausu-cho	1431	3	
Shintotsukawa-cho	1432	2	
Moseushi-cho	1433	3	
Chippubetsu-cho	1434	3	
Uryu-cho	1436	3	
Hokuryu-cho	1437	3	
Numata-cho	1438	3	
Takasu-cho	1452	2	
Higashikagura-cho	1453	2	
Tohma-cho	1454	2	
Pippu-cho	1455	2	
Aibetsu-cho	1456	2	
Kamikawa-cho	1457	2	
Higashikawa-cho	1458	2	
Biei-cho	1459	2	
Kamifurano-cho	1460	2	
Nakafurano-cho	1461	2	
Minamifurano-cho	1462	1	
Shimukappu-mura	1463	2	
Wassamu-cho	1464	2	
Kenbuchi-cho	1465	2	
Shimokawa-cho	1468	2	
Bifuka-cho	1469	2	
Otoineppu-mura	1470	3	
Nakagawa-cho	1471	2	
Horokanai-cho	1472	2	
Mashike-cho	1481	2	
Obira-cho	1482	2	
Tomamae-cho	1483	2	
Haboro-cho	1484	2	
Shosambetsu-mura	1485	2	

Enbetsu-cho	1486	2	
Teshio-cho	1487	2	
Sarufutsu-mura	1511	2	
Hamatombetsu-cho	1512	2	
Nakatombetsu-cho	1513	2	
Esashi-cho	1514	2	
Toyotomi-cho	1516	3	
Rebun-cho	1517	3	
Rishiri-cho	1518	2	
Rishirifuji-cho	1519	2	
Horonobe-cho	1520	2	
Bihoro-cho	1543	2	2
Tsubetsu-cho	1544	2	
Shari-cho	1545	2	
Kiyosato-cho	1546	2	
Koshimizu-cho	1547	2	
Kunneppu-cho	1549	2	
Oketo-cho	1550	3	
Saroma-cho	1552	2	
Engaru-cho	1555	3	3
Yubetsu-cho	1559	2	
Takinoue-cho	1560	2	
Okoppe-cho	1561	2	
Nishiokoppe-mura	1562	2	
Omu-cho	1563	2	
Ozora-cho	1564	2	
Toyoura-cho	1571	2	
Sobetsu-cho	1575	2	
Shiraoi-cho	1578	2	2
Atsuma-cho	1581	2	
Toyako-cho	1584	2	
Abira-cho	1585	2	
Mukawa-cho	1586	2	
Hidaka-cho	1601	1	
Biratori-cho	1602	2	
Niikappu-cho	1604	2	
Urakawa-cho	1607	2	
Samani-cho	1608	2	
Erimo-cho	1609	2	
Shinhidaka-cho	1610	2	2
Otofuke-cho	1631	2	2
Shihoro-cho	1632	3	
Kamishihoro-cho	1633	3	
Shikaoi-cho	1634	2	
Shintoku-cho	1635	1	
Shimizu-cho	1636	1	
Memuro-cho	1637	1	1
Nakasatsunai-mura	1638	2	
Sarabetsu-mura	1639	2	
Taiki-cho	1641	2	
Hiroo-cho	1642	2	
Makubetsu-cho	1643	2	2
Ikeda-cho	1644	2	
Toyokoro-cho	1645	2	
Honbetsu-cho	1646	2	
Ashoro-cho	1647	2	
Rikubetsu-cho	1648	2	
Urahoro-cho	1649	2	
Kushiro-cho	1661	2	2
Akkeshi-cho	1662	2	
Hamanaka-cho	1663	2	
Shibecha-cho	1664	2	
Teshikaga-cho	1665	2	
Tsurui-mura	1667	3	
Shiranuka-cho	1668	2	
Betsukai-cho	1691	3	3
Nakashibetsu-cho	1692	2	2
Shibetsu-cho	1693	2	
Rausu-cho	1694	2	

In this case, the process was able to predict the cluster of a rather reduced portion of the Municipalities (51 out of 179) due to the limited information available in terms of average age of built structures. Nevertheless, the results showed a complete correspondence among the assigned and predicted values (51 out of 51 Municipalities, 100%). Indeed, for each (considered) Municipality, the discriminant function proved able to provide the same result of the cluster analysis. It might be noteworthy that such performance was granted for all 3 clusters, that had a representation in the albeit restricted sample of this last analytical step.

Sustainability

The sustainability *core* could be characterised through a limited set of indicators due to the complexity of retrieving relevant information at an appropriate scale for this investigation. Nonetheless, the collected indicators were enough to allow for some combinations, C_n (Table 7.74), in order to identify the optimal arrangement that would explain the differences among the levels of sustainability previously outlined.

Table 7.74 — Indicators and their combinations per each dimension of the sustainability core.

DIMENSION	INDICATOR		COMBINATION									
			C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
ecosystems integrity	forest and grassland extension		x	x	x	x						
	forests extension						x		x	x	x	x
	grasslands extension							x	x	x	x	x
	wildlife sanctuary extension	absolute	x		x	x	x	x	x	x	x	
		percentage		x								x
ecosystem benefits	private forests		x	x	x	x	x	x	x	x	x	x
	fisheries and aquaculture entities		x	x	x	x	x	x	x	x	x	x
physical processes state	water intake of water supply businesses	absolute	x	x		x	x	x	x			
		per person			x					x	x	x
	difference from optimal pH value in river water		x	x	x	x	x	x	x	x	x	x
external pressures	cultivated land area		x	x	x	x	x	x	x	x	x	x
	revenue from livestock		x	x	x						x	
	revenue from beef cattle					x	x	x	x	x		x

Examining the main outcomes of the basic statistical tests (Table 7.75), it is possible to observe how the overall discriminant potential of the combinations is almost comparable, as the canonical correlation ranges between 0.489 (C_4) and 0.594 (C_8). It might be interesting to note that the shift from the second (0.592) and first (0.594) highest values was allowed by turning the indicator related to the water intake from the absolute (C_7) to the relative metric (C_8), whereas employing the relative metric (C_{10}), rather than the absolute one (C_8) referred to the wildlife sanctuaries was highly detrimental (0.516 for C_{10}). At the same time, the statistical significance of the tested arrangements is always granted (sig. < 0.05 for all combinations, with a 95% of confidence), although only few of them share the most desirable, that is lowest value (sig. < 0.001 for C_5, C_7, C_8). Combining these metrics, it appears that combination 8 might held the most reliable outcome, hence this set of indicators was examined more in depth (Table 7.76).

Table 7.75 — Main statistical tests for each combination of indicators for sustainability.

STATISTICS	COMBINATION									
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
canonical correlation (eigenvalue)	0.526	0.518	0.513	0.548	0.560	0.489	0.592	0.594	0.537	0.516
Sig. (Wilks' lambda)	0.003	0.004	0.005	0.001	0.000	0.007	0.000	0.000	0.005	0.010

In particular, the first function of combination 8 exhibited the highest (0.594) canonical correlation (Table 7.77), thus emerging as the most efficient combination of indicators, thence it was possible to focus the further analysis on it. Furthermore, the canonical correlation allowed to estimate a discriminant potential of about 35.3% (indeed, $0.594^2 = 0.353$), that is, such function would be able to explain about the 35% of the variation among the clusters of sustainability. Although it might be not particularly high, this performance overwhelmed that of the second function, that delivered a significantly lower canonical correlation (0.237). Indeed, the prominence of the first function was evident also in terms of eigenvalue (0.545 > 0.059) and of relative discriminant power (variance = 90.2% for function 1), hence the choice would be rather obvious. In addition, the second function was not statistically significant (sig. = 0.705 > 0.05), hence it could not be considered in any case (Table 7.78). In turn, the first function was significant (sig.< 0.001, with a 95% of confidence) and provided a reasonably high chi-square value (46.806). Consequently, the final step of the analytical procedure revolved around this function.

Table 7.76 — Indicators and their codes for combination 8 per each dimension of the sustainability core.

DIMENSION	INDICATOR		CODE
ecosystems integrity	forests extension		FOREST_AREA
	grasslands extension		GRASS_AREA
	wildlife sanctuary	extension	WLDLF_SANCT
ecosystem benefits	private forests		PRIV_FOREST
	fisheries and aquaculture entities		FISH_ACQCUL
physical processes state	water intake of water supply businesses	per person	WAT_INT_POP
	difference from optimal pH value in river water		WAT_QUAL
external pressures	cultivated land area		AGRIC_AREA
	revenue from beef cattle		BEEFCATTLE_REV

Table 7.77 — Eigenvalue statistics for the combination 8 of indicators for sustainability.

FUNCTION	EIGENVALUE	PERCENTAGE OF VARIANCE	CUMULATIVE PERCENTAGE	CANONICAL CORRELATION
1	0.545	90.2	90.2	0.594
2	0.059	9.8	100.0	0.237

Table 7.78 — Wilks' lambda statistics for the combination 8 of indicators for sustainability.

TEST OF FUNCTION(S)	WILKS' LAMBDA	CHI-SQUARE	DF	SIG.
1 through 2	0.611	46.806	18	0.000
2	0.944	5.479	8	0.705

In particular, at this point it was possible to draw the explicit equation of the standardised first function of combination 8 (Eq. 11):

$$F = 0.923 * \mathbf{FOREST\_AREA} - 0.490 * \mathbf{GRASS\_AREA} + 0.338 * \mathrm{WLDLF\_SANCT} - 0.309 * \mathit{PRIV\_FOREST} - 0.242 * \mathit{FISH\_ACQCUL} - 0.325 * \mathrm{WAT\_INT\_POP} + 0.390 * \mathrm{WAT\_QUAL} + 0.730 * \mathbf{AGRIC\_AREA} + 0.020 * \mathit{BEEFCATTLE\_REV} \tag{11}$$

The most relevant indicators in terms of discriminating power are evidence in bold in Eq. 11, while the less influencing indicators are highlighted in italics. It might be noteworthy that the first (weight: 0.923) and third (weight: 0.490) most powerful indicators were related to the extension of forests and grasslands, especially when these metrics were previously merged into one indicator (see Table 7.74), but the tested combinations did not deliver a similar promising outcome (see Table 7.75). The second most significant indicator (weight: 0.730) was related to the extension of the agricultural area, hence eventually the function was dominated by metrics referred to the presence of vegetation, both wild and cultivated, in the Municipalities. On the opposite side, the indicators that held the most limited discriminant power (weight: 0.020) were associated to the profits stemming from beef farming, followed by the enterprises engaged in fisheries and aquaculture as well as the extension of cultivated woods (weight: 0.242 and 0.309, respectively), although the potential of these last two indicators was more comparable to the others. In any case, at this point it was possible to proceed towards the last phase of the analysis, that concerns the verification of the actual accuracy of the discriminant function in identifying the cluster of each Municipality (Table 7.79).

Table 7.79 — Clusters assigned after the cluster analysis and predicted after the discriminant analysis of sustainability.

MUNICIPALITY		CLUSTER OF RESILIENCE	
RŌMAJI	ID	ASSIGNED	PREDICTED
Sapporo-shi	1100	1	
Hakodate-shi	1202	2	2
Otaru-shi	1203	3	
Asahikawa-shi	1204	1	1
Muroran-shi	1205	2	
Kushiro-shi	1206	3	1
Obihiro-shi	1207	3	3
Kitami-shi	1208	3	1
Yubari-shi	1209	3	
Iwamizawa-shi	1210	1	3
Abashiri-shi	1211	2	1
Rumoi-shi	1212	3	2
Tomakomai-shi	1213	1	2
Wakkanai-shi	1214	1	3
Bibai-shi	1215	2	2
Ashibetsu-shi	1216	1	1
Ebetsu-shi	1217	2	2
Akabira-shi	1218	2	
Monbetsu-shi	1219	2	1
Shibetsu-shi	1220	3	3
Nayoro-shi	1221	1	1
Mikasa-shi	1222	3	2
Nemuro-shi	1223	2	2
Chitose-shi	1224	1	1
Takikawa-shi	1225	2	2
Sunagawa-shi	1226	3	
Utashinai-shi	1227	2	
Fukagawa-shi	1228	3	1
Furano-shi	1229	1	1
Noboribetsu-shi	1230	2	2

Eniwa-shi	1231	1	
Date-shi	1233	1	2
Kitahiroshima-shi	1234	2	
Ishikari-shi	1235	1	1
Hokuto-shi	1236	2	2
Tobetsu-cho	1303	1	1
Shinshinotsu-mura	1304	2	
Matsumae-cho	1331	2	
Fukushima-cho	1332	2	
Shiriuchi-cho	1333	2	
Kikonai-cho	1334	2	
Nanae-cho	1337	2	1
Shikabe-cho	1343	2	2
Mori-machi	1345	3	1
Yakumo-cho	1346	3	1
Oshamambe-cho	1347	2	2
Esashi-cho	1361	2	
Kaminokuni-cho	1362	2	1
Assabu-cho	1363	2	
Otobe-cho	1364	2	
Okushiri-cho	1367	2	
Imakane-cho	1370	2	1
Setana-cho	1371	2	2
Shimamaki-mura	1391	2	
Suttsu-cho	1392	2	2
Kuromatsunai-cho	1393	2	
Rankoshi-cho	1394	2	2
Niseko-cho	1395	2	2
Makkari-mura	1396	2	2
Rusutsu-mura	1397	2	2
Kimobetsu-cho	1398	3	
Kyogoku-cho	1399	2	2
Kutchan-cho	1400	2	
Kyowa-cho	1401	2	
Iwanai-cho	1402	2	2
Tomari-mura	1403	3	
Kamoenai-mura	1404	2	
Shakotan-cho	1405	2	
Furubira-cho	1406	2	
Niki-cho	1407	2	
Yoichi-cho	1408	2	
Akaigawa-mura	1409	2	2
Nanporo-cho	1423	2	
Naie-cho	1424	3	2
Kamisunagawa-cho	1425	2	
Yuni-cho	1427	2	2
Naganuma-cho	1428	2	2
Kuriyama-cho	1429	2	2
Tsukigata-cho	1430	2	

Urausu-cho	1431	2	2
Shintotsukawa-cho	1432	1	1
Moseushi-cho	1433	3	2
Chippubetsu-cho	1434	2	
Uryu-cho	1436	2	2
Hokuryu-cho	1437	2	
Numata-cho	1438	2	2
Takasu-cho	1452	2	2
Higashikagura-cho	1453	2	
Tohma-cho	1454	2	
Pippu-cho	1455	2	
Aibetsu-cho	1456	2	2
Kamikawa-cho	1457	3	1
Higashikawa-cho	1458	2	
Biei-cho	1459	1	1
Kamifurano-cho	1460	2	
Nakafurano-cho	1461	2	
Minamifurano-cho	1462	3	
Shimukappu-mura	1463	1	
Wassamu-cho	1464	2	
Kenbuchi-cho	1465	2	2
Shimokawa-cho	1468	2	1
Bifuka-cho	1469	2	3
Otoineppu-mura	1470	2	
Nakagawa-cho	1471	1	1
Horokanai-cho	1472	3	
Mashike-cho	1481	3	
Obira-cho	1482	2	2
Tomamae-cho	1483	2	
Haboro-cho	1484	2	
Shosambetsu-mura	1485	2	
Enbetsu-cho	1486	3	
Teshio-cho	1487	3	2
Sarufutsu-mura	1511	2	
Hamatombetsu-cho	1512	2	2
Nakatombetsu-cho	1513	2	2
Esashi-cho	1514	1	1
Toyotomi-cho	1516	1	
Rebun-cho	1517	2	
Rishiri-cho	1518	2	
Rishirifuji-cho	1519	2	
Horonobe-cho	1520	1	
Bihoro-cho	1543	2	2
Tsubetsu-cho	1544	2	
Shari-cho	1545	3	3
Kiyosato-cho	1546	2	2
Koshimizu-cho	1547	2	2
Kunneppu-cho	1549	2	
Oketo-cho	1550	2	

Saroma-cho	1552	2	2
Engaru-cho	1555	3	1
Yubetsu-cho	1559	2	2
Takinoue-cho	1560	2	1
Okoppe-cho	1561	2	2
Nishiokoppe-mura	1562	2	2
Omu-cho	1563	2	
Ozora-cho	1564	2	2
Toyoura-cho	1571	2	2
Sobetsu-cho	1575	2	2
Shiraoi-cho	1578	1	3
Atsuma-cho	1581	2	2
Toyako-cho	1584	2	2
Abira-cho	1585	1	
Mukawa-cho	1586	1	1
Hidaka-cho	1601	1	3
Biratori-cho	1602	1	1
Niikappu-cho	1604	1	
Urakawa-cho	1607	1	
Samani-cho	1608	2	
Erimo-cho	1609	2	
Shinhidaka-cho	1610	1	
Otofuke-cho	1631	3	3
Shihoro-cho	1632	2	
Kamishihoro-cho	1633	3	3
Shikaoi-cho	1634	2	2

Shintoku-cho	1635	3	3
Shimizu-cho	1636	2	2
Memuro-cho	1637	2	3
Nakasatsunai-mura	1638	3	
Sarabetsu-mura	1639	2	
Taiki-cho	1641	2	3
Hiroo-cho	1642	2	2
Makubetsu-cho	1643	3	3
Ikeda-cho	1644	2	2
Toyokoro-cho	1645	2	2
Honbetsu-cho	1646	2	
Ashoro-cho	1647	3	
Rikubetsu-cho	1648	2	
Urahoro-cho	1649	2	2
Kushiro-cho	1661	2	
Akkeshi-cho	1662	3	
Hamanaka-cho	1663	2	
Shibecha-cho	1664	2	3
Teshikaga-cho	1665	2	1
Tsurui-mura	1667	2	2
Shiranuka-cho	1668	2	
Betsukai-cho	1691	3	3
Nakashibetsu-cho	1692	2	3
Shibetsu-cho	1693	2	2
Rausu-cho	1694	2	

Also in this case, the incomplete dataset did not allow to consider all the Municipalities in the comparative analysis, although a rather high portion was included (102 out of 77 Municipalities). In particular, here the most critical information concerned water quality and the revenues from beef cattle. Nevertheless, it was still possible to estimate the predictive accuracy of the discriminant function. Indeed, it appeared quite appreciable, as the majority of the Municipalities (71 out of 102, that is 70%) were allocated to the same cluster by the cluster and the discriminant analyses.

At this point, both phases of the methodology proposed for the present study were completed, for both *cores*, hence the analytical process came to an end also for the Hokkaidō case study. Consequently, it might be possible to proceed towards the discussion of the delivered outcomes.

8. Discussion

The methodology proposed within this research framework was developed in order to investigate the condition of disaster resilience and of environmental sustainability and it was implemented at a Municipal scale in two case studies, the Marche Region and the Hokkaidō. In the lines above the analytical processes were developed and presented, hence at this point it is possible to proceed towards the interpretation of the delivered outcomes, especially examining the results through the lenses of the panarchy paradigm.

Consequently, in the following paragraphs the emerged features of each case study will be explored, moving through the phases of the implemented methodology per each *core* and eventually drawing together the arose considerations.

8.1 Marche Region

The 229 Municipalities that compose the Marche Region (Table 6.3) served as the minimum geographical units for the overall analysis. The first phase of the process aimed at grouping the Municipalities on the basis of their behaviour in critical conditions, through a cluster analysis. Consequently, the resilience and sustainability *cores* were described through one indicator per each *attribute* of the *cores*. Later, the analytical processes intended to explain such differences considering the characteristics of the Municipalities, that is exposing the features that contributed to build those conditions of resilience and of sustainability by means of a discriminant analysis.

8.1.1 First phase – classification

Resilience

A pivotal part of the analysis was played by the centroids, as they define the centres of the clusters, thence the differentiation among the groups. In this case, the initial centroids already belonged to different quarters of the space defined by the indicators, though the adjustment introduced by the k-means clustering enhanced a more evident distance in the final centroids (Table 7.2, 7.3 and 7.4), hence suggesting a more efficient separation among the clusters. This is a desirable condition, since the more the clusters are far from each other and the more evident is the difference in the characteristics of their composing elements, in this case in the disaster behaviour of the Municipalities. Additionally, the cycle of iterations needed to adjust the positions of the centroids resulted rather brief, thus suggesting a high stability, and consequently reliability, of the grouping.

Indeed, all indicators resulted significant and efficient in differentiating the clusters, with two of them (the economic-related indicators) exhibiting comparable weights and anyhow none of them overwhelming the others (Table 7.5). As a consequence, it appears that the selected indicators were appropriate to describe their capacities in terms of disaster resilience and their combination was rather balanced. Thence, the distribution of the Municipalities between the three clusters might be assumed as reliable (Table 7.6). Even though it is uneven, it is a consequence of the influence of these indicators. Rather, what might be relevant at this point is to assign a level of resilience to each cluster. In this regard, the bar graph might be especially beneficial (Fig. 7.1). In the graph, each cluster is represented through the related centroids of the three indicators. In particular, values above the baseline represent relative increase, whereas below the baseline suggest a decrease. Hence, cluster 1 is characterised by a decrease in the population exposed to flood hazard and in the amount of recovery funds received by the Municipality, and an increase in the taxable income two years after the events. Cluster 2 exhibits a decrease in the population exposed, a negligible amount of resources allocated to flood recovery and an evident decrease of the local income. Lastly, cluster 3 shows a marked trend in exposed population and received funds for disaster recovery, while the taxable income is clearly deteriorating. Then, it is necessary to point out the most desirable conditions of disaster resilience. it might be assumed that higher levels of resilience would tend towards a reduction of the level of exposure, since the less population is susceptible to be affected and the lowest the risk, that is the less probability of suffering losses there is; similarly, they should correspond to the least possible amount of fund allocated to disaster recovery, as it would mean that the amount of damages would be limited; lastly, the highest levels of resilience should be related to revenues, as the possibility to rely on consistent assets should grant the possibility to prepare before and cope after the strike of threatening events. In light of these considerations, cluster 1 towards 3 appear to represent decreasing levels of disaster resilience. Indeed, the first cluster appears to embody the most desirable conditions of low susceptibility and wider coping capacities, whereas the third cluster stands on the exact opposite side, with high potential to suffer from disasters and limited assets to face them. In the middle, the second cluster shows a low exposure of population, similarly to cluster 1, and a decrease in the income, similarly to cluster 3, while the damages are not relevant. The association of the levels of resilience to the clusters seems rather solid, hence there is no need to further investigate the theme on the basis of the weights of the indicators. That is, at this point it might be possible to assign the high level of resilience (HR) to cluster 1, the medium level (MR) to cluster 2 and the low level (LR) to cluster 3 (Fig. 8.1).

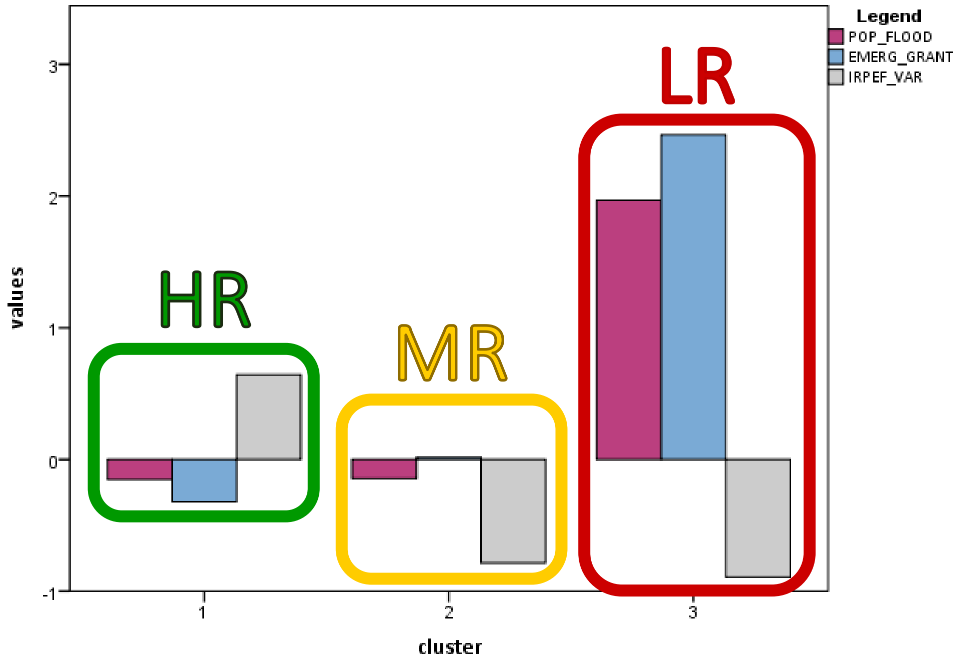


Figure 8.1 — Bar graph of the centroids per each cluster and each indicator, in terms of levels (high H, medium M, low L) of resilience (R).

As a consequence, it appears that most of the Municipalities (127 out of 229) that compose the Marche Region fall within the first cluster corresponding to the highest level of resilience, while the remaining are mainly included in medium level (86) and only a limited portion of the Municipalities (16) are associated to the lowest level (Table 8.1).

Table 8.1 — Distribution of the Municipalities of Marche Region between the clusters and the levels (high H, medium M, low L) of resilience (R).

CLUSTER	LEVEL OF RESILIENCE	NUMBER OF MUNICIPALITIES
1	HR	127 (55.46%)
2	MR	86 (37.55%)
3	LR	16 (6.99%)

Overall, it appears the Marche Region holds a promising potential in terms of capacities to face and cope with a flood event. Indeed, the analysis allowed to compare the disaster behaviour of the Municipalities and it emerged that more than half (55.46%) performs considerably better than the others and, in parallel, only a limited share of the Municipalities (6.99%) might require a significant enhancement of the local capacities. At the same time, the Municipalities allocated to the medium level of resilience should not be overlooked. Although it is encouraging that they stand in a balanced condition, this also suggests that improvements might consolidate and further improve the local resilience approach.

At this point, it might be interesting to visualise the distribution of the levels of resilience throughout the territory of the Region (Fig. 8.2).

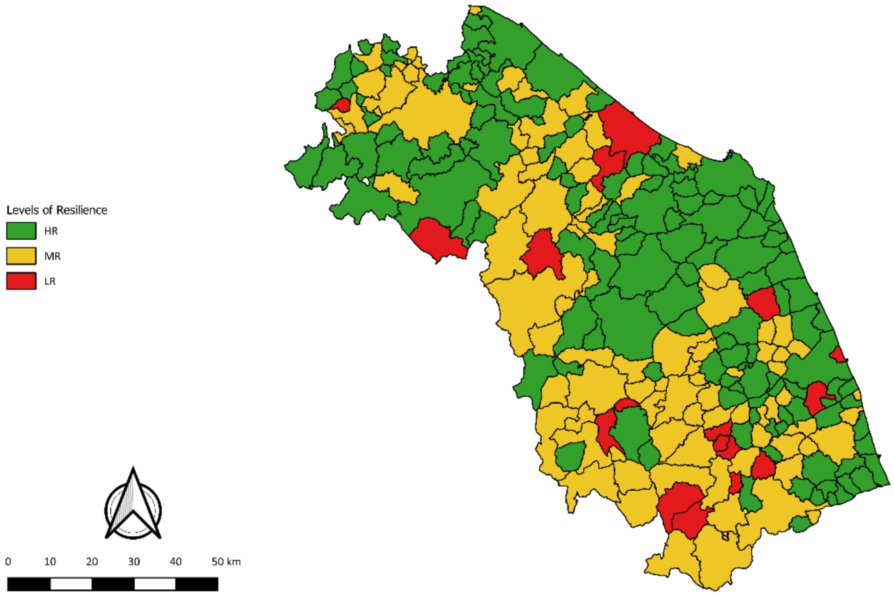


Figure 8.2 — Distribution of the levels (high H, medium M, low L) of resilience (R) among the Municipalities of the Marche Region.

The levels of resilience appear throughout distributed over the Regional territory, although it might be possible to identify some approximative alternation of homogeneous groups of medium and high levels proceeding from North to South, dotted by the lowest levels. Indeed, the grouping does not seem to be based on the morphological features of the Region (e.g. lowest levels in the Western mountainous area), even though it might be noteworthy that indeed most of the Municipalities laying along the coast are associated with the highest level of resilience, with few exceptions: Gabicce Mare, Falconara Marittima, Pedaso and Massignano (MR), and Senigallia and Porto San Giorgio (LR). Rather, the emerging distribution appears to gather Municipalities along an almost horizontal axis. This directrix resembles that of the hydrographic network and thence of the river basins (Fig. 8.3).

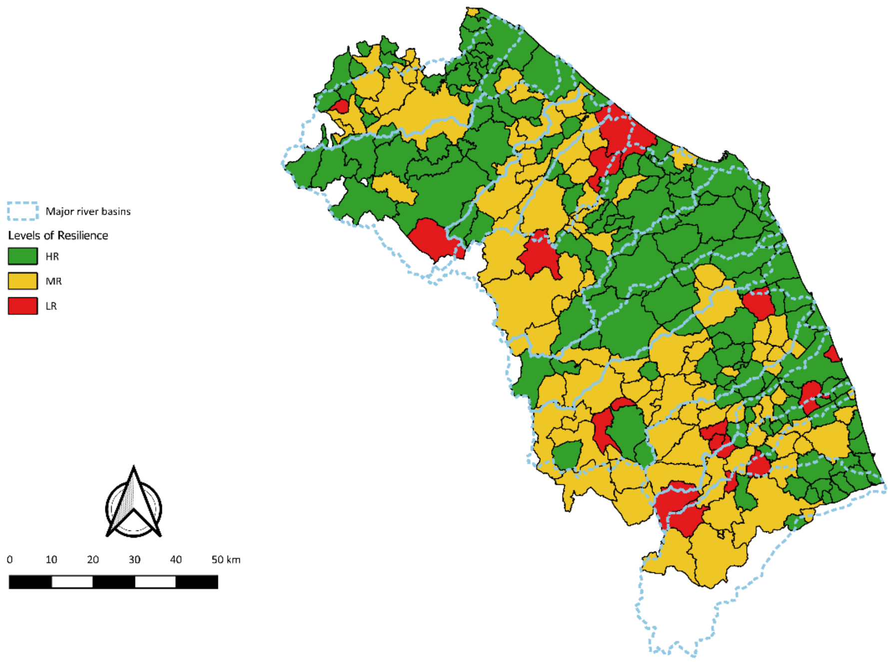


Figure 8.3 — Distribution of the levels (high H, medium M, low L) of resilience (R) and of the river basins of the Marche Region.

It might be interesting to observe that the river basins of the Marche Region appear overall homogeneous in terms of disaster behaviour related to flood risk, with average medium or high levels of resilience characterising each specific basin. The most exemplificatory case is that of the Musone river basin, that is exclusively composed of Municipalities associated with the highest level of resilience. The few exceptions are represented by the basins related to the Foglia, Esino and Chienti rivers, that appear more heterogenous. This feature might be relevant in terms of flood impact and management: one indicator of the cluster analysis was related to flood damages and it held a relevant differentiating power (Table 7.5), hence the consistent characterisation might indeed inform on the effectiveness of the strategy enacted along the rivers. At the same time, the differences might be due to some specific features, that might hint at other processes ongoing in the local territories. For instance, the indicator related to the distribution of population might maintain record of local socio-demographic dynamics such as the migration from the mountainous areas to the coast. Similarly, it might be possible to trace those trends through the indicator related to the personal income. Indeed, the employed indicators mirror such a composite condition. Although the cluster analysis evidenced the higher differentiating power of the economic-related indicators, concerning the amount of damages and the recovery of the household capacities in the short term, when looking back at the distribution of their quantifications among the Municipalities, it appears challenging to trace a definite trend that would clearly separate between the groups. In addition, the indicator related to the exposed population contribute to blur the examination, thus further limiting the possible identification of the major differentiating traits and suggesting a complex, multifaceted reality. At the same time, it might be noteworthy that the Marche Region underwent some severe events in the assumed period for the present investigation. In particular, Central Italy was involved in a seismic sequence that included two disruptive earthquakes, on 24th August and on 30th October 2016, characterised by a magnitude of 6.0 Mw and 6.5 Mw respectively (INGV, 2017). The Marche Region severely suffered from the events: the affected area extended for 3978 km^2 (approximately 42.32% of the regional territory), where 31714 people (2.08% of the overall population) were involved (Regione Marche, n.d.-c). Given the dreadful consequences that concerned the local territories, it might be expected that the overall resilience of those Municipalities was hindered. Consequently, even though the quantification of the indicators employed for the cluster analysis might be influenced by wider, more complex processes that are not exclusively flood-related, the outcome of the cluster analysis might still be valid, as those processes affected also the local capacities to cope with flood risk. For instance, local authorities might have diverted a relevant amount of resources from risk management to recovery funds, hence hampering the overall risk preparation strategies. At the same time, citizens might have been affected by the earthquake, thus losing assets and resources to face other threats. Indeed, this might confirm that when dealing with disaster resilience, the Social-Ecological System has a complex behaviour that is influenced by a series of factors, some of which unpredictable, as the occurring of an earthquake might be. In other words, what occurs at a certain scale of the Social-Ecological System might indeed influence and undermine the stability of other scales, triggering a cascade of consequences that might reach even originally unrelated fields. Hence, the multifaceted and interlaced nature of the Social-Ecological System is confirmed once more.

Sustainability

As previously mentioned, for the sustainability *core* it was possible to test several different combinations of indicators in order to optimise the outcome of the cluster analysis. In particular, the second combination of those illustrated here (Table 7.7) was selected, based on the overall performance. Indeed, the centroids of the clusters were rather stable, as only three iterations were necessary in order to stabilise their positions, that anyway remained almost unaltered and well differentiated (Table 7.13, 7.14 and 7.15). Consequently, it might be assumed that the clustering of the Municipalities based on their environmental sustainability was rather consistent from the onset of the analytical process, thence suggesting that the employed indicators were appropriately sorted to describe this *core*, also considering the ideal statistical significance that they exhibited (Table 7.16). Nonetheless, their potential in separating the groups was not equal: in this case, the alterations perpetrated to natural landscapes played the most significant role, followed by the critical conditions of flora and fauna, whereas the amount of abducted water for anthropic use was only marginal (Table 7.16). At this point, it might be interesting to investigate the allocation of the Municipalities among the levels of sustainability and then the distribution of such levels throughout the territory of the Marche Region. In order to draw this picture, it is necessary to preliminary associate each cluster to a level of sustainability. In particular, in this case it was assumed that a high rate of natural land converted to urbanised and industrialised areas would be detrimental for the local sustainability, as the potential of natural ecosystems to perform their functions would be limited by the disappearance of natural landscapes. Similarly, an increase in the quantity of abducted water for anthropic uses would be unfavourable, as it would imply a substantial human impact on the natural systems, thus potentially undermining their equilibria. Lastly, a considerable presence of species in unfavourable conditions would be an evident sign of unhealthy conditions of the natural ecosystems. In light of the above considerations, it might be beneficial to look back at the bar graph representing the clusters through their centroids (Fig. 7.3). In particular, cluster 1 exhibits a decrease in all the indicators, suggesting a lower portion of territory converted in anthropic landscapes, higher amount of clean water abducted from natural sources and less threatened species. Cluster 2 shows rather different features: although the conversion of land is limited, the quantity of natural water and of endangered species tends in the opposite direction, with an evident increase. Lastly, the trend is reversed for cluster 3, that displays a marked increase of conversion from natural to urbanised and industrialised areas, while the rate of abducted water and of species in unfavourable conditions is among the lowest. As a consequence, in this case cluster 1 is assumed to represent the highest level of sustainability (HS), whereas cluster 2 is associated to the medium level (MS) and cluster 3 the remaining lowest level (LS) of sustainability (Fig. 8.4). While the identification of the HS might be almost intuitive, the other levels might require some further considerations, as the trends of the indicators are not consistent hence it is not possible to draw a univocal interpretation. In this case, the weights of the indicators might help to shed some light. Here, the indicator related to the land take holds a dominant role, especially compared to the other indicators, hence the most discriminating power should be associated to this indicator and partially to that concerning the condition of animal and vegetable species. Consequently, as cluster 3 shows a dramatic increase in the conversion of natural land, with the other indicators closer to an invariance, it is associated to the lowest conditions in terms of sustainability. On the contrary, cluster 2 is significantly less concerning in terms of alteration of natural areas, although the conditions are still not ideal, as the other features tend towards unfavourable conditions, thence the attribution of the medium level of sustainability. It is acknowledged here that in this case the role of the researcher is pivotal, even more than in the resilience case. That is, the correspondence among clusters and levels of sustainability is a matter of interpretation. Here, the evaluation was especially influenced by the weights associated to each indicator through the analytical process, hence an objective parameter guided the choice, but it was still a subjective analysis, thus viable of personal biases.

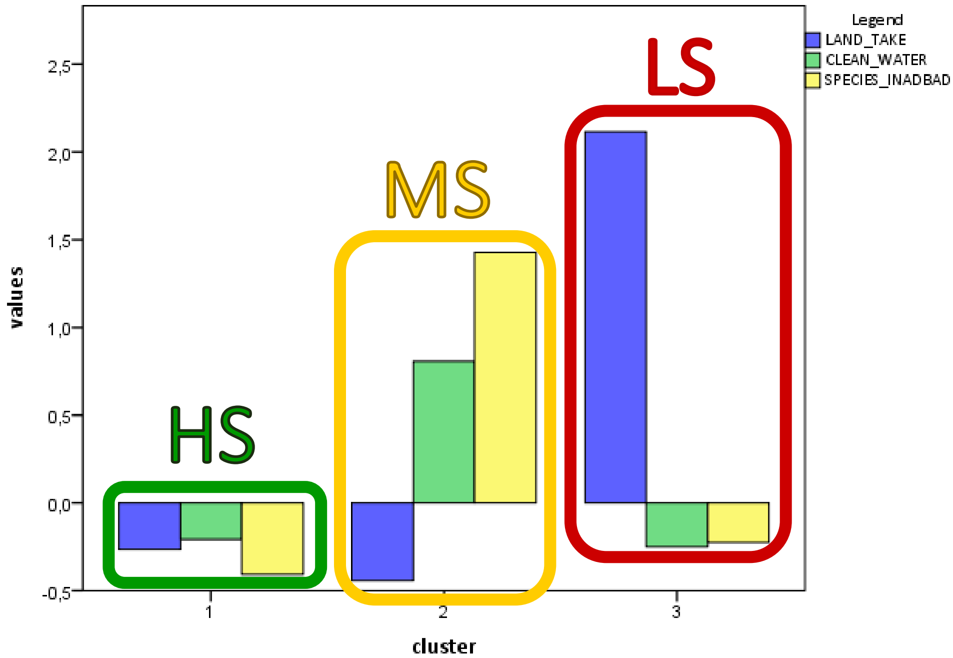


Figure 8.4 — Bar graph of the centroids per each cluster and each indicator, in terms of levels (high H, medium M, low L) of sustainability (S).

Nonetheless, assuming the validity of these considerations, it might be possible to associate the Municipalities to the corresponding level of sustainability (Table 8.2). It appears that the majority (152 out of 229) of the Municipalities is associated to the highest level of sustainability, while the second most populated level (48) is the medium, eventually followed (29) by the lowest level.

Table 8.2 — Distribution of the Municipalities of Marche Region between the clusters and the levels (high H, medium M, low L) of sustainability (S).

CLUSTER	LEVEL OF SUSTAINABILITY	NUMBER OF MUNICIPALITIES
1	HS	152 (66.38%)
2	MS	48 (20.96%)
3	LS	29 (12.66%)

Following this distribution, it appears that the environmental sustainability of the Municipalities of the Marche Region is rather encouraging, as a considerable portion (66.38%) exhibits the most desirable conditions in terms of coexistence with the natural environment. This is further consolidated when considering that only a very limited portion of the Municipalities (12.66%) might require a significant enhancement of the local strategies of sustainability. In other words, it appears that the Regional territory is overall characterised by favourable conditions, dotted by more fragile spots. In this regard, a geographical visualisation of the situation might be beneficial to draw some interesting insights (Fig. 8.5).

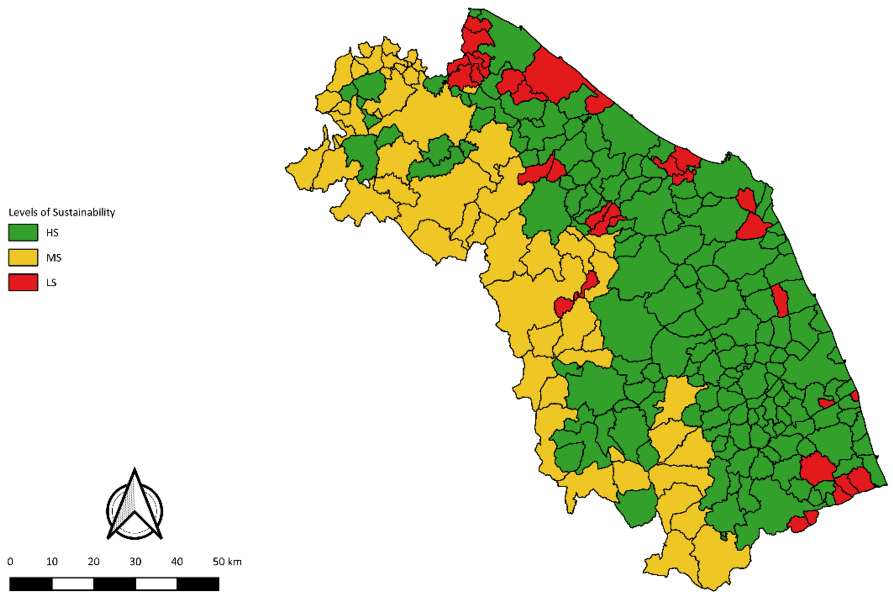


Figure 8.5 — Distribution of the levels (high H, medium M, low L) of sustainability (S) among the Municipalities of the Marche Region.

The Municipalities appear rather well differentiated in two parallel bands, one for HS and one for MS, directed from North-West towards South-East. It might be noteworthy that the Municipalities that exhibits the less desirable conditions are often aggregated into pockets of 2 to 7 elements, that punctuate those bands, mostly the one corresponding to the higher level of sustainability, and are generally shifted towards the Eastern side. Indeed, the distribution of the bands seem to follow the morphological features of the territory, that is characterised by mountains in the Western area that progressively decline in hills and eventually reach the coastline in the Eastern side, while being crossed by narrow river plains (Fig. 8.6).

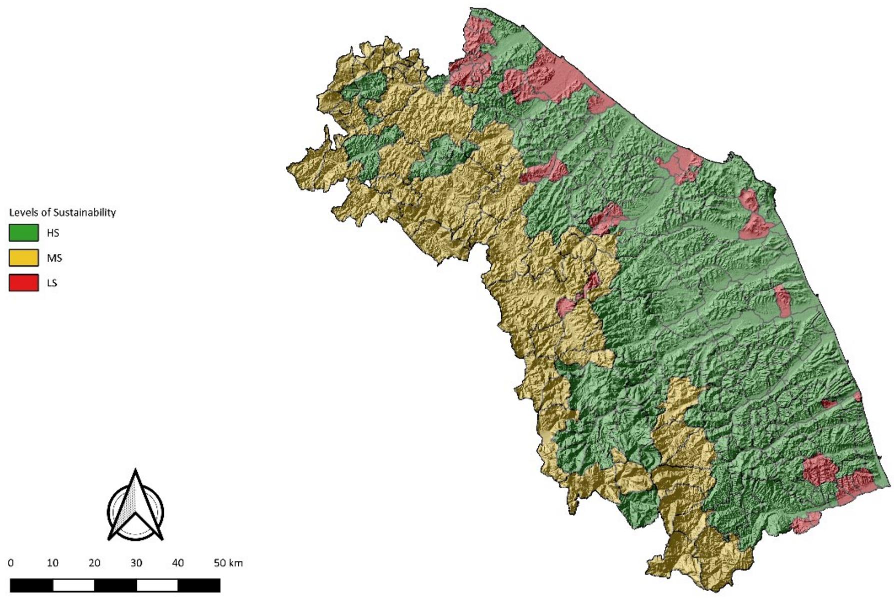


Figure 8.6 — Distribution of the levels (high H, medium M, low L) of sustainability (S) and the morphological features of the Marche Region.

Observing the morphology of the Marche Region, it emerges an overall lower performance of the mountain areas in terms of sustainability, as the medium level is distributed along the Appennini chain, with better performing Municipalities constituting some pockets in the Pesaro-Urbino Province and in the area of the Macerata Province, then extending throughout the hill area towards the coasts. As mentioned, the least desirable conditions are exhibited by small groups of neighbouring Municipalities, mainly disseminated around the estuaries and partly along the river plains, especially the Metauro, Cesano, Esino and Tronto rivers. This distribution might be surprising, considering that the inner territories have implemented substantial strategies to foster the protection of the environment, for instance promoting the preservation of wildlife through protected areas, such as the "*Parco Nazionale dei Monti Sibillini*" and the "*Parco Nazionale del Gran Sasso e Monti della Laga*" in the south-western corner of the regional territory, and the "*Parco Naturale Regionale della Gola della Rossa e di Frasassi*" in the central area, which are the widest in the Marche Region (Regione Marche, n.d.-a). These protected areas are subjected to a specific regulation, aimed at limiting the human impact on the natural systems and thence contribute to the enhancement of the local conditions of the ecosystems. In light of the outlined clusters, it might appear that those strategies were not sufficient to achieve the most desirables attributes of sustainability, thus some improvements might be encouraged. Furthermore, it might be noteworthy that similar initiatives were enacted also in the coastal areas, such as the "*Parco Naturale Regionale del Monte San Bartolo*" in the northern part and the "*Parco Naturale Regionale del Conero*" in the central part of the Region, though they appear to lay in the most advantageous conditions in terms of sustainability. One of the most relevant consequences of the protected areas concern the zoning of the pertaining territory based on the allowed human activities and transformations of the local landscapes (*Legge Quadro Sulle Aree Protette 6 Dicembre 1991 n. 394*, 1991). Since in this case the conversion of natural environments into urban and industrial areas is a determining factor in differentiating the behaviour of the Municipalities, it appears that the beneficial influence of the protected areas might be failing to extend to the overall territory of the Municipality. Indeed, when examining the quantification of the indicators among the Municipalities, the effect of the conversion of natural environments into anthropic areas emerges especially effective in identifying the least desirable conditions of sustainability. On the contrary, the picture becomes relatively blurred between the two other clusters. In this case, though, it is possible to observe that the conditions of species in the Municipalities associated to the intermediate levels of sustainability are generally significantly direr. In addition, when examining the most desirable conditions, it seems that the lower performances in terms of land take were more efficaciously compensated by better results specifically in terms of protection of local species. In other words, it seems that the pockets of low sustainability along the coasts might be especially due to the heavy impacts of anthropic processes that alter the natural environment, hence tailored activities might be planned to reverse this detrimental trend. At the same time, the inner territories might be benefit from the enhancement of power of the protected areas and in general from fostering of the interaction with the more pristine surrounding natural setting, strengthening the efforts to preserve native species. Here in particular, local socio-demographic dynamics might have influenced the outcome leading to the less encouraging performances. For instance, the abandonment of agricultural activities might have prompted a more substantial transformation for urban or industrial purposes of the inner territories, especially compared to the coastal areas, traditionally more developed, thence possibly more stable in terms of land use change, thus also hampering the survivability of indigenous species and of the whole natural habitats. Overall, this situation appears to suggest that the protection of natural landscapes should be encouraged on a wider basis, in order to foster a general and sounder coexistence with the natural ecosystems. Such an approach would also influence both the pivotal indicators, related to the conditions of the local ecosystems. Indeed, the protection of the local pristine conditions might positively affect the state of flora and fauna, thence enhancing the mutual interactions of the anthropic and of the natural components of the local Social-Ecological System.

8.1.2 Second phase – characterisation

Resilience

The second phase of the analytical procedure employed a further set of indicators in order to describe the different *dimensions* of the resilience *core*. The previous research endeavours were especially relevant to this phase, as they informed the selection of the possibly significant variables that could enhance or conversely jeopardise local capacities. Among the different combinations that were tested, one was selected as the most effective (Table 7.20). In particular, the potential to discriminate among the clusters resulted the highest (Table 7.21) along with a satisfactory statistical significance (Table 7.22). Though these metrics are encouraging, the estimated discriminant power (22%, see Ch. 7.1.2) appears not particularly high. That is, the discriminant function is able to explain a limited part of the variations occurred between the 3 clusters of resilience. This might suggest that although the indicators described a wide range of characteristics of the local communities, some relevant traits might have been missed. Consequently, including a wider range of variables might turn beneficial to enhance the overall performance of the function. Nevertheless, in this case the indicators describing the presence of women and of elderly appeared especially significant in determining the assigned cluster and thence the level of resilience of the Municipalities, followed by the volunteers engaged in no-profit organisations (Eq. 8). This is particularly relevant, as demographic variables have traditionally been included in the assessments of resilience and the presence of women and elderlies have habitually been considered as an inherent factor that determines the ability to cope with disasters. Indeed, these components of the population hold a peculiar approach to risk scenarios and events. Women are traditionally associated with a greater prudence, although their ability to physically react to threats might be limited, similarly to elderlies, who might in turn carry the memory and thus the experience of past events. Consequently, female and elder components of a community might be determining in defining the overall disaster behaviour. In this perspective, the drawn discriminant function (Eq. 8) is in line with the previous endeavours, confirming the significance of these demographic characteristics of local communities. The emergence of the volunteers, though, is partially unexpected, as this kind of variable is not always included in resilience assessments. Nevertheless, no-profit organisations are typically devoted to the enhancement of the local community, enriching it either through cultural activities or social assistance, or even advocating petitions dealing with issues risen by the population before local authorities. Hence, the presence of volunteers might suggest a sounder engagement of people in the improvement of their community as well as a pervasive social cohesion that might turn pivotal during emergency times. In spite of the mentioned issue, the discriminant function was still able to deliver an appreciable assignation of the clusters. Indeed, 66% of the Municipalities were associated to the same level of resilience by both the cluster and the discriminant analysis (Table 7.23). Hence, although this performance might be consolidated through a more accurate comprehension of the specific features of the case study, the outcome is still encouraging with regards to the predictive potential of the function. As previously mentioned, a discriminant function not only supports the identification of the most relevant variables of a stated problem, but it also provides a tool to model that problem. In this case, the discriminant function enables the prediction of the level of resilience of a Municipality based on its inherent features, bypassing the disaster metrics required by the previous clustering exercise. As a consequence, it enables the monitoring of the possible alterations in the resilience capacities of a Municipality, through the changes ongoing in the Municipality itself. In this case, the accuracy of such prediction still needs some refinement, but it is promising in the potential of this approach.

Sustainability

The second phase of the sustainability assessment proceeded through the selection of the most appropriate function to describe the approach of the Municipalities towards environmental issues. In this case, the function held a significant discriminating potential, as it was able to explain around the 53% of the variability among the clusters (Table 7.29), hence proving to be more significant compared to the resilience function. Indeed, the predicted clusters correspond to the 72% of those previously assigned by the cluster analysis, confirming the sounder performance of the sustainability function. It might be noteworthy that the number of indicators included is lower than in the resilience case, though delivering a more notable outcome. This might suggest that along with the quantity of the indicators, their quality holds a higher significance. That is, in order to properly describe a problem, it appears that the inclusion of the appropriate variables is more meaningful than employing a wide range of general variables. Nevertheless, it is acknowledged that the more information is supplied and the more thorough and accurate picture might be portrayed, thence refining the final outcome. The present experience further suggests that a fundamental element consists in including the "right" variables in the manifold of the details. In addition, it appeared pivotal to foster the collection of information. Indeed, a significant portion of the Municipalities (80 out of 229) could not be assigned a cluster through the discriminant function (Table 7.31) because of a lack of vital data. If this deficiency persisted, it would hamper the predictive potential of the function. As previously mentioned, holding a discriminant function allows to monitor the performance of the Municipalities through time, bypassing the need to quantify problematic indicators, but rather relying on more accessible ones. Nevertheless, the assessment of variables related to the state of the environment appears not to receive extensive support, thence it might be challenging to even gather significant indicators in the first place. In turn, this might undermine the overall understanding of the conditions of a Social-Ecological System (SES), as environmental sustainability constitutes a pivotal driver of the survivability of the Social-Ecological System in the long term. In particular, in this case it emerged that favouring the inclusion of a thorough characterisation of the quality of the local habitats in terms of geobotanical value was particularly beneficial for the overall performance of the discriminant function (Table 7.26). Thence, it might be assumed that the conditions of the environment are a fundamental feature to comprehend the inherent sustainability of the local landscapes. Hence, it is relatively surprising that eventually the wight of these variables was not particularly high. Possibly, they added some relevant information, although the most important features were described by other indicators, namely the extension of forest related to farms, the land for agricultural use and the variation in flood dynamics. This seems to confirm that enriching the description of a *sub-unit* is beneficial for the overall performance, although the adoption of the appropriate variables should be a priority. In general terms, it might be noteworthy that in this case most of the pivotal indicators were related to the condition of the natural environment, especially the more pristine features (expressed through assessment of the condition of forests and the geobotanical value of the area), and to the integration of human activities in that environment (through the areas devoted to agriculture). While these features hold a general significance, as they describe the impact of anthropic processes on environmental integrity, the other relevant indicator is related to the alterations occurring to natural physical processes, possibly due to the impact of anthropic activities, as well, but at higher scales. Indeed, changes in river and thus flood dynamics might be considerably influenced by the ongoing and progressively worsening environmental alterations worldwide (IPCC, 2014, 2018). Consequently, this might suggest that the local sustainability is indeed a multifaced issue and that local dynamics are affected by multi-scaled processes that need to be comprised even in local assessments.

8.1.3 Insights on local panarchy conditions

The previous analytical processes delivered a classification in terms of disaster resilience and of environmental sustainability of the Municipalities of the Marche Region. Nevertheless, the Social-Ecological Panarchy suggests that such *cores* should work in synergy in order to foster an integrated development of local communities. Consequently, as they equally represent a pivotal element for the survivability of Social-Ecological Systems, it might be interesting to combine the assessed levels of resilience and of sustainability in order to draw a more comprehensive representation of the status of the Municipalities of the Marche Region. In this case, the procedure aims at simply juxtaposing the two classifications: as mentioned, there is no evident reason to privilege one *core* over the other through weights and the combination should be as straight as possible in order to maintain all the collected and synthesised information (Table 8.3 and 8.4). Moreover, this process leads to the identification of the position of each Municipality within their own *adaptive cycle* (see Fig. 5.2). That is, this association further allows to visualise the condition of resilience and sustainability, and thus observe through the panarchy point of view the overall Regional territory (Fig. 8.7).

Table 8.3 — Level (high H, medium M, low L) of resilience (R) and of sustainability (S) of the Municipalities of the Marche Region.

MUNICIPALITY		LEVEL OF RESILIENCE	LEVEL OF SUSTAINABILITY
NAME	ID		
Acqualagna	41001	HR	HS
Apecchio	41002	HR	MS
Auditore	41003	MR	MS
Belforte all'Isauro	41005	MR	MS
Borgo Pace	41006	HR	MS
Cagli	41007	HR	MS
Cantiano	41008	LR	MS
Carpegna	41009	HR	MS
Cartoceto	41010	MR	LS
Fano	41013	HR	LS
Fermignano	41014	HR	HS
Fossombrone	41015	HR	MS
Fratte Rosa	41016	MR	HS
Frontino	41017	LR	MS
Frontone	41018	HR	MS
Gabicce Mare	41019	MR	HS
Gradara	41020	HR	LS
Isola del Piano	41021	HR	HS
Lunano	41022	HR	HS
Macerata Feltria	41023	MR	HS
Mercatello sul Metauro	41025	HR	MS
Mercatino Conca	41026	HR	MS
Mombaroccio	41027	MR	LS
Mondavio	41028	HR	HS
Mondolfo	41029	HR	LS

Montecalvo in Foglia	41030	HR	HS
Monte Cerignone	41031	HR	MS
Monteciccardo	41032	HR	HS
Montecopiolo	41033	HR	MS
Montefelcino	41034	HR	HS
Monte Grimano Terme	41035	MR	MS
Montelabbate	41036	HR	LS
Monte Porzio	41038	HR	HS
Peglio	41041	HR	HS
Pergola	41043	MR	MS
Pesaro	41044	HR	HS
Petriano	41045	HR	HS
Piandimeleto	41047	MR	MS
Pietrarubbia	41048	HR	HS
Piobbico	41049	MR	MS
San Costanzo	41051	MR	HS
San Lorenzo in Campo	41054	MR	LS
Sant'Angelo in Vado	41057	HR	HS
Sant'Ippolito	41058	MR	HS
Sassocorvaro	41059	MR	MS
Sassofeltrio	41060	HR	MS
Serra Sant'Abbondio	41061	HR	MS
Tavoleto	41064	MR	MS
Tavullia	41065	HR	LS
Urbania	41066	HR	MS
Urbino	41067	MR	MS
Vallefoglia	41068	HR	LS
Colli al Metauro	41069	HR	HS
Terre Roveresche	41070	MR	HS
Agugliano	42001	HR	HS
Ancona	42002	HR	HS
Arcevia	42003	MR	HS
Barbara	42004	HR	HS
Belvedere Ostrense	42005	HR	HS
Camerano	42006	HR	LS
Camerata Picena	42007	HR	LS
Castelbellino	42008	HR	LS
Castelfidardo	42010	HR	LS
Castelleone di Suasa	42011	HR	LS
Castelplanio	42012	HR	LS
Cerreto d'Esi	42013	MR	LS

Chiaravalle	42014	HR	LS
Corinaldo	42015	MR	HS
Cupramontana	42016	MR	MS
Fabriano	42017	MR	MS
Falconara Marittima	42018	MR	LS
Filottrano	42019	HR	HS
Genga	42020	LR	MS
Jesi	42021	HR	HS
Loreto	42022	HR	HS
Maiolati Spontini	42023	HR	LS
Mergo	42024	MR	MS
Monsano	42025	HR	HS
Montecarotto	42026	MR	HS
Montemarciano	42027	HR	HS
Monte Roberto	42029	HR	HS
Monte San Vito	42030	HR	HS
Morro d'Alba	42031	HR	HS
Numana	42032	HR	HS
Offagna	42033	HR	HS
Osimo	42034	HR	HS
Ostra	42035	LR	HS
Ostra Vetere	42036	MR	HS
Poggio San Marcello	42037	MR	HS
Polverigi	42038	HR	HS
Rosora	42040	MR	HS
San Marcello	42041	MR	HS
San Paolo di Jesi	42042	HR	HS
Santa Maria Nuova	42043	HR	HS
Sassoferrato	42044	MR	MS
Senigallia	42045	LR	HS
Serra de' Conti	42046	HR	HS
Serra San Quirico	42047	HR	MS
Sirolo	42048	HR	HS
Staffolo	42049	HR	HS
Trecastelli	42050	MR	HS
Apiro	43002	HR	MS
Appignano	43003	HR	HS
Belforte del Chienti	43004	HR	HS
Bolognola	43005	HR	HS
Caldarola	43006	MR	HS
Camerino	43007	MR	HS
Camporotondo di Fiastrone	43008	MR	HS
Castelraimondo	43009	MR	MS

Castelsantangelo sul Nera	43010	MR	HS
Cessapalombo	43011	MR	HS
Cingoli	43012	HR	HS
Civitanova Marche	43013	HR	HS
Colmurano	43014	MR	HS
Corridonia	43015	HR	HS
Esanatoglia	43016	MR	MS
Fiastra	43017	HR	HS
Fiuminata	43019	HR	MS
Gagliole	43020	HR	MS
Gualdo	43021	MR	HS
Loro Piceno	43022	HR	HS
Macerata	43023	MR	HS
Matelica	43024	HR	MS
Mogliano	43025	HR	HS
Montecassiano	43026	MR	HS
Monte Cavallo	43027	HR	HS
Montecosaro	43028	HR	LS
Montefano	43029	HR	HS
Montelupone	43030	HR	HS
Monte San Giusto	43031	MR	HS
Monte San Martino	43032	LR	HS
Morrovalle	43033	LR	HS
Muccia	43034	MR	HS
Penna San Giovanni	43035	MR	HS
Petriolo	43036	HR	HS
Pieve Torina	43038	MR	HS
Pioraco	43039	HR	HS
Poggio San Vicino	43040	MR	LS
Pollenza	43041	HR	HS
Porto Recanati	43042	HR	HS
Potenza Picena	43043	HR	HS
Recanati	43044	HR	HS
Ripe San Ginesio	43045	MR	HS
San Ginesio	43046	MR	MS
San Severino Marche	43047	HR	HS
Sant'Angelo in Pontano	43048	MR	HS
Sarnano	43049	MR	MS
Sefro	43050	MR	MS
Serrapetrona	43051	MR	HS
Serravalle di Chienti	43052	MR	MS

Tolentino	43053	MR	HS
Treia	43054	HR	HS
Urbisaglia	43055	MR	HS
Ussita	43056	MR	MS
Visso	43057	MR	MS
Valfornace	43058	LR	HS
Acquasanta Terme	44001	MR	MS
Acquaviva Picena	44002	HR	HS
Appignano del Tronto	44005	HR	HS
Arquata del Tronto	44006	MR	MS
Ascoli Piceno	44007	MR	HS
Carassai	44010	MR	HS
Castel di Lama	44011	HR	HS
Castignano	44012	MR	HS
Castorano	44013	HR	HS
Colli del Tronto	44014	HR	HS
Comunanza	44015	MR	HS
Cossignano	44016	MR	HS
Cupra Marittima	44017	HR	HS
Folignano	44020	HR	LS
Force	44021	MR	HS
Grottammare	44023	HR	HS
Maltignano	44027	MR	LS
Massignano	44029	MR	HS
Monsampolo del Tronto	44031	HR	LS
Montalto delle Marche	44032	MR	HS
Montedinove	44034	HR	HS
Montefiore dell'Aso	44036	HR	HS
Montegallo	44038	LR	MS
Montemonaco	44044	LR	MS
Monteprandone	44045	HR	LS
Offida	44054	HR	LS
Palmiano	44056	LR	HS
Ripatransone	44063	MR	HS
Roccafluvione	44064	MR	HS
Rotella	44065	LR	HS
San Benedetto del Tronto	44066	HR	HS
Spinetoli	44071	HR	LS
Venarotta	44073	HR	HS
Altidona	109001	HR	HS
Amandola	109002	MR	MS
Belmonte Piceno	109003	HR	HS
Campofilone	109004	HR	HS

Falerone	109005	HR	HS
Fermo	109006	HR	HS
Francavilla d'Ete	109007	HR	HS
Grottazzolina	109008	HR	HS
Lapedona	109009	HR	HS
Magliano di Tenna	109010	HR	HS
Massa Fermana	109011	MR	HS
Monsampietro Morico	109012	MR	HS
Montappone	109013	HR	HS
Montefalcone Appennino	109014	LR	HS
Montefortino	109015	MR	MS
Monte Giberto	109016	MR	HS
Montegiorgio	109017	HR	HS
Montegranaro	109018	MR	HS
Monteleone di Fermo	109019	HR	HS
Montelparo	109020	MR	HS
Monte Rinaldo	109021	HR	HS
Monterubbiano	109022	LR	HS
Monte San Pietrangeli	109023	MR	HS
Monte Urano	109024	MR	HS
Monte Vidon Combatte	109025	HR	HS
Monte Vidon Corrado	109026	HR	HS
Montottone	109027	MR	HS
Moresco	109028	HR	LS
Ortezzano	109029	HR	HS
Pedaso	109030	MR	LS
Petritoli	109031	HR	HS
Ponzano di Fermo	109032	HR	HS
Porto San Giorgio	109033	LR	HS
Porto Sant'Elpidio	109034	HR	HS
Rapagnano	109035	MR	HS
Santa Vittoria in Matenano	109036	HR	HS
Sant'Elpidio a Mare	109037	HR	HS
Servigliano	109038	MR	HS
Smerillo	109039	LR	HS
Torre San Patrizio	109040	MR	HS

Table 8.4 — Aggregation of municipalities based on their combined levels (high H, medium M, low L) of resilience (R) and sustainability (S), including the highlight of the cumulative presence in the fore-loop of the adaptive cycle.

NUMBER OF MUNICIPALITIES	COMBINED LEVEL OF RESILIENCE AND SUSTAINABILITY	SHARE OF THE MUNICIPALITIES
88	HR-HS	38.43%
18	HR-MS	7.86%
53	MR-HS	23.14%
159	*fore-loop*	69.43%
25	MR-MS	10.92%
8	MR-LS	3.49%
5	LR-MR	2.18%
0	LR-LS	0.00%
21	HR-LS	9.17%
11	LR-HS	4.80%

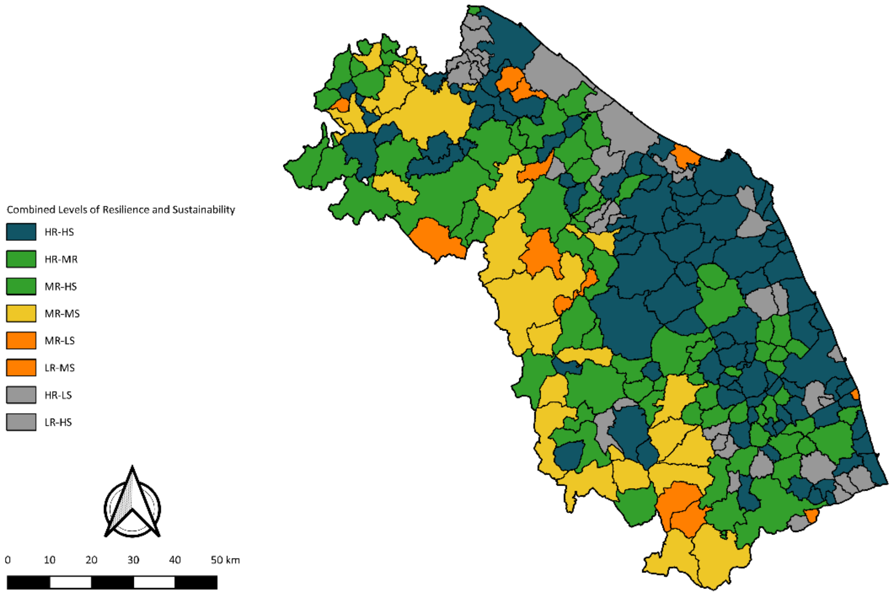


Figure 8.7 — Distribution of the combined levels (high H, medium M, low L) of resilience (R) and sustainability (S) among the Municipalities of the Marche Region.

The Municipalities of the Marche Region appear rather varied in their combined characteristics of resilience and sustainability, although it might be noteworthy that the worst combined level (LR-LS) remains unpopulated. In other words, within the present framework, all Municipalities were outside the *release phase*, hence there was no identified collapse for the time considered. Rather, the wider portion of the Municipalities resided within the *fore-loop* (69.43%), as the result of the three combined levels that enclose it (HR-HS 38.43%, HR-MR 7.86%, MR-HS 23.14%). In particular, the most desirable combined level was rather densely populated, accounting for the highest share of the Municipalities, thence delivering an encouraging perspective of the status of the Marche Region. Nevertheless, it might be relevant to observe how these Municipalities appear aggregated around a main nucleus in the central-eastern area of the Region, while extending with a scattered pattern southward. In general, the most desirable conditions are exhibited predominantly along the coastline, whereas the mountain and hill bands present an inhomogeneous composition. Similarly, most of the Municipalities that result locked in adverse traps are mainly condensed in the half part of the Region pointed towards the Adriatic Sea. As mentioned, such *traps* represent an overwhelming predominance of a *core* over the other. In other words, it embodies a case in which the enhancement of a resilient approach did not integrate an environmental sustainability perspective, or the opposite situation, where the management of environmental issues did not take into account resilience constraints. In a few words, it represents an unbalanced situation, towards either of the two extremes. Subsequently, in general terms, the coastal area shows a significant rate of Municipalities that achieved the highest performance in at least one of the two *cores*, thus suggesting that awareness and proactivity towards risk and environmental issues are commonly nurtured in the Marche Region. In particular, flood-related questions result more unsettling for the mountain-hill area rather than for the coasts. This might be due to the inherent deeper fragility of those territories, both from a physical, natural and a socio-economic standpoint. In general terms, Municipalities in the inner area of the Region might retain fewer assets, resources and capabilities to deal with complex threats and problems, while residing in an area that is especially susceptible to suffer from their impact. Indeed, the features that primarily led to this portrayal evidence that there a significant portion of land was transformed into built-up areas, although this did not translate in a sound economic picture, but rather in a fragile context. This fragility extended to the structural domain, where it was exposed by the higher request and acquirement of external funds to recover from the experienced damages, as well as to the environmental domain, in relation to the higher rate of endangered species, possibly a further cascading effect of the overall unstable conditions that significantly impact on the natural ecosystems. In terms of *adaptive cycles*, such Municipalities stand either in the segments surrounding the *release phase*, that is the most critical section of the *cycle*, or in the curve that attempts to move past it, towards a new development course. In other words, those areas lie in more unstable and potentially unpredictable conditions, that call for a focused support in order to foster their capabilities. Nevertheless, it should be borne in mind that this outcome comes from a comparative analytical procedure. That is, the above discussed Municipalities are in the less desirable conditions compared to the other Municipalities: that might not automatically mean that they are on the verge of a collapse in absolute terms. Rather, they reveal the most fragile areas of the Region, that might thus represent a priority when discussing where to place investments and resources. On the opposite side, the best performing Municipalities are relatively more stable and promising, being comparingly closer to the most lively and consolidating segments of the *cycle*, that is the *fore-loop*. Thence, they might represent a chance to comprehend the inner processes, with the aim of later adapting and implementing them in other areas. In other words, they might inspire an overall advancement of the conditions of resilience and sustainability of the Region. In this regard, the second phase of the analytical procedure might support the identification of the features that might be pivotal in boosting the overall conditions, through the evidence of the most significant characteristics to mould a resilient and sustainable behaviour. In particular, in this case the presence of female and elder population appears rather relevant, but while this feature is inherent and it cannot be influenced, further attention should be posed on the other pivotal factor, that is the engagement in associations. In this sense, encouraging the involvement of local communities in discussing, planning and managing local issues might strengthen social ties as well as raise the awareness on the critical questions, thus also enhancing a more comprehensive overall response capacity. At the same time, it appears fundamental to preserve natural habitats, especially forests and woods, and to limit the alterations of the natural environments, favouring lower-impact land use, as it might be agricultural activities compared to industrial settlements. Undoubtedly, environmental changes pose a threat not only on a global scale, but also at smaller scales, and their effects, such as the alteration of precipitation patterns and thence of river dynamics, might jeopardise local equilibria. As a consequence, local authorities should foster adaptation strategies, in order to strengthen the local capabilities to cope with these ongoing alterations, although mitigation of the human sources of change should be enhanced as well. It might be observed that these considerations stem from a conceptual and then analytical model that focused of flood risk. As a consequence, such suggestions should apply to this specific threat. Nevertheless, the implications appear to hold a more general validity: a sounder engagement of the local populations in the development of their communities might be pivotal to foster a more attentive awareness to any kind of potential issue, as well as a thorough management of local natural processes might represent an overall stabilising factor.

8.2 Hokkaidō

The 179 Municipalities that compose Hokkaidō (Table 6.7) were employed as the minimum geographical units so as to implement the outline methodology. In this case, the preliminary clustering of the Municipalities went through a series of tests in order to identify the most effective combination of indicators, one per each *attribute* of the *cores*, in defining groups of homogeneous attitudes towards risk and environmental issues. Then, the analytical procedure employed a discriminant analysis, aimed at revealing the characteristics of the Municipalities that moulded such behaviour, in terms of both resilience and sustainability, considering an assortment of characterising indicators.

8.2.1 First phase – classification

Resilience

Among the tested set of indicators, the preferred combination was especially relevant in terms of comparability among case studies, as it closely resembled the description adopted to assess the resilient behaviour of the Marche Region (Table 7.1 and 7.32). In this case, the cycle of iterations required a relatively long process to stabilise the position of the clusters (Table 7.44), although the differentiation remained evident throughout the process (Table 7.43 and 7.45), thence suggesting that it was possible to identify a significant difference among the Municipalities in terms of disaster behaviour. Such an outcome is especially appreciable, as it consolidates the subsequent attribution of the levels of resilience: the more differentiated are the cluster, the straighter is the allocation of the Municipalities. All the indicators resulted significant in determining the distribution of the Municipalities among the clusters, although their weights were not homogeneous. Indeed, the influence of flood damage resulted particularly significant, only followed by the variation in the economic welfare. The presence of human settlements within flooding areas appeared to hold a limited effect in differentiating among the groups, possibly because of enacted regulations or innate habits in land-use planning and management, that might have normalised this feature throughout the Prefectural territory, thus limiting its potential to distinguish different approaches. In any case, all indicators held a tangible differentiating power, thence the grouping might still be considered valid. As a consequence, at this point it might be possible to translate each cluster to a level of resilience. Here, the bar graph (Fig. 7.6) might results especially beneficial to interpret the meaning of the different position of the centroids in the space. In particular, it might be argued that a higher rate of exposed population should be associated to a lower level of resilience, since it would represent an inherent vulnerability of the community, that consequently might likely suffer from an adverse event. In other words, it would be related to a missed chance to learn from the previous or expected events, thence a lower resilient capacity. In a similar vein, a higher rate of damages might suggest that the flood event overwhelmed the local abilities to cope with it, thus significantly affecting the local communities. Eventually, the variation in the economic income might hint at the recovery process after the event and in particular the depth of those effects. Indeed, the more severe the consequences, the wider effort to respond and bounce back, thus revealing the communities that held sufficient assets to face the challenge. Observing the above-mentioned bar graph, it appears that cluster 1 represents the condition of higher exposition of population to flooding, the widest damages after the flood and a minor decline in the economic conditions. On the opposite side, cluster 3 suggests a situation where a limited portion of the population is exposed to floods, the amount of suffered damages was low as well, whereas the increase in income was rather significant. Compared to each other, cluster 1 might be associated to a level of low resilience (LR), while cluster 3 to a level of high resilience (HR). In the middle, cluster 2 exhibits a limited portion of exposed population and of suffered damages, though the economic welfare is not particularly encouraging. Consequently, also in light of the above associations, it appears reasonable to relate a medium level of resilience (MR) to cluster 2 (Fig. 8.8).

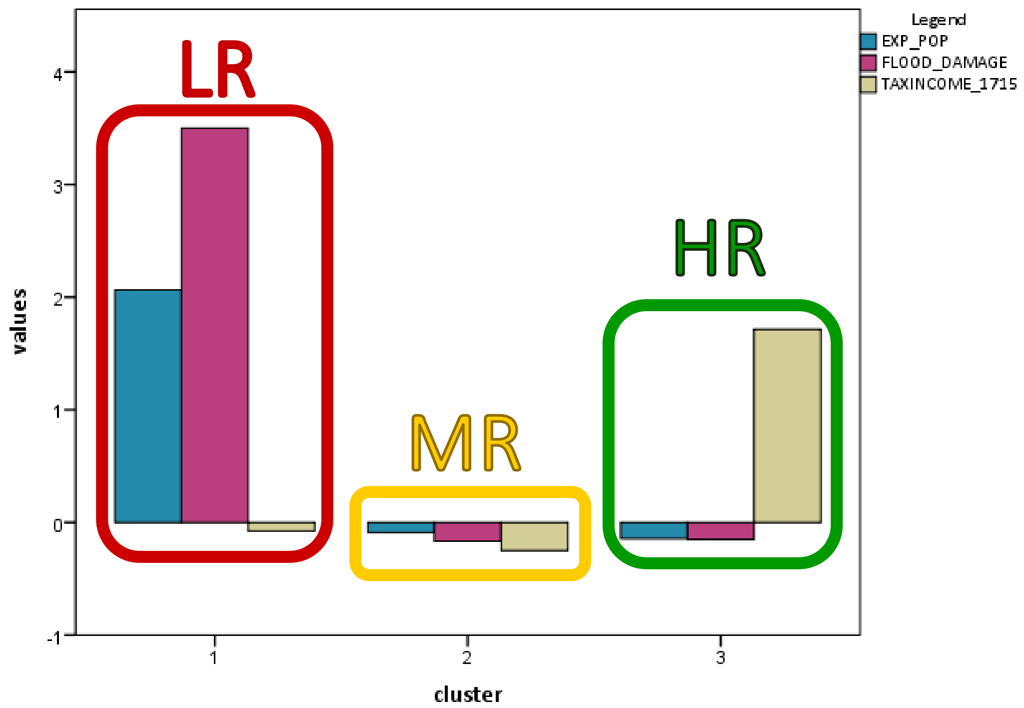


Figure 8.8 — Bar graph of the centroids per each cluster and each indicator, in terms of levels (high H, medium M, low L) of resilience (R).

As a consequence, it appears that a significantly limited share of the Municipalities (8 out of 179) exhibits a concerning condition in terms of resilient capacities, whereas most of the local communities (149 out of 179) shared relatively intermediate features, and some (22 out of 179) achieved the most desirable status (Table 8.5).

Table 8.5 — Distribution of the Municipalities of Hokkaidō between the clusters and the levels (high H, medium M, low L) of resilience (R).

CLUSTER	LEVEL OF RESILIENCE	NUMBER OF MUNICIPALITIES
1	LR	8 (4.47%)
2	MR	149 (83.24%)
3	HR	22 (12.29%)

Overall, the Municipalities of Hokkaidō appear rather homogenous in terms of disaster behaviour, exhibiting a similar performance that aggregates them in a comparatively balanced condition (83.24%) of neither *attribute* being fostered more than the others, though neither being particularly developed. Consequently, in relative terms, Hokkaidō does not appear to lie in alarming conditions, although some improvements might be encouraged. Nevertheless, the limited share of Municipalities (4.47%) that exhibits a low coping capacity should represent a priority of interest to enhance the overall resilience of the Prefecture. Thence, it might be interesting to identify the areas of the Prefectures where the most significant critical issues lie (Fig. 8.9). Nevertheless, also in this case it should be borne in mind that these considerations are valid in comparative terms, that is the attribution of the resilience level represents the relative behaviour of a Municipality compared to that of the other Municipalities of the Prefecture.

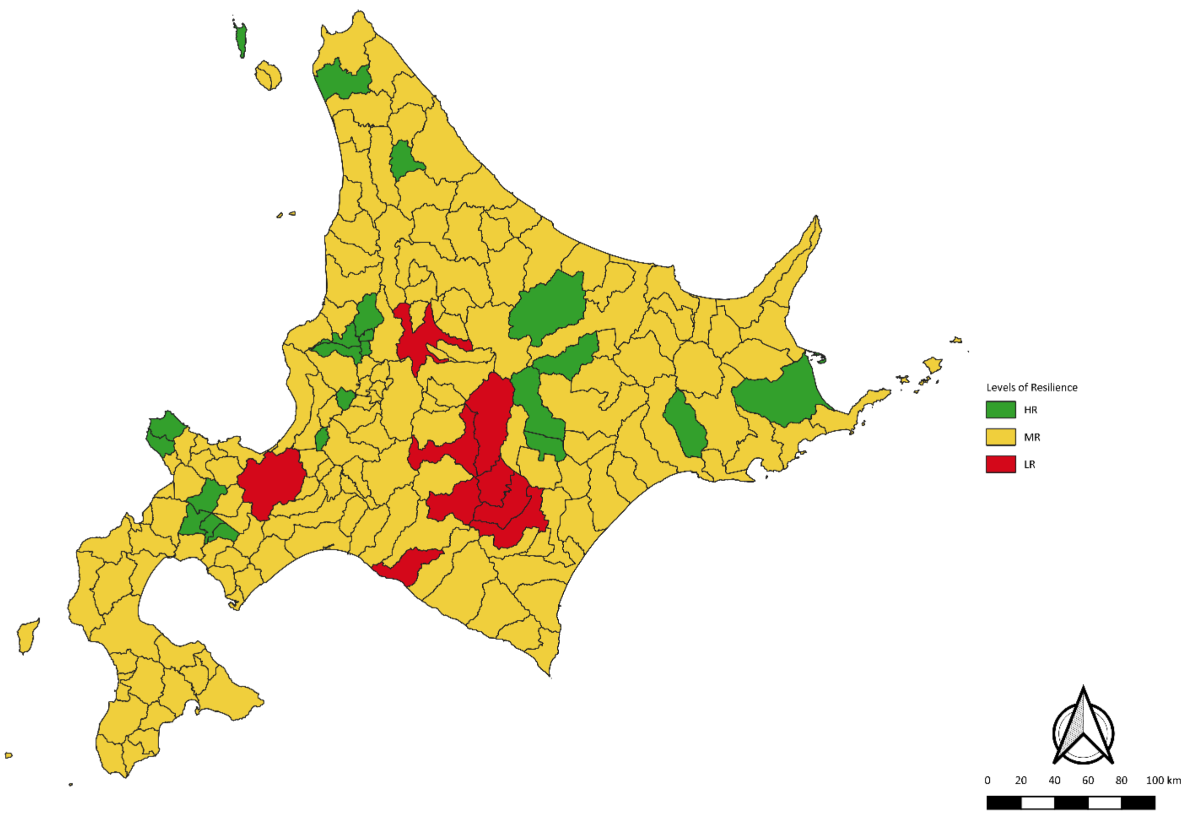


Figure 8.9 — Distribution of the levels (high H, medium M, low L) of resilience (R) among the Municipalities of Hokkaidō.

As previously mentioned, the distribution of the levels of resilience appears rather consistent throughout the Prefecture. The Municipalities that were associated with the most performing behaviour seems to be scattered over the territory and in some case aggregated in groups of 2 to 5 components. On the contrary, the more critical *units* seemed to be limited to some specific areas, forming a main group (6 out of 8 Municipalities: Hidaka-cho, Memuro-cho, Minamifurano-cho, Obihiro-shi, Shimizu-cho, Shintoku-cho) in the central part of the Prefecture, with two additional satellite *units* (Asahikawa-shi and Sapporo-shi) in the side facing the Sea of Japan. Such agglomerative behaviour might suggest that some specific local features might have introduced a significant factor of locality (Fig. 8.10).

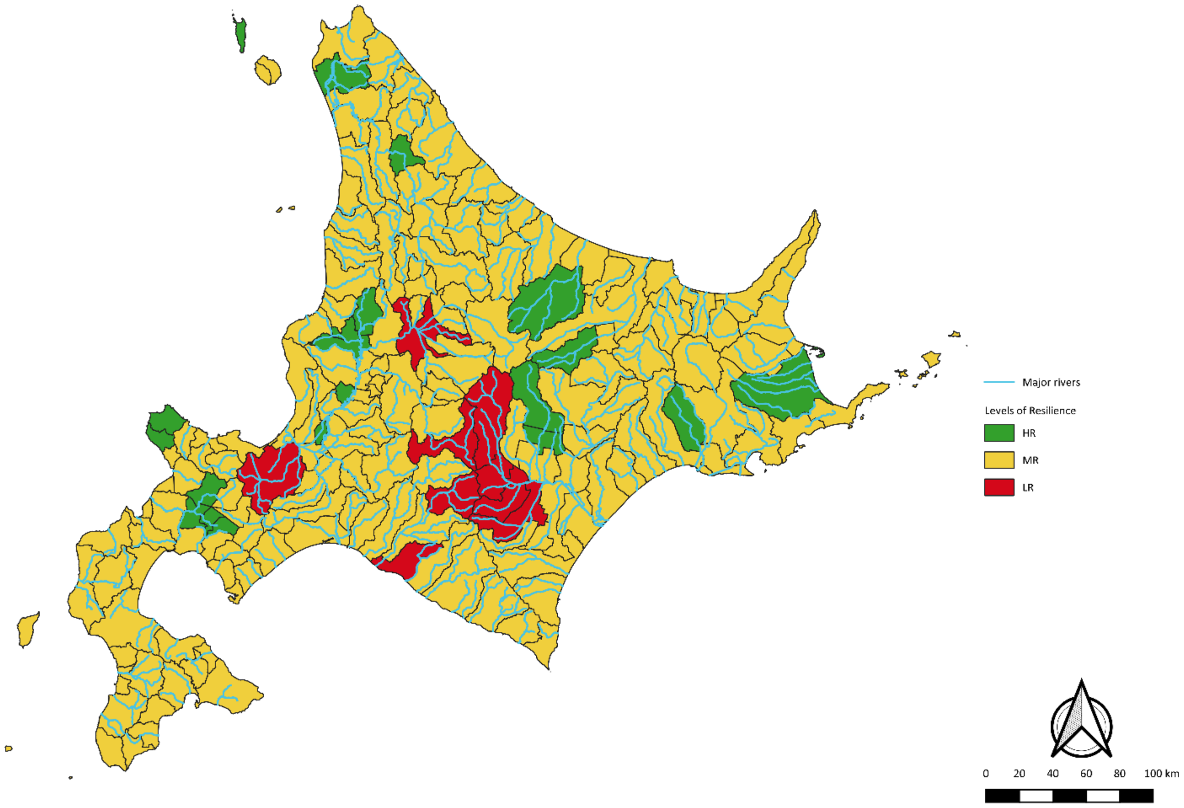


Figure 8.10 — Distribution of the levels (high H, medium M, low L) of resilience (R) and of the rivers of Hokkaidō.

Indeed, the cluster of Municipalities (Hidaka-cho, Memuro-cho, Minamifurano-cho, Obihiro-shi, Shimizu-cho, Shintoku-cho) that exhibit the most critical resilience capacities lie in the upstream area of the Tokachi river, whereas the other two (Asahikawa-shi and Sapporo-shi) stand alongside the Ishikari river, in the further upstream and the downstream of the river (respectively). In light of this observation and of the weight held by the indicator related to flood damages in determining the distribution of the Municipalities between the clusters, it might appear that the peculiarities of these rivers, and especially of the Tokachi river, might have played a significant role in influencing the resilience of those communities. Indeed, going back to the quantification of that indicator, it is possible to identify a correspondence with the Municipalities that reported the widest amount of damages after the flooding event and those grouped together upstream of the Tokachi river. In particular, the absolute amount of damages reached an order of magnitude higher than the second most affected group, where belongs Asahikawa-shi, for instance. This correspondence suggests that the Tokachi river basin, especially the innermost part, might be especially susceptible to suffer from extreme events, as indeed appears to have happened in 2016. Consequently, the Tokachi river basin might decidedly benefit from dedicated efforts to strengthen the local capabilities to cope with and manage a flood event. In more general terms, the magnitude of consequences endured after the 2016 event was pivotal in separating the Municipalities into two main behavioural groups, isolating those that were most vulnerable. Nevertheless, Sapporo-shi fall outside these boundaries, since the reported damages were not particularly high. Thence, a different factor from the consequences of the flood must have led to such an unfavourable association. Indeed, this Municipality exhibits the highest absolute rate of population exposed to flood hazard. In other words, for Sapporo-shi the feature determining its allocation in the lowest level of resilience was the potential damage, the missed chance to adapt the built areas to the natural dynamics, that is the inherent susceptibility, not the actual damages after the impacted flood. This might substantiate the relevant role played by a comprehensive planning and management of human landscapes in preventing disasters from occurring and impacting on human communities. This might also turn especially significant when large settlements are involved, places holding a tangible magnetism for long-term perspectives as well as for short-term visits, thus drawing a wide variety of people for personal capacities and vulnerabilities. As a consequence, such places should be subjected to a tailored strategy in order to allow every of their inhabitants and guests to be able to face the challenges that they comprise along with the opportunities that they provide.

Sustainability

Similarly to the previous cases, a set of indicators were available to describe the sustainability *core* (Table 7.48*)*, although the metrics of the selected combination eventually exhibited a rather consistent performance, as few iterations (Table 7.55) were necessary to stabilise the position of the centroids, that indeed maintained unaltered their initial evident differentiation in the ideal space (Table 7.54 and 7.56). Consequently, also in this case the subsequent distribution of the Municipalities between the clusters might be assumed as reliable, since the differences among the groupings were that evident since the beginning. In particular, indicators were related to absolute rather than relative values, thus probably supporting the differentiating potential of the combination. In any case, all indicators were statistically significant to the analytical process and were associated to comparable weights, although the indicator related to the distribution of alien species resulted slightly more powerful than the others in separating the clusters (Table 7.57). Likewise the stability of the centroids, such homogenous distribution of the differentiating potential might suggest that the implemented metrics were equally significant, thence held a unique and irreplaceable meaning in terms of environmental sustainability. Nevertheless, it might be interesting to note that even with a limited advantage, the first indicator for relevance concerned the presence of the raccoon (浣熊 *araiguma*). In other words, the most influencing factor embodied the direct impact on natural equilibria that the pressure to gratify human delight might cause, when mass attention rises as a trending wave and then dissipates when the expectations are not met or the momentaneous interest fades away. Such a dynamic probably occurred in the raccoon case, as a trivial trend prompted by a movie focused the mass interest on this wild alien species, and when the unsuitability for the family life emerged along with the shift of the attention towards the following trending theme, the animals were released in the local habitats, hampering the stability of the complex ecosystems. This consideration provides a first key to read the clusters in terms of levels of sustainability. In a few words, it might be reasonably assumed that the wider a territory is colonised by an alien species that competes with the local ones, and the lower the inherent vigour of the local ecosystem, thence the lower the sustainability of the local human community. Similarly, the more extensively the vegetation is negatively affected, and the less the ecosystems are able to deliver their services. Consequently, this trend might be translated into a lower level of sustainability of the human system that has induced such an alteration. Eventually, the presence of infrastructures related to the power supply system might be considered as a negative impact, thus contributing to lower the overall level of sustainability, given the inevitable modification of local features in order to transform natural dynamics into energy for anthropic purposes. These keys of interpretation might be applied to the bar graph (Fig. 7.8), in order to eventually identify the levels of sustainability between the outlined clusters. In this case, cluster 1 represents a situation where the amount of altered vegetation is comparably extensive as well as the presence of the *araiguma* in the area, although the number of establishments related to the power supply system is lower. On the other side, cluster 3 suggests a significant alteration of the local vegetation and presence of power supply establishments, whereas the *araiguma* has a limited spread over the area. Eventually, cluster 2 embodies the most consistent conditions: the altered vegetation as well as the presence of power supply establishments and of *araiguma* specimens all show a descending trend. While cluster 3 might be the most immediate to be associated with a corresponding level of sustainability, in particular the highest level (HS), as it embodies the most desirable conditions where the anthropic impact on natural ecosystems is limited, the matter might turn to be relatively more debatable for the other two clusters. In this case, the weight associated to the indicators might come to facilitate the process. Indeed, the differentiating power of the *araiguma*-related metric appeared more solid than that of the power supply establishments (Table 7.57). Consequently, the low level of sustainability (LS) might be associated to cluster 1, while the medium level (MS) might be assigned to cluster 3 (Fig. 8.11).

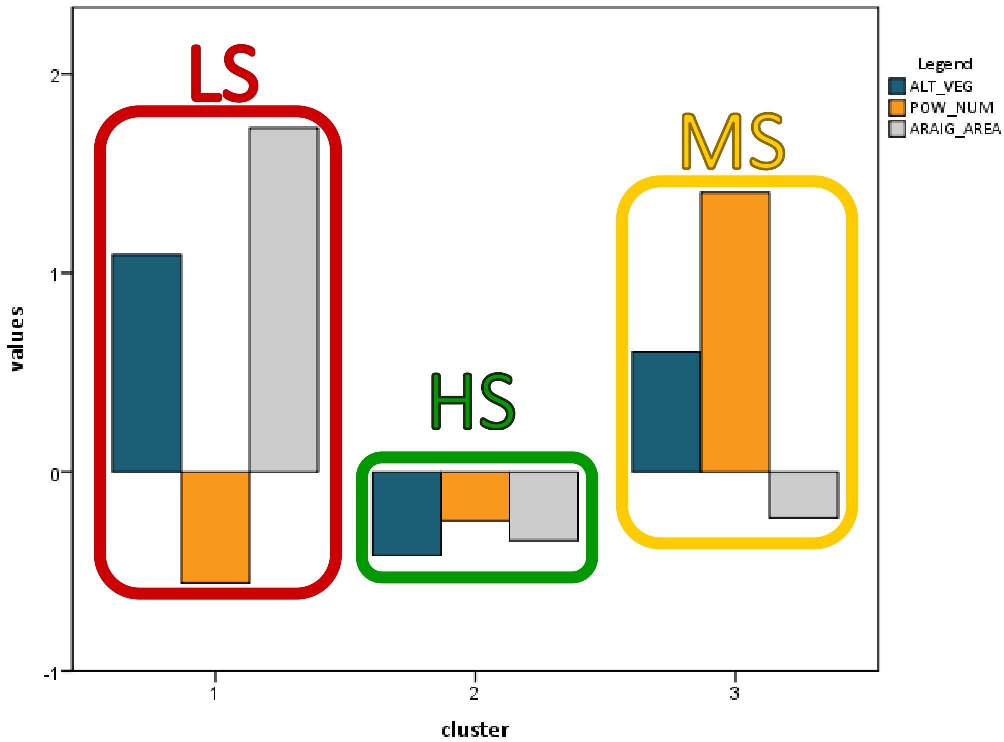


Figure 8.11 — Bar graph of the centroids per each cluster and each indicator, in terms of levels (high H, medium M, low L) sustainability (S).

In light of this interpretation, it appears that a high share of the Municipalities has a rather sound relation with the natural environment of Hokkaidō (119 out of 179), while the remaining Municipalities are almost equally distributed between a balanced (32 out of 179 Municipalities) and a critical (28 out of 179) interaction with the local ecosystems (Table 8.6).

Table 8.6 — Distribution of the Municipalities of Hokkaidō between the clusters and the levels (high H, medium M, low L) sustainability (S).

CLUSTER	LEVEL OF RESILIENCE	NUMBER OF MUNICIPALITIES
1	LS	28 (15.64%)
2	HS	119 (66.48%)
3	MS	32 (17.88%)

The overall environmental sustainability of Hokkaidō seems quite consolidated, as the wide majority of the Municipalities achieved the most desirable conditions (66.48%) and only a limited fraction exhibits a more concerning approach (15.64%). Although such classification remains valid only in relative terms, it might still be interesting to identify which areas of Hokkaidō present the most significant challenges to improve the local interactions with the natural ecosystems (Fig. 8.12).

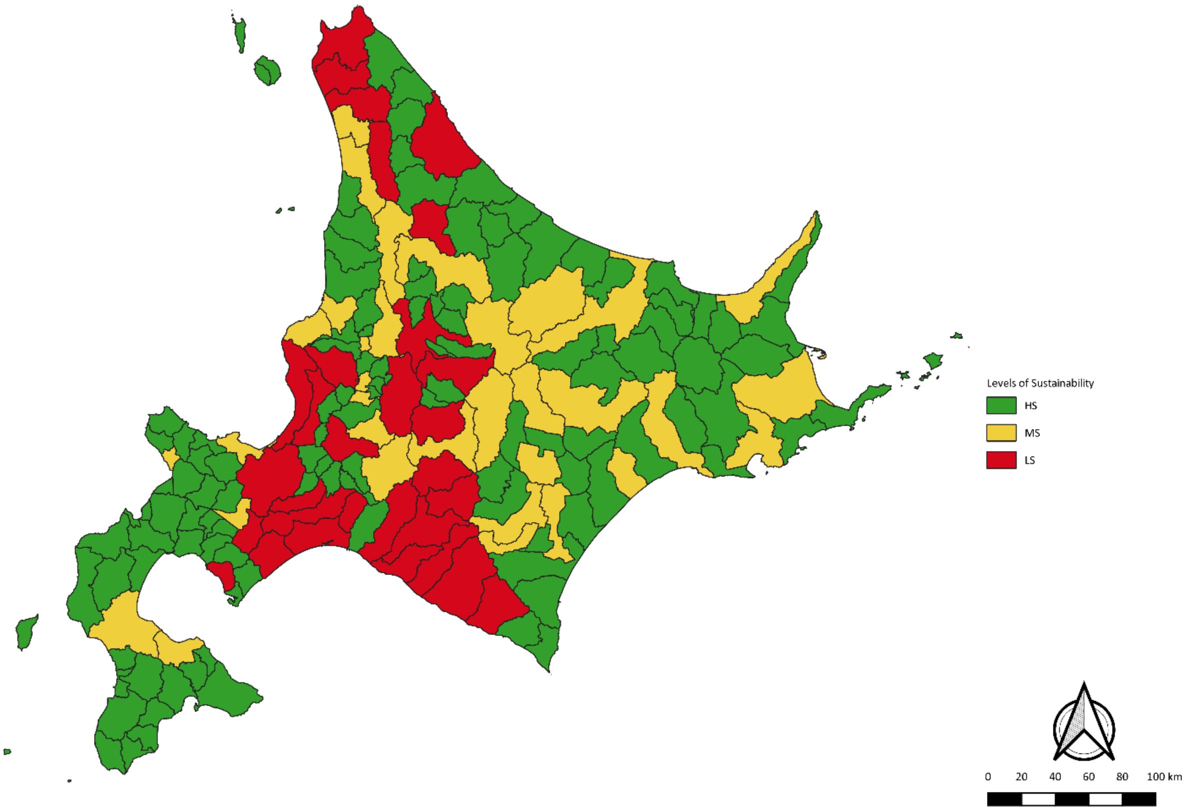


Figure 8.12 — Distribution of the levels (high H, medium M, low L) and sustainability (S) among the Municipalities of Hokkaidō.

Observing the distribution of the levels of sustainability throughout the territory of the Prefecture, it appears that a central, vertical band gathers the lowest levels and expands towards the eastern side through the (majority of the) medium levels. In other words, it seems almost as if these Municipalities were connected through a pattern that involves the central part of the island, further extending northwards and eastwards. Consequently, it might be relevant to investigate the possible underlying causes of such a common behaviour, that might be identified in either topographical or social features (Fig. 8.13).

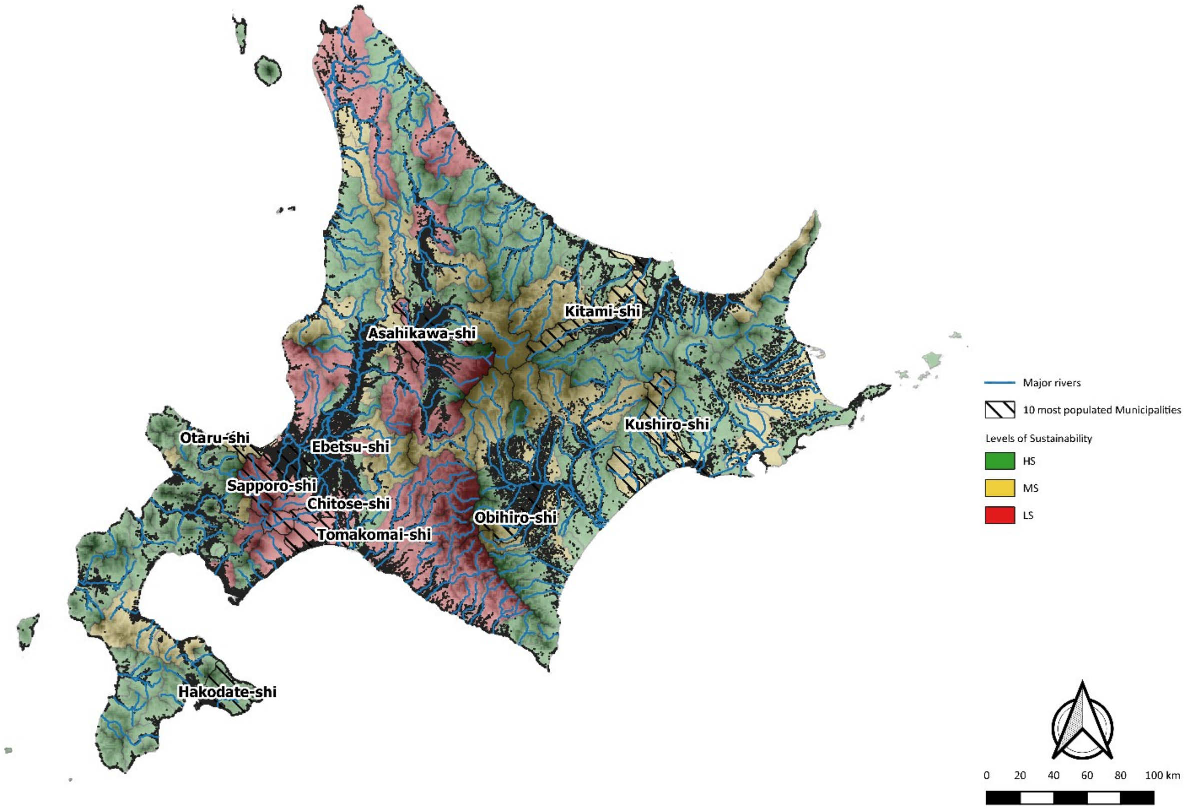


Figure 8.13 — Distribution of the levels (high H, medium M, low L) of sustainability (S) and morphological features among the Municipalities of Hokkaidō.

Taking a closer look to the specific characteristics of sustainability within Hokkaidō, it is possible to tentatively identify a major factor that catalyses the behaviour towards the most critical end, that is the attraction exerted by some of the most important Municipalities of the Prefecture. Indeed, most of the lowest Levels are associated to the area surrounding Sapporo-shi and extending towards Chitose-shi and Tomakomai-shi, whereas a second visible cluster revolves around Asahikawa-shi. In these cases, the topographical and the social features might result simultaneously significant, as the presence of a fluvial plain typically corresponds to a concentration of people, infrastructures and assets. It might be notable to mention that both these clusters pertain to the Ishikari river system, although involving the final and the initial section of the river basin, respectively. It might be also relevant to observe how the Chitose-shi and Tomakomai-shi section are not related to the Ishikari river: however, the absence of significant natural barriers, such as high mountains, might have reinforced the effect of the social factor in terms of population distribution and thence of related pressure on the environment. In addition, among the 10 most populated Municipalities (Sapporo-shi, Hakodate-shi, Otaru-shi, Asahikawa-shi, Kushiro-shi, Obihiro-shi, Kitami-shi, Tomakomai-shi, Ebetsu-shi, Chitose-shi) the absolute majority shows medium to low levels of sustainability, thus reinforcing the suggestion that the resources and potential available to larger administrative units to improve their coexistence with the surrounding environment might not be sufficient to compensate the inevitable impacts of anthropic settlements. In particular, coming back to the metrics that led to such classification, it might be interesting to investigate what determined the allocation to the different levels of the 10 most populated Municipalities. It emerges that, especially concerning the extremes, they do not exhibit an overall strongly polarised behaviour, but rather the picture is blurred and the prevalence of a feature over the others often moved the allocation towards a level instead on an other. In other words, for instance, the association to the lowest level was not determined by an unambiguous common tendency towards the least desirable values of the employed indicators, but rather by a significantly low performance in a specific domain. The case of Sapporo-shi is indicative in this sense: the number of establishments referring to the power supply system appeared unaltered and the effects of the vegetation are rather significant, even though they do not achieve the higher end; yet, the wide spread of the *araiguma* raccoon might have forced the Municipality to fall within the cluster of the low level of sustainability. Indeed, this indicator showed one of the highest values for this indicator (see Appendix II), thus confirming the potentially prominent role played by the invasion of alien species in determining the sustainability of a community. In this case the role of humans and of their desires heavily impacted the integrity of the area: it might be worthy to remind the peculiar dynamics that led to the diffusion of this alien raccoon, that is a passing fancy after the release of a movie. In this case, the critical point might lie in a sounder awareness of environmental issues and of the potential impacts of human activities on the equilibria of natural ecosystems in the long term. Indeed, the awareness of the consequences of human actions might prevent inappropriate behaviour, such as the import and release of species that might jeopardise and destroy the local landscapes as they are recognised by their inhabitants, as well as causing further impacts on the local economy, especially those related to the ecosystems services and functions, such as agricultural industries. On the opposite side of Sapporo-shi lie Hakodate-shi and Ebetsu-shi. In this case, the belonging to the highest level of sustainability is not determined by a general convergence towards the most desirable values of the adopted indicators, but rather by an particularly encouraging performance in a domain that compensates for a less desirable condition in an other domain. In both cases such alternation refers to the indicators of altered vegetation and *araiguma* raccoon distribution, as the presence of the power supply establishments did not exhibit variations nor was particularly significant in either case. For Hakodate-shi, the (relatively) critical issue concerned the extension of the impact on the vegetation, with the value not extremely high, but still comparable to those otherwise attributed to medium levels of sustainability. Nonetheless, the Municipality did not report the presence of *araiguma* specimens in its territory, hence suggesting a sounder integrity of the local ecosystem functions and services, at least with regards to this potential ecological stressor. Consequently, the overall performance of the Municipality resulted as the most desirable, as detrimental drivers of pressure appeared rather limited and contained within this community. Similarly (but in the opposite sense), Ebetsu-shi displays a presence of alien racoon not alarming, though significant enough to pertain to the higher end of the possible values. At the same time, a lower impact on the local vegetation seems to compensate for that ecological stressor, alleviating the pressure on the local ecosystems. As a consequence, also in this case the condition appears overall balanced and suggests a stronger interconnection with the natural environment compared to other cases, especially among the most populated Municipalities. Until this point, the discussion involved the Municipalities that exhibited a strong relation between the lower levels of sustainability and the social and topographical features of their territories. However, not all clusters of criticalities completely responded to this observed portrayal. In particular, two additional groups of Municipalities, associated by the low level of sustainability, resulted excluded. One of these groups lied in the northern side of the island (Wakkanai-shi, Nakagawa-cho, Toyotomi-cho, Horonobe-cho) and the other lied in the central-south area (Shimukappu-mura, Mukawa-cho, Hidaka-cho, Biratori-cho, Niikappu-cho, Urakawa-cho, Shinhidaka-cho). As mentioned, these cases are physically separated from the other dominant groups, pertain to different river basins and do not show a particularly high presence of population. Thence, it might be interesting to investigate the reasons behind the apparently low performance of these Municipalities. In these cases, the number of power supply establishments was substantially homogeneous among all the Municipalities and similar to the values of the other clusters of low sustainability. The other indicators (altered vegetation and distribution of the *araiguma* raccoon) varied more evidently, although the values always tended to the least desirable end, especially for one of the metrics when the other was less concerning. In other words, these two additional clusters of low sustainability were characterised by a generalised trend towards a significant impact on the natural ecosystems, in terms of induced changes to the equilibria of the vegetation or the introduction of alien species, or both. It might be interesting to bear in mind that these areas do not show a particularly significant human presence: the two most populated Municipalities (Wakkanai-shi and Shinhida-cho) respectively host about 1/50 and 1/78 of Sapporo's population (most populated Municipality, assigned a low level of sustainability), and at the same they host 1/7 and 1/11, respectively, of Hakodate's population (third most populated Municipality, assigned a high level of sustainability). As a consequence, it might be suggested that such impacts might not be attributed to the additive effects of an extended anthropic network, but rather to the intense impact of a restricted community. If that was the case, in these areas the enhancement of strategies to raise environmental awareness and the endorsement of an attentive management of natural resources might turn especially beneficial to improve the local relation with the local ecosystems in order to influence the behaviour and actions of those communities.

8.2.2 Second phase – characterisation

Resilience

The second phase of the analytical process came back once more to the selection of indicators and in particular of the most performing combination of indicators that could allow the peculiarities of the Municipalities to surface (Table 7.66). Given the statistical consistency of the combination, this case was particularly interesting because of the rather high discriminant potential that could be estimated (Table 7.71 and 7.72). Indeed, the combination appeared to be able to explain about the 81.4% of the variation among the clusters. This results especially encouraging in terms of reliability of the integrative function and on the choice of the adopted metrics. In other words, the significant potential of the combination seem to suggest that the indicators included in the assessment were the proper ones to catch the most significant features of the Municipalities, and in particular those that effectively influence the resilient behaviour and thence represent a factor of difference among the Municipalities. In this sense, it might be noteworthy that the efficiency increased sensibly with the adoption of relative rather than absolute metrics. It might appear as if the shift towards relative values amplified the differentiating potential of the combination. This is actually coherent with the conceptual meaning of those metrics: the reduction of the measures to the same unit of reference (e.g. person, 1000 people) is meant to eliminate the disturbance that could be exerted by the different dimensions of the Municipalities. In addition, when testing the actual accuracy of its predictive potential, the discriminant function delivered a remarkable outcome: although limited by a severe lack of information concerning one indicator, the function demonstrated able always to assign the same cluster that was identified by the previous cluster analysis to the Municipalities. Thence, this appears as an additional confirmation of the reliability of the selected combination. As a consequence, it might turn especially informative to investigate which indicators contributed the most to such a discriminating potential. Also in this domain, it was possible to observe a rather peculiar outcome. Indeed, some indicators emerged as undoubtedly dominating the influence on the overall differentiating potential of the function: the investment in social welfare and the presence of doctors in medical facilities appeared as pivotal to identify the different clusters of resilience capacities, followed only at a sensible distance by the funds provided to the firefighting corps. In other words, the differences in disaster behaviour of the Municipalities seemingly depended mostly on the extension and solidity of the social and health care network. Indeed, in general terms, the presence of an extensive welfare system might be illustrative of an attentive care devoted to the most fragile persons, and thence it might demonstrate a proactive awareness towards the reduction of the factors of vulnerability. This approach might be complemented by the implementation of a solid first-response system, exemplified by the public support to the firefighting corps. In a more general perspective, reducing susceptibility while enhancing an effective emergency response might reasonably represent an efficient strategy to strengthen resilience capacities. As a final note, it might be interesting to observe how the demographic features (e.g. age, gender, immigrants) that are usually addressed as the main factors influencing the resilience of a community did not particularly contribute to the discrimination among the different levels of resilience, in this case. This might be due to the overall homogeneity of the Municipalities, that blurred the picture. In this case, a "traditional" assessment of resilience might have delivered an homogeneous outcome as well, whereas the introduction of indicators referring to a wider range of domains as well as the analytical identification of the relative weights might have proved beneficial for the emergence of the local peculiar features, in terms of both strengths and weaknesses when characterising the resilience behaviour.

Sustainability

In this case, the choice among the tested combinations was guided by the overall better performance exhibited by one of the options. In particular, the canonical correlation resulted the highest, although it was not particularly relevant in terms of differentiating potential (about 35.3%). This might suggest that this process might especially benefit from a broadening in the set of indicators. In particular, inclusion of metrics referring to a wider range of domains should be encouraged the, in order to capture those features that mark the most evident differences in terms of sustainable behaviour among the Municipalities. This enhancement might be particularly significant, also in light of the limited number of indicators that could be included in the present case due to the difficulties in retrieving pertinent information. Nevertheless, when comparing the predicted clusters by the discriminant function to those assigned by the cluster analysis, it was possible to observe a rather valuable outcome, as the wide majority of the Municipalities (70%) were associated to the same level of sustainability. Consequently, although the performance is already rather appreciable, it appears that the above-mentioned improvement of the combination of indicators might indeed strengthen the accuracy of the discriminant function. In this way, the monitoring tool available for this case study would be particularly reliable, especially when combined with the resilience function. In any case, it might be interesting to investigate which features were the most effective in drawing the differences among the Municipalities. It appears that the role of the vegetation is pivotal in this case, in terms of both woods and grassland, natural and farmed. In addition, it might be relevant to bear in mind that the general performance of the function increased especially when forests and grasslands were considered as separated metrics. Overall, the fact that the highest discriminating power was held by this kind of indicators might be especially significant for Hokkaidō, a Prefecture renowned for its natural landscapes and relying on agricultural activities. In other words, it was possible to draw the most evident difference among the Municipalities through the extension of the vegetable area in a human setting already tightly interlaced with the natural ecosystems. Consequently, it appears reasonable that the alterations induced to the natural environment signal more than other features a substantially different approach towards the ecosystems. That is, in a setting generally characterised by a sort of symbiosis between human activities and ecosystem functions, a deviation from this general trend represents an evident dissonance. In this sense, the monitoring of the sustainable development of local communities might be especially relevant for the Social-Ecological System of Hokkaidō, where the interdependence of the human and natural components is so evident. Nevertheless, in this case it would be especially significant not only to enhance the accuracy and reliability of the predictive function, but also to complete the collection of data. Indeed, in this case the application of this tool was hampered by some missing information that prevented the function to be employed, thence the level of sustainability to be predicted for some Municipalities. This is a critical issue for the effective applicability of this kind of tool. As mentioned, one of the possible employments relates to the monitoring of the local path of sustainable development: if the present conditions persisted, this process would be hindered, since the assessment would not be able to encompass all the Municipalities. Consequently, along with the inclusion of a wider set of indicators, it might be relevant to enhance the available information of those already selected, or in turn replace them with others owning a similar meaning, but with a denser dataset (and thence verifying once again the overall reliability of the predicted levels of sustainability).

8.2.3 Insights on local panarchy conditions

Once the assessment procedure was completed for both resilience and sustainability *cores*, the Municipalities of Hokkaidō resulted associated to the related levels. At this point, it might be interesting to proceed through the investigation towards the identification of the combined level of disaster resilience and environmental sustainability. Indeed, as previously mentioned, each *core* represents only one facet of the comprehensive status of the Municipality and more in general of the Social-Ecological System. Hence, it is necessary to juxtapose the assigned levels in order to re-compose the complex picture while maintaining the equal relevance of the two *cores* (Table 8.7 and 8.8). Later, it is possible to visualise once more the Municipalities (Fig. 8.13), but in this case interpreting their status in terms of their position in the respective *adaptive cycle* (see Fig. 5.2), thence eventually portraying the status of Hokkaidō through the semantics of the panarchy metaphor.

Table 8.7 — Level (high H, medium M, low L) of resilience (R) and of sustainability (S) of the Municipalities of the Hokkaidō.

MUNICIPALITY		LEVEL OF RESILIENCE	LEVEL OF SUSTAINABILITY
RŌMAJI	ID		
Sapporo-shi	1100	LR	LS
Hakodate-shi	1202	MR	HS
Otaru-shi	1203	MR	MS
Asahikawa-shi	1204	LR	LS
Muroran-shi	1205	MR	HS
Kushiro-shi	1206	MR	MS
Obihiro-shi	1207	LR	MS
Kitami-shi	1208	MR	MS
Yubari-shi	1209	MR	MS
Iwamizawa-shi	1210	MR	LS
Abashiri-shi	1211	MR	HS
Rumoi-shi	1212	MR	MS
Tomakomai-shi	1213	MR	LS
Wakkanai-shi	1214	MR	LS
Bibai-shi	1215	MR	HS
Ashibetsu-shi	1216	MR	LS
Ebetsu-shi	1217	MR	HS
Akabira-shi	1218	MR	HS
Monbetsu-shi	1219	MR	HS
Shibetsu-shi	1220	MR	MS
Nayoro-shi	1221	MR	LS
Mikasa-shi	1222	MR	MS
Nemuro-shi	1223	MR	HS
Chitose-shi	1224	MR	LS
Takikawa-shi	1225	MR	HS
Sunagawa-shi	1226	MR	MS
Utashinai-shi	1227	MR	HS
Fukagawa-shi	1228	MR	MS
Furano-shi	1229	MR	LS
Noboribetsu-shi	1230	MR	HS
Eniwa-shi	1231	MR	LS
Date-shi	1233	MR	LS
Kitahiroshima-shi	1234	MR	HS
Ishikari-shi	1235	MR	LS
Hokuto-shi	1236	MR	HS
Tobetsu-cho	1303	MR	LS
Shinshinotsu-mura	1304	HR	HS
Matsumae-cho	1331	MR	HS
Fukushima-cho	1332	MR	HS
Shiriuchi-cho	1333	MR	HS
Kikonai-cho	1334	MR	HS
Nanae-cho	1337	MR	HS
Shikabe-cho	1343	MR	HS
Mori-machi	1345	MR	MS
Yakumo-cho	1346	MR	MS
Oshamambe-cho	1347	MR	HS
Esashi-cho	1361	MR	HS
Kaminokuni-cho	1362	MR	HS
Assabu-cho	1363	MR	HS
Otobe-cho	1364	MR	HS
Okushiri-cho	1367	MR	HS
Imakane-cho	1370	MR	HS
Setana-cho	1371	MR	HS
Shimamaki-mura	1391	MR	HS
Suttsu-cho	1392	MR	HS
Kuromatsunai-cho	1393	MR	HS
Rankoshi-cho	1394	MR	HS
Niseko-cho	1395	HR	HS
Makkari-mura	1396	HR	HS
Rusutsu-mura	1397	HR	HS
Kimobetsu-cho	1398	MR	MS
Kyogoku-cho	1399	MR	HS
Kutchan-cho	1400	HR	HS
Kyowa-cho	1401	MR	HS
Iwanai-cho	1402	MR	HS
Tomari-mura	1403	MR	MS

Kamoenai-mura	1404	HR	HS
Shakotan-cho	1405	HR	HS
Furubira-cho	1406	MR	HS
Niki-cho	1407	MR	HS
Yoichi-cho	1408	MR	HS
Akaigawa-mura	1409	MR	HS
Nanporo-cho	1423	MR	HS
Naie-cho	1424	MR	MS
Kamisunagawa-cho	1425	MR	HS
Yuni-cho	1427	MR	HS
Naganuma-cho	1428	MR	HS
Kuriyama-cho	1429	MR	HS
Tsukigata-cho	1430	MR	HS
Urausu-cho	1431	HR	HS
Shintotsukawa-cho	1432	MR	LS
Moseushi-cho	1433	HR	MS
Chippubetsu-cho	1434	HR	HS
Uryu-cho	1436	HR	HS
Hokuryu-cho	1437	HR	HS
Numata-cho	1438	HR	HS
Takasu-cho	1452	MR	HS
Higashikagura-cho	1453	MR	HS
Tohma-cho	1454	MR	HS
Pippu-cho	1455	MR	HS
Aibetsu-cho	1456	MR	HS
Kamikawa-cho	1457	MR	MS
Higashikawa-cho	1458	MR	HS
Biei-cho	1459	MR	LS
Kamifurano-cho	1460	MR	HS
Nakafurano-cho	1461	MR	HS
Minamifurano-cho	1462	LR	MS
Shimukappu-mura	1463	MR	LS
Wassamu-cho	1464	MR	HS
Kenbuchi-cho	1465	MR	HS
Shimokawa-cho	1468	MR	HS
Bifuka-cho	1469	MR	HS
Otoineppu-mura	1470	HR	HS
Nakagawa-cho	1471	MR	LS
Horokanai-cho	1472	MR	MS
Mashike-cho	1481	MR	MS
Obira-cho	1482	MR	HS
Tomamae-cho	1483	MR	HS
Haboro-cho	1484	MR	HS
Shosambetsu-mura	1485	MR	HS
Enbetsu-cho	1486	MR	MS
Teshio-cho	1487	MR	MS
Sarufutsu-mura	1511	MR	HS

Hamatombetsu-cho	1512	MR	HS
Nakatombetsu-cho	1513	MR	HS
Esashi-cho	1514	MR	LS
Toyotomi-cho	1516	HR	LS
Rebun-cho	1517	HR	HS
Rishiri-cho	1518	MR	HS
Rishirifuji-cho	1519	MR	HS
Horonobe-cho	1520	MR	LS
Bihoro-cho	1543	MR	HS
Tsubetsu-cho	1544	MR	HS
Shari-cho	1545	MR	MS
Kiyosato-cho	1546	MR	HS
Koshimizu-cho	1547	MR	HS
Kunneppu-cho	1549	MR	HS
Oketo-cho	1550	HR	HS
Saroma-cho	1552	MR	HS
Engaru-cho	1555	HR	MS
Yubetsu-cho	1559	MR	HS
Takinoue-cho	1560	MR	HS
Okoppe-cho	1561	MR	HS
Nishiokoppe-mura	1562	MR	HS
Omu-cho	1563	MR	HS
Ozora-cho	1564	MR	HS
Toyoura-cho	1571	MR	HS
Sobetsu-cho	1575	MR	HS
Shiraoi-cho	1578	MR	LS
Atsuma-cho	1581	MR	HS
Toyako-cho	1584	MR	HS
Abira-cho	1585	MR	LS
Mukawa-cho	1586	MR	LS
Hidaka-cho	1601	LR	LS
Biratori-cho	1602	MR	LS
Niikappu-cho	1604	MR	LS
Urakawa-cho	1607	MR	LS
Samani-cho	1608	MR	HS
Erimo-cho	1609	MR	HS
Shinhidaka-cho	1610	MR	LS
Otofuke-cho	1631	MR	MS
Shihoro-cho	1632	HR	HS
Kamishihoro-cho	1633	HR	MS
Shikaoi-cho	1634	MR	HS
Shintoku-cho	1635	LR	MS
Shimizu-cho	1636	LR	HS
Memuro-cho	1637	LR	HS
Nakasatsunai-mura	1638	MR	MS
Sarabetsu-mura	1639	MR	HS
Taiki-cho	1641	MR	HS

Hiroo-cho	1642	MR	HS
Makubetsu-cho	1643	MR	MS
Ikeda-cho	1644	MR	HS
Toyokoro-cho	1645	MR	HS
Honbetsu-cho	1646	MR	HS
Ashoro-cho	1647	MR	MS
Rikubetsu-cho	1648	MR	HS
Urahoro-cho	1649	MR	HS
Kushiro-cho	1661	MR	HS
Akkeshi-cho	1662	MR	MS
Hamanaka-cho	1663	MR	HS
Shibecha-cho	1664	MR	HS
Teshikaga-cho	1665	MR	HS
Tsurui-mura	1667	HR	HS
Shiranuka-cho	1668	MR	HS
Betsukai-cho	1691	HR	MS
Nakashibetsu-cho	1692	MR	HS
Shibetsu-cho	1693	MR	HS
Rausu-cho	1694	MR	HS

Table 8.8 — Aggregation of municipalities based on their combined levels (high H, medium M, low L) of resilience (R) and of sustainability (S), including the highlight of the cumulative presence in the fore-loop of the adaptive cycle.

NUMBER OF MUNICIPALITIES	COMBINED LEVEL OF RESILIENCE AND SUSTAINABILITY	SHARE OF THE MUNICIPALITIES
17	HR-HS	9.50%
4	HR-MS	2.23%
100	MR-HS	55.87%
121	*fore-loop*	67.60%
25	MR-MS	13.97%
24	MR-LS	13.41%
3	LR-MR	1.68%
3	LR-LS	1.68%
1	HR-LS	0.56%
2	LR-HS	1.12%

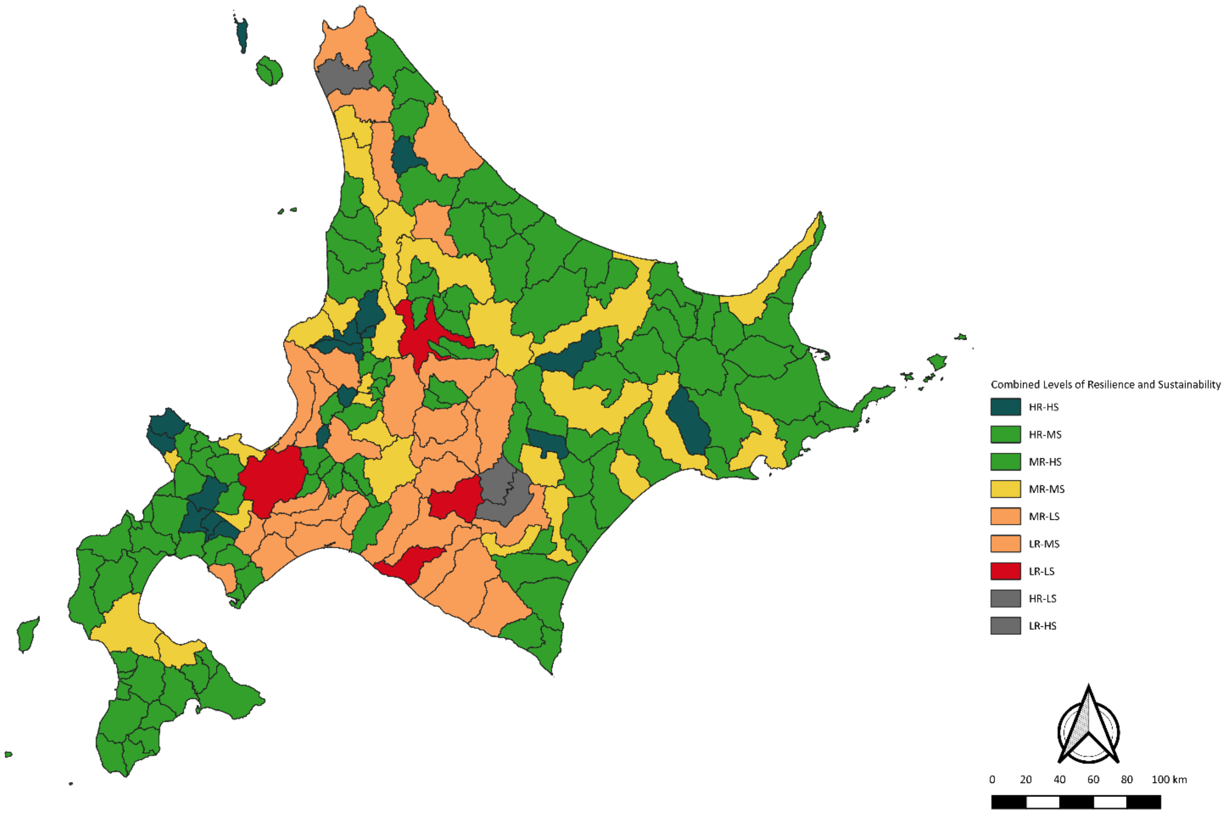


Figure 8.14 — Distribution of the their combined levels (high H, medium M, low L) of resilience (R) and of sustainability (S) among the Municipalities of the Hokkaidō.

The overall picture of Hokkaidō appears rather varied in terms of combined levels of resilience and sustainability. Indeed, all levels are represented. Even though this might be especially encouraging for the most desirable conditions, as the highest capacities of resilience and sustainability find their embodiment in several Municipalities, this also means that the least desirable conditions might be spotted across the Prefecture, in terms of both combined lowest levels and *traps*. From a quantitative standpoint, although only a limited portion exhibits the combination of the highest levels (9.50%), the overall situation is rather reassuring, as the majority of the Municipalities (67.60%) lies in the *fore-loop*, that is the assumed most desirable segment of the *adaptive cycle*. Nevertheless, the presence in the segments surrounding the most unstable and uncertain phase of the *adaptive cycle*, that is the *release phase*, should not be underestimated: about 1 every 6 Municipalities (16.77%) presents a low level of either resilience or sustainability, apart from those in an extremely unbalanced situation, that account for a very limited fraction of the Municipalities (1.68%). In a few words, although the territory of Hokkaidō mainly implements a successful approach towards disaster and environmental issues, there still appear to be some clusters demonstrating comparatively less effective interactions. It might be relevant to remind that such observations are valid in relative terms: that is, from the performed assessment it emerges that some Municipalities might have enacted strategies that result less efficient than others in addressing local issues. hence, even though this investigation does not allow for a generalised comparison among different geographical areas, it might still provide some insights that could turn relevant for local policies and management strategies. In particular, it might be beneficial to identify the distribution of the levels across the Prefecture. It appears that the Municipalities associated to the highest levels of resilience or sustainability (HR-HS, HR-MS, MR-HS) are scattered throughout the Prefecture: even if some examples can be found also in the inner land, the majority lies along coastline. On the contrary, the conditions that might raise the most consistent concern seem to be mainly aggregated in a central nucleus that includes all the variations in terms of low and medium levels and revolves around the three Municipalities allocated in the most critical level (LR-LS), that are Sapporo-shi, Asahikawa-shi and Hidaka-cho. As a consequence, it appears that the inner areas would be those that might benefit the most from a focused management and investment strategy. In this case, especially for the worst scenario, it might be relevant to trace back the reasons that led to such an adverse portrayal. In other words, it might be interesting to bring back and combine also the outcomes of the previous analytical processes that explored the resilience and the sustainability *cores*. In particular, the investigation around disaster behaviour was dominated by two different themes: flood damages (Asahikawa-shi and Hidaka-cho) and population exposure (Sapporo-shi). That is, such indicators resulted the most relevant to determine attribution of the lowest levels of resilience for these Municipalities. Although concerning different domains of the resilience *core*, both metrics address a common, fundamental feature of human communities, that is their susceptibility, the harsh consequences that they might suffer in the case of an adverse event. In other words, the emerging importance of themes such as flood damages and exposure appears to confirm that a significant driver of disasters lies within human behaviour and attitudes: strategies fostering adaptation approaches as well as focusing on awareness raising might sensibly reduce the destabilising impacts of an extreme event, thence boosting the resilient capacities of local communities. From the sustainability side, the overall picture is even more homogeneous. Indeed, the lowest level was mainly due to the extremely concerning extension of *araiguma* distribution, even though also the alteration of the local vegetation played a significant role. Nevertheless, the presence of alien specimens, whose introduction was caused by the abandonment following the owners' personal disappointment, is an evidence of the profound consequences of human behaviour. In particular, this dynamic exemplifies the severe alterations to the ecosystems that human communities might cause, driven by a mere whim. Consequently, also in this case raising awareness on the environmental costs stemming from personal choices and deeds might turn especially beneficial to improve the overall interaction with local ecosystems, particularly in the long term. Nevertheless, it might be relevant as well to take a closer look to those Municipalities that successfully linger in the *fore-loop* of their *adaptive cycle*. In particular, it might be noteworthy their scattered distribution throughout the Prefecture: this appears to suggest that such a desirable condition should reasonably disregard geographical features, rather concerning more inherent and general traits. Thence, the second phase of the assessment procedure might result particularly informative in identifying pivotal qualities that could enhance the overall convergence towards the *fore-loop*. In this case, investments would seemingly drive the most significant enhancement of the local resilient and sustainability capacities when focused on developing a widespread network of social welfare infrastructures and on promoting a sound preservation strategy of local vegetation. Indeed, a higher attention devoted to the most vulnerable components of a community might prove an overall greater proactivity towards the mitigation of the factors that exacerbate the risks pending on a community, as well as the availability of sufficient resources to implement such a forward-looking aim. At the same time, furthering the preservation of natural equilibria, especially through the preservation of local habitats and the promotion of lower-impact activities (favouring agriculture rather than heavy industries, for instance), might significantly increase the overall wellbeing of the local ecosystems, thus strengthening the capacity to perform functions and deliver the services that are vital for human communities. It might be noteworthy that such observations derive from an assessment procedure focusing on a specific threat, that is flood risk. As a consequence, it might be claimed that their validity should be restricted to that specific scenario, and especially to this particular case study. Nonetheless, they appear to hold a more general meaning, as reducing local vulnerability as well as nurturing local ecosystems might reasonably be adopted as a common strategy to enhance resilience and sustainability. In addition, while significant at any scale, such strategy would hold a particular meaning at the local scale, where impacts are more direct and severe, when both exerted and suffered by humans.

9. Partial conclusions

The *objective* that drove the present discussion intended to delve into the interactions among the human and the natural components of a Social-Ecological System and in particular the conditions that allow for an overall long-term survivability of such System. In order to pursue such aim, it was deemed necessary firstly to define a theoretical framework in order to model the inherent dynamics, and secondly to develop a methodology that would support a quantitative assessment of the recognisable conditions.

The *first part* of this research addressed the question of whether and how it would be possible to investigate the conditions of a Social-Ecological System. In particular, the pivotal starting point lied in the adoption of the panarchy model as a proper means to further the comprehension of these complex systems. Nevertheless, a preliminary endeavour concerned the adaptation of the panarchy model, developed within the ecological domain, to the theme of disaster risk reduction. This allowed to outline the **Social-Ecological Panarchy model**, that aims at visualising the possible interactions among the components of a Social-Ecological System and in particular the critical features that might enhance or jeopardise the long-term survivability of the System. After such theoretical development, it was possible to structure a framework that served as a basis to design a quantitative methodology, useful to identify the levels of resilience and of sustainability of a specific Social-Ecological System, that is the **Combined Assessment of Resilience and Sustainability** (**CARES**) **methodology**.

In the *second part* of the research, such framework was applied to two case studies, the Marche Region (Italy) and Hokkaidō (Japan), considering a scenario dominated by a flood risk, assuming a Municipal scale of analysis. Such case studies, although geographically and culturally different, held some significant traits in common. For instance, the overall topographical features, and in particular the river dynamics, share a common picture, as well as it emerges a common tendency towards communities tightly entangled with the natural environment, exemplified by the high relevance that agricultural activities still hold in both areas. Furthermore, floods represent a significant threat for both Marche Region and Hokkaidō, to the point that it was possible to select a convenient time interval for each case study so that it comprised a comparable number of events and witnessed the involvement of the overall territories in a flood disaster. The application of the proposed methodology to these case studies allowed to investigate their specific features in terms of **Levels of resilience** and **of sustainability**. The case of the Marche Region exhibits an overall prevalence of the most desirable conditions, of both resilience and sustainability, whereas the least favourable conditions are showed by a limited portion of Municipalities. The case of Hokkaidō was rather different: the majority of the Municipalities proved a medium degree of resilience capacities, while their sustainability approach appeared generally more robust. Although the assessment methodology does not allow for a direct comparison of the outcomes, some insights might still be drawn from the analogous analytical application. For instance, it might be interesting to observe how for both Marche Region and Hokkaidō, and for both resilience and sustainability the most critical issues might be the localised in the mountainous and hill areas, whilst the coastlines exhibit a sounder general status. Furthermore, such criticalities seem often clustered in small groups, including up to ten elements. These common traits reasonably suggest a general inherent fragility of the inner areas, fragility often not related to the specific peculiarities of a Municipality, but rather associated to the local characteristics of a narrow area, circumscribed although laying beyond the administrative boundaries. As a consequence, it appears that such enclaves would especially benefit from a tailored strategy to enhance the local capacities to nurture the interactions with the natural environment and possibly to cope with extreme events. In this regard, some significant insights might come from the identification of the traits of the behaviour of Municipalities in critical conditions that more than the other determined the allocation in the lowest levels. In terms of resilience, it emerges a common dominant role played by the damages suffered by the local communities during a flood event. Furthermore, the analytical procedure would suggest the weight of the variation of the income of local communities, but while this might be confirmed for the Mache Region, it is denied by the Hokkaidō case, where the population exposure to floods appears more significant. Hence, as a general criterion, the improvement and adaptation of the anthropic features to the local natural dynamics appears pivotal to influence disaster behaviour. From a sustainability perspective, the picture was more multifaceted, although also in this case a common trait arose, that is the direct alterations caused to the natural ecosystems by anthropic activities. Even though it is represented alternatively through the conversion of natural areas into urban and industrial settlements or through the changes occurred in vegetation distribution, this feature suggests that the approach implemented in relation with the surrounding natural landscape significantly affects the sustainability of a Municipality. Accordingly, the promotion of the preservation of the natural features of a territory appears to be a standard holding a general and central validity in terms of sustainable behaviour.

While these considerations are related to the specific behaviour of a Municipality in critical conditions, it was deemed relevant to identify the general characteristics that moulded that behaviour, that led to that outcome: the *third part* of the research thence focused on the **features that typified the case studies**. In particular, the focus was on those features commonly included in similar investigations. Although also in this case the outcomes are not interchangeable and directly comparable, it is still possible to draw some informative insights on the relative weight of the different included metrics. In terms of resilience, the characterisation revealed rather different between the two case studies. Indeed, while for the Marche Region the demographic variables emerged as the most relevant, followed by the presence of volunteers, for Hokkaidō the network of the welfare system resulted the most important feature. Consequently, although in one case the inherent structure of the community was determining, as a common criterion it emerges the relevance of the structure of the response to the emergency, in one case represented by the population devoted to the social welfare and protection, in the other case by the support to social and firefighters duties and the presence of doctors. As a matter of fact, when investigating the reasons behind a specific disaster behaviour, the robustness of the response system might result reasonably significant, especially in defining the outcome of that behaviour. This is in partial contrast with the indicators commonly adopted to assess the resilience of a community. Indeed, often wide space is dedicated to demographic and economic variables (for instance: female population, elderlies, level of education, income, house ownership), whereas the outcomes of this research suggest that even though they certainly contribute in outlining the resilience capacities, they might not be the most significant factor for every case study. As a consequence, though it is important to include them in an assessment methodology given the implied meaning that they hold in terms of attitudes, it seems that the information that this kind of indicator can provide should be always complemented by other indicators that contribute to the representation of the multifaceted nature of a community and that it might be especially significant to include some observations concerning the abilities in force to actually deal with a disaster. On the other hand, based on collection of adopted variables, the outcome of this research also suggest which domains should favoured in order to see an increase in the overall resilience of the community. In this sense, it appears reasonable the implicit recommendation of strengthening the social and health welfare system and the emergency response system in order to foster the capabilities of a community to cope with an extreme event. At the same time, when considering the theme of sustainability, the discussion is partly complicated by the process of data collection that forced the inclusion of a more limited and more diverse set of metrics. Nevertheless, also in this case a common trait arose among the others, that is the presence and extension of vegetation, both natural (forest land) and semi-natural (agricultural land). As a common criterion, then, the protection and nurturing of woods and natural environments seemingly hold a distinctive relevance for the enhancement of the sustainable capacities of a community. Indeed, the preservation of natural habitats is pivotal for the survivability of ecosystems, as they provide the setting for species to live and prosper, sustaining the biodiversity of an area, thus fostering the provision of ecosystem services and functions. Similarly, not only an agricultural setting might constitute a specific habitat per se (paddy fields might be an obvious exemplification), but it might also deliver specific ecosystem services (for instance, air or water quality maintenance), thus contributing to the stability of the local natural environment. In light of these considerations, it appears plausible that the grade of sustainability of a community might be determined and thence could be improved enhancing their relation with the local natural environment, especially in terms of forest and agricultural land.

Once the assessment of resilience and of sustainability was completed, it was possible to move to the *fourth part* of the research, aimed at re-composing the complex picture. In particular, combining, side by side, the evaluations of resilience and sustainability it was possible to assess the **panarchical status** of each Municipality. In other words, the territory of the case studies was classified based on the position held by each Municipality within their *adaptive cycle*. The distribution of the combined levels of resilience was rather varied throughout the case studies, although, as it could be expected, the inner areas suggested the presence of issues that might be more urgent to address, compared to other sections of the region. In other words, it appears that the majority of the Municipalities lying in the most critical segments of their *adaptive cycles*, that are those surrounding the *release phase*, are mainly located in the mountainous and hill areas of the Marche Region as well as of Hokkaidō. As a consequence, in both cases it seems that the development and implementation of local strategies to enhance a sounder interaction with the natural environment and phenomena should be encouraged and assumed as a priority in the overarching management of the Region and Prefecture, respectively. At the same time, the presence of Municipalities trapped in unpaired conditions should not be underestimated: *traps* still represent an undesirable status, as the prominence of either resilience or sustainability domain over the other is symptomatic of an unbalanced relation with the surrounding environment, that could hamper an global successful development in the long-term. In spite of such critical issues, both case studies exhibited an overall encouraging condition, as the majority of the Municipalities lied in most desirable segment of the *adaptive cycle*, that is the *fore-loop*. Although a comparable portion of Municipalities presented such status, the Marche Region showed a more balanced support of resilience and sustainability simultaneously, with a slight preference over sustainability, whereas Hokkaidō appeared to favour sustainability more substantially compared to resilience. Within the panarchy metaphor, apparently both case studies reside in the *fore-loop* with a tendency to shift towards the *conservation phase*. While this indeed is a desirable condition, as it denotes a successful human-nature interaction, it might also suggest that endeavours should be directed towards the enhancement of strategies to strengthen the resilience capacities of the local communities, in order to move the Municipalities towards the centre of the *fore-loop* of their *adaptive cycles*. In both cases, indeed, while the most severe issues are more spread in terms of sustainability (that is, the low level of sustainability is more populated compared to the low level of resilience), the best performances in terms of resilience are less common compared to sustainability (that is, the high level of resilience is less populated compared to the high level of sustainability). Hence, both cases suggest that severe environmental issues exist and push to be addressed, but except for such clusters of extreme negative conditions, a broader effort should be devoted to the increase of the general ability of local communities to effectively cope with disasters, in order to disseminate as far as possible the best practices in terms of disaster risk management and reduction. In a few words, environmental issues emerge as local urgencies, whereas disaster risk reduction seems to require a more general advancement. Such observation might provide an informative insight in the design of policy instrument for the management of those administrative units. In particular, bringing to light the different temporal perspectives and urgency of these issues might result constructive when identifying the most appropriate approach, that should necessarily address such mismatch, thence being differentiated and adapted to the specific needs. For instance, environmental problems might require tailored and rapid resolutions, whereas the enhancement of disaster resilience might find a higher benefit from a pervasive activity spread throughout the territory. Clearly, this guideline remains valid only for the Marche Region and Hokkaidō case studies, though the methodology that drew attention to such issues could be applied to other areas and similar outcomes could be derived. In other words, although the conclusion does not hold a universal validity, the methodology could still be adapted and implemented in order to derive a similar insight on the specific conditions and needs of the local communities.

This is the point where a further issue emerged: as the quantitative assessment came to its conclusion, what is the actual reliability of its outcomes? Do the set of indicators actual capture all the relevant features of the Municipality? Does the delivered picture actually represent the resilience and sustainability capabilities? Analytical processes and statistical tests provide a verification that address the methodological validity of the procedure: what about the conceptual validity? The inherent meaning of the methodological framework and outcome is questionably something that could be verified through other metrics and tests. Another actor needs to be called in, that is local communities. Their truth, perspectives and perception provide a unique viewpoint on the inner dynamics of a Municipality, thus providing an irreplaceable term of comparison for the interpretation provided by numbers and positivist analyses. Consequently, beginning from the next chapter, the discussion will turn towards the outline of the picture as drawn by those who actually live and experience the effects of the local interactions among humans and nature.

vi. PART 3 – …*to perception*

10. Literature review: positivist paradigm through local surveys

The exploration of the themes of resilience and of sustainability has progressed along a rather linear path up until this point: previous research efforts were scrutinised, an interpretivist paradigm was elaborated, hypothesis and research questions followed to be later tested through a proposed positivist paradigm, defined as a Combined Assessment of Resilience and Sustainability (CARES), that revealed the conditions of real-case Social-Ecological Panarchies (SEP). That is, since the beginning, the discussion moved towards a quantitative assessment, based on commonly agreed advices that suggest the importance and appropriateness of objective metrics concerning these issues. Yet, this chain of subsequent steps might be missing a crucial link. The proposed methodology might be applied to quantitatively assess the level of resilience and sustainability of a local community, but that community is not just composed of quantifiable structures: people inhabit, live and advance that community. Consequently, the thoughts, ambitions, expectations of local people are determinant of the characteristics and development of that community. Hence, when assessing resilience and sustainability, it might be relevant to question: what do people think of the resilience level of their community? What about their sustainability? What do they think is essential for survivability? What is the threshold before recognising a critical system failure? After all, given that it is people that mould a community, they should also be allowed to influence the pivotal *cores* of that community.

The engagement of local populations in the management activities of their communities is a recent phenomenon, although it is increasingly gaining attention and endorsement. Actually, the call to involve locals and exploit local knowledge is gaining a wide echo (Bodoque et al., 2016). For instance, the Sendai Framework for Disaster Risk Reduction explicitly advocates the inclusion of local stakeholders and more vulnerable groups in the planning of effective strategies and in their successful implementation as a crucial progress towards building more resilient communities (UNDRR, 2015). In general, local populations appear to play a pivotal role in effectively enhancing or determining the failure of the strategies concerning disaster resilience as well as environmental sustainability. Indeed, exploring the willingness to adopt protective measures or to support risk reduction plans could turn crucial in order to boost the efficacy of enacted policies (Kellens et al., 2011). In turn, a similar assessment concerning the perception of environmental issues could be critical to design proper communication and educational strategies, as well as to consolidate the public acknowledgement of local policies (Vincenzi et al., 2018). As a consequence, the strictly quantitative approaches that have been widely employed to assess resilience and sustainability might not be able to comprehend all the facets of such a complex picture. Research efforts are indeed shifting towards more integrated approaches, some that encompass more qualitative measures (Kellens et al., 2013; Reed et al., 2005; Santoro et al., 2019). In other words, research questions are increasingly often investigating the local perception of resilience and of sustainability, as a crucial element to foster both *cores* (Hawkes & Rowe, 2008; Vincenzi et al., 2018). In order to adhere to this direction, the proposed methodology should be expanded in order to include a further positivist paradigm, that still finds its roots in the interpretivist approach (the Social-Ecological Panarchy model, but moves towards a qualitative assessment strategy.

Before delving into the methodological issues, it might be significant to explore the very origin of the matter: what is a "perception"? This noun is basically defined either as the belief formed on the basis of how things seem or as the ability of being aware of the surrounding reality through the exercise of inherent senses (Cambridge English Dictionary, n.d.-b). Both concepts revolve around the role of external senses. In other words, "perception" deals with the representation of a surrounding reality as it is processed through the five senses. Consequently, the matter of perception is inherently and fundamentally subjective. A manifold of variables influences this issue, stemming from personal, to social and environmental characteristics. Evidently, the question of perception is a rather multifaceted problem to address. Additionally, when it comes to the perception of more specific themes, such as disaster risk and environmental sustainability, the level of complexity can not but amplify. Even though risk perception and environmental perception concern different domains, hence they have been examined from different perspectives, some common features have emerged. In particular, risk and environmental perception is not a mere consequence of physical characteristics and objective events. Rather, they are affected by attitudes, behaviours, expectations, constructs developed both at an individual and at a societal level (Sjöberg, 2000; Vincenzi et al., 2018). An exemplification of the consequence of this multifaced issue can be identified in the discussion relating to risk perception. While risk might be assumed as the probability of the occurrence of a certain hazard, hence it can be referred to some objective variables, risk perception is influenced also by the sense of security provided by the overall community to the individual, thus a multi-dimensional function of personal attitudes and priorities, social cohesion and external pressures (Boholm, 1998). From these observations it derives that a phenomenon might be decoded in completely different ways depending on the population involved, as well as an objective metric itself might assume different meanings depending on the population addressed (Boholm, 1998). Coming back to the risk domain, a further example is provided by the seminal work of Slovic (1987). "*The concept of "risk" means different things to different people*" (p. 283): the author showed as such a difference reaches a critical peak when the judgements of laypeople and experts are compared. In particular, it appeared clearly that even though laypeople might be able to provide objective quantification of risk, such as estimates of mortality rate, their judgement is indeed richer in variables. Where experts mainly rely on measurable indicators of harm to victims, laypeople consider also broader social impacts, such as the consequences for future generations or the potential of extreme mishaps. More in general, among the various aspects that influence risk perception, some seem to be more relevant: the familiarity with the hazard typology and dynamics (e.g. train wreck vs. nuclear power), and the severity of the consequences (extension of the produced harm). Nonetheless, such a discrepancy in judgement might not be always substantial. For instance, when asked to rank a series of environmental risks, laypeople and experts delivered consistent evaluations of the proposed risks connected to global environmental changes (ozone depletion, species loss, climate change), especially positioning them in the levels with higher potential impacts (McDaniels et al., 1996).

Nonetheless, these complex issues have not refrained, but rather inspired research efforts. In particular, those endeavours are based on the assumption that perception and attitudes can indeed be measured (Boholm, 1998; Sjöberg, 2000). Although relatively recent, this line of investigation has already been enriched by a multitude of operative methodologies. Yet, an overall agreement on a common assessment strategy has not been found, in the domain of both disaster resilience and environmental sustainability. In particular, the discussion surrounding risk perception opened in the 1940s by White and his revolutionary thesis (1945) that exposed the influence of past experience of flood on the behaviour under the threat of a future flood (Kellens et al., 2013). Not much later, a further pioneering contribution to the field was provided by Starr, who quantitatively estimated the correlations between public acceptability of risk and a manifold of variables (e.g. voluntariness of risk, related benefits) and exposed the potential informative value for risk management (Starr, 1969). Stemming from these seminal works, two major approaches have been developed through the decades: a psychometric approach, rooting in the positivist tradition, and a cultural theory approach, relying on the concept of risk as a societal construct (Liu et al., 2018), even though the psychometric approach appears to be well rooted in the risk perception tradition (Kellens et al., 2013). At the same time, it should be noted that there is not a common implemented methodology: questions and approaches are not universally established, but rather developed and adjusted to each study (Kellens et al., 2013; Liu et al., 2018). This might be possibly due to the explorative stage where this line of research lies (Kellens et al., 2013). In this crucial phase, knowledge needs to be gathered in order to build a consensus not only in terms of methodological issues, but also of relevant variables to include. For instance, sociodemographic variables have been proved to hold a crucial role in shaping risk perception (e.g. Liu et al., 2018) and their inclusion has been strongly advised, whereas some studies overlooked their relevance (Kellens et al., 2011); at the same time, other studies ascertained a limited influence of those characteristics, in favour of more general aspects, such as social, cognitive and practical motivations (Roder et al., 2019). As mentioned, in a similar vein the question of sustainability perception remains an open field of discussion. The general concern over environmental issues has been growing in the last decades, thus in this age of impending environmental changes, it would be especially relevant to estimate the potential response elicited in local populations (Andries et al., 2012). Nonetheless, the development of an assessment methodology appears not straightforward nor established, in spite of the several fields that have been already investigated: environmental policy, food, tourism, consumption habits (Vincenzi et al., 2018). In the same way, the outcomes are not unanimous: university students have been found to be rather aware of the growing threats and of the crucial role played by sustainable development for a long-term survivability (Andries et al., 2012), while laypeople appeared to hold a general low of sustainability perception (Vincenzi et al., 2018). Moreover, in some cases sociodemographic dimensions exhibited a significant relation with sustainability perception (e.g. Andries et al., 2012), whereas in some other cases further variables appeared determinant. For instance, when highly polluted riverine areas, the experience of views and smells coming from the river was crucial to mould the local perception (Guida Johnson et al., 2015). At the same time, the vicinity and the tighter relation to the riverine area appeared fundamental, to the point that the higher awareness expressed by women faded with the increasing distance from the water body, thus limiting the influence of commonly employed demographic variables (Guida Johnson et al., 2015). Indeed, when that kind of spatial variation was specifically explored, cluster of different environmental perception emerged evidently, in spite of socioeconomic features of the addressed community (Brody et al., 2005).

Stemming from this brief exploration, it appears confirmed that resilience and sustainability share a common exploratory status in the field of research concerning related perception. This being the case, qualitative methodologies appear to be especially suitable to contributing in unravelling crucial knots. As a matter of facts, these techniques have been widely applied in both areas (Santoro et al., 2019; Sjöberg, 2000; Vincenzi et al., 2018). In particular, the focus of discussion here are strategies that entail a direct contact and involvement with people, soliciting the disclosure of their thoughts, experiences and impressions either explicitly or through relevant proxies. Indeed, all the above-mentioned studies concerning perception, either dealing with risk or with environmental issues, were performed applying this kind of methodologies. This domain has been commonly divided into two main approaches, separating once more between qualitative from quantitative techniques. Where qualitative strategies focus on a selected group of respondents in order to deeply explore their ideas and comprehend the scenarios that formed in their minds, accumulating details and new aspects, quantitative strategies act quite in the opposite direction (Sjöberg, 2000). In this case, the aim to derive general traits and unveil salient common features. Where qualitative approaches enrichen and widen the picture, quantitative approaches extrapolate the dominant lines and abridge the sketch. Consequently, quantitative approaches might result especially relevant when researchers or policy makers need to grasp the most important features of a question and thence design the further steps, aware that qualitative approaches might in parallel provide in-depth details, when necessary (Sjöberg, 2000).

Once established the relevance of quali-quantitative strategies (i.e. questionnaires), it might be interesting to explore some specific features of these techniques. It has already been mentioned that there is not an overall agreement on the variables to include in the investigation, and that a similar inhomogeneity affects the kind of questions to deliver. At the same time, the psychometric paradigm appears to be adopted by a variety of studies. This approach employs questionnaires in order to collect the perceptions of the respondents through preferences expressed on rating scales and concerning several features of the investigated problem (Benthin et al., 1993; Kellens et al., 2013). Indeed, rating scales appear to exhibit a significant suitability for collecting information concerning individual perception. A particularly common scale is that called Likert and Likert-type scale (Boylan & Lawrence, 2020). The Likert scale was introduced in the 1930s with the specific aim to investigate and grasp people's attitudes (Likert, 1932). This technique provides a single statement that solicits the expression of a preference: the answers provide a gradation of accordance, usually identified through a sequence of integer numbers, with stages horizontally arranged, evenly separated and with verbal labels symmetric to a neutral middle (Uebersax, 2006). Nonetheless, some variations are accepted, especially in the structure (including the visual appearance) of the question and in the type of verbs employed to collect the rate of agreement, and they fall under the classification of Likert-type scales (Guerra et al., 2016). Even though in this approach it is fundamental to provide enough options in order to include a representative depiction of the respondent's personal perspective on the matter, it is advised not to exceed in the width of such available range. In facts, too many possibilities might result confusing, thus hampering the reliability of the answers (Sjöberg, 2000). Hence, options should be kept between 3 to 7 points (Boylan & Lawrence, 2020; Sjöberg, 2000). Once established the kind of questions, it is the turn to select the appropriate strategy to involve respondents. The manifold of available techniques fall into two main categories: probability or non-probability methods, depending on whether the aim is to target the general trends or to focus on a population, characterised through specific features (Kellens et al., 2013). The prevalence of one or the other might depend on the purpose of the research as well as on the employed methodology: for instance, flood risk perception appears to be dominated by questionnaires delivered to probability-sampled respondents, in order to grant the representativeness of the outcome (Kellens et al., 2013), whereas among (generic) risk perception surveys interviews appear to play a major role, administered through non-probability sampling techniques, such as convenience sampling and purposive sampling (Kellens et al., 2011). Concerning risk perception, some further relevant elements emerge: first, even though it might be possible to identify complex risk scenarios that might affect a selected population, it happens often that the investigation is reduced to a single-hazard, thus focusing questions and perspectives (Kellens et al., 2011). In addition, it has been advised not to rely on risk perception in order to estimate the willingness to reduce risk itself, but rather the two issues should be treated as independent one from the other and not as a mutual proxy (Sjöberg et al., 2004). As a matter of facts and perhaps counter-intuitively, several studies have shown that a manifold of variables influence risk perception, to the point that risk perception is more related to the probability of unwanted outcomes, whereas the demand for risk mitigation is more related to the perceived severity of hazard impacts, rather than to "risk" as a whole (Sjöberg et al., 2004).

The matter of perception and of perception assessment is a complex problem and the above brief exploration is meant just as a contribution to sketch a general picture on the state of these themes. Even though the exploration was somehow coarse, it was possible to identify some relevant facets, most of which shared by both the resilience and sustainability domain. For instance, the demand to actively engage local populations in the management of their territories results a strong call also for assessment efforts (Bodoque et al., 2016), where more and more frequently quantitative techniques are being associated with "softer" strategies of investigation (Kellens et al., 2013; Reed et al., 2005; Santoro et al., 2019). Nonetheless, qualitative investigations are not mere object of research interest, but rather the assessment of resilience and of sustainability perception is increasingly recognised as a pivotal element to effectively address those complex issues (Hawkes & Rowe, 2008; Vincenzi et al., 2018). In spite of this urgency, individual perception is influenced by a wide range of conditions, experiences and constructs developed both at the personal and at the societal level (Boholm, 1998; Sjöberg, 2000; Vincenzi et al., 2018), hence its assessment might result especially challenging. This complexity might be mirrored by the early stages of the research in this field, that is still developing explorative endeavours. As a consequence, several methodologies, approaches and operative implementations have been proposed, although an agreement is yet to be reached both in the resilience and in the sustainability discourse (Liu et al., 2018; Vincenzi et al., 2018). Nevertheless, it is possible to draw some general guiding principles. Assumed that the purpose of the investigation aims at sketching some overarching trends, the exploration should be performed by means of quali-quantitative techniques (i.e. questionnaires) (Sjöberg, 2000), guided by the tenets of the psychometric paradigm (Kellens et al., 2013), rooted in the positivist tradition (Liu et al., 2018). In terms of operative characteristics, Likert and Likert-type scales have found extensive approval (Boylan & Lawrence, 2020), even though it is commonly suggested to limit the range of available options to express personal preference (Sjöberg, 2000). In this case, it might also be inferred that the most appropriate sampling technique should rely as far as possible on casualty, rather than on specific biases (Kellens et al., 2013).

At this point it might be relevant to take some steps back to the assessment methodology proposed in this study. The newly gathered information is informative to broaden the investigation from where it halted. In particular, local territories were examined through objective, quantitative assessment of resilience and sustainability. Nonetheless, the demand to include the standpoint of local populations emerges evidently from the above discussion. Hence, the proposed methodology should be expanded in order to include a third phase: the enhanced proposed methodology would associate a further qualitative investigation to the previous quantitative metrics. In this case, the focal interest would concern risk perception as well as environmental perception, even though some peculiarities might be identified. In particular, the nucleus of the discussion would still revolve around the level of resilience and sustainability of a community. Yet, at this point the question wonders what level is actually perceived by the local population. In other words, the investigation would survey the perceived level of resilience, not the overall risk awareness. Analogously, the investigation would survey the perceived level of sustainability, not the general concern over environmental issues. Furthermore, the paradigm centred on the Social-Ecological Panarchy would still drive the operative development of this phase and a possible interpretation of the outcomes. Given this common foundation, it would be even possible to attempt a tentative comparison between the classification deriving from the quantitative effort and that drawn from this qualitative investigation. Furthermore, it might be the appropriate chance to collect some information on some relevant issues concerning the two *cores* and to interpret it through the lens of the panarchy metaphor: for instance, according to local populations, which are the fundamental functions of the anthropic and of the natural systems? Where is the threshold that marks the boundary of a collapse? Are there any relations among individual or local peculiarities and perceived levels of resilience and sustainability?

From this point on, the discussion will converge towards the delineation of driving questions that, along with the interpretivist paradigm (Social-Ecological Panarchy model) already presented, will inform and assist in the expansion of the positivist paradigm (Combined Assessment of Resilience and Sustainability) towards the investigation of local perceptions of resilience and of sustainability.

11. Further assumptions, objective, hypotheses and questions

Local populations live in close relation with their territories. The interaction of locals with their surrounding environment has shaped and is shaped by a continuous exchange of information and resources that flows throughout the complex Social-Ecological System. As a consequence, the development path of local communities inevitably keeps memory and records of the local geographical narratives. At the same time, the needs, expectations and concerns of local populations are a pivotal driving force towards the enhancement of a comprehensive and sound local development. In brief, the involvement of local populations is crucial to foster a resilient and sustainable development for the overall Social-Ecological System. This approach is especially relevant when external viewpoints or sterile metrics might miss or misinterpret relevant features of local issues. Consequently, while it is fundamental to actively engage local populations in the management of their territories, it is equally essential to grasp and foster as far as possible the perspectives of locals on their landscapes. Nevertheless, such an endeavour appears to remain in its exploratory stage. In particular, there is still a demand to collect information in order to draw a thorough picture to gain some insights for the following management strategies.

As previously mentioned, the primary *objective* of this study is to further the understanding of human-nature interactions and of their consequences on the survivability of the overall Social-Ecological System. In order to pursue this aim, the panarchy model was adopted as a leading inspiration to mould the heuristics of the Social-Ecological Panarchy, and thence to quantitatively investigate the conditions of resilience and sustainability of local communities. At this point, the concern shifts and converges towards local populations, and the Social-Ecological Panarchy model might be implemented once more in order to further the comprehension of how locals interpret and project their territories.

In this perspective, accounting also for the further literature exploration, an additional *hypothesis* was formed:

There is a mismatch between measured and perceived level of resilience and sustainability.

In other words, although there should a constant strive to foster disaster resilience and environmental sustainability strategies, the engagement of local populations in those endeavours is still not a common practice. Indeed, preliminary efforts are directed also towards the comprehension of risk and environmental perception. Consequently, local populations might not be aware of the development course undertook by their community and might perceive a condition of resilience and of sustainability that is not informed enough to align with an objectively measurable level.

From here, some related *sub-hypotheses* descend:

First, *local populations tend to underestimate the level of resilience and of sustainability.*

The general low involvement of local populations in the management of their territories might result in a partial awareness of the local initiatives implemented to reduce risk and strengthen sustainability.

Second, *higher levels of resilience and of sustainability blur the mismatch between measure and perception.*

When a manifold of activities is enhanced, the engagement of the local population should be promoted as well, or at least a higher visibility should be granted.

Third, *perceived higher levels of resilience and of sustainability correspond to higher tolerance of disaster-related nuisances.*

When the awareness of local plans and strategies is high, there is also higher trust and tolerance towards possible inconveniences after an unfortunate event.

In order to test those hypotheses, the scope moves towards local populations and towards surveying their perceptions, thoughts and expectations. Thence, the methodological framework would be broadened and adjusted to this emerged interest.

In particular, some *research questions* might be helpful to draw an appropriate structure to this additional operative phase.

First, *is there any difference between the level of resilience as objectively measured and subjectively assessed?*

Given that local populations are in the forefront when an extreme event strikes, it is fundamental that they are aware of the capacities and assets available to cope with such undesirable situations. Groundless confidence might be highly detrimental, but undervaluing the local capabilities might induce a similar unfavourable attitude.

Second, *is there any difference between the level of sustainability as objectively measured and subjectively assessed?*

Local people are those actually interacting with the surrounding environment. In order to foster a balanced coexistence, it is crucial that they are conscious of the changes altering their landscapes as well as that they are engaged in the efforts to promote a sustainable lifestyle in everyday activities.

Third, *where do local populations draw the thresholds among the most crucial phases of the* adaptive cycle*?*

Ascertained that local populations live and develop their communities, efforts should be invested in adjusting those communities to the needs and expectations of their inhabitants. Hence, it might be interesting to explore which are the functions that are considered fundamental for everyday life, where is set the limit of tolerance for their failure, what is the accepted extension of recovery. Similarly, these same issues might be directed towards the natural environment, wondering what are the most valued services and what is the acceptable level of damaged and of loss.

After unravelling the above issues, some other concerns emerged. Although perception is influence by a manifold of variables, stemming from personal experiences as well as from societal conditions, a significant role might be played by individual peculiarities and especially socio-demographic characteristics. This matter has been debated both in the resilience and in the sustainability discussion, even though a definitive answer has not been found. Hence, a further *hypothesis* might be proposed:

The perceived level of resilience and sustainability is influenced by socio-demographic aspects.

The perspective, experiences and ambitions of a person might be significantly affected by the conditions created by their status, origin, gender, education and other features that contribute to shape one individuality. Consequently, their approach towards disaster resilience and environmental sustainability might be influence as well by the personal and societal constructs experienced by that person.

Consequently, it was necessary to include some more *research questions*:

First, *is there any relation among the perceived level of resilience and the overall sociodemographic variables? Is there any relation among the perceived level of sustainability and those variables?*

It might be interesting to capture the eventual dominant attributes that might influence the perception of an individual. If this was possible, then it would also be possible to formulate some prediction on the expected behaviour of a local population.

Second, *if there is indeed a relation, are those variables the same that emerged from the previous quantitative assessment?*

In case that indeed some demographic variables appear to significantly influence the perception of resilience and sustainability, it might be interesting to verify if they correspond to the variables that determine those conditions of resilience and sustainability. In other words, it might be relevant to ascertain whether the personal characteristics that lead to a specific level of resilience and sustainability are the same characteristics that influence the perception of those levels. If that was the case, it might be possible to inform and adapt local management strategies to the probable conditions of susceptibility or willingness towards specific risk and environmental issues.

As previously mentioned, at this point it is necessary to rearrange the proposed methodology, in order to include the means to address these further emerged questions. In particular, it is necessary to come back where the development of a methodological framework led to a crossroads: the discussion already explored the path of a quantitative assessment by means of objective indicators. Hence, it is time to undertake the other viable path, the one that progresses towards a qualitative assessment by means of individual surveys.

12. Qualitative methodology

At this point, the investigation is entering the last domain that will be included. Indeed, while the previous exploration delved into the quantification of the conditions of a Social-Ecological System, the research path needs to come back once again to the early development stages of a methodological approach. Indeed, the discussion will shortly advance towards the other half of the overall assessment strategy, that encompasses qualitative techniques aiming at comprehending and adopting the unique perspective of local communities on the dynamics unfolding in local Social-Ecological Systems.

12.1 Statement of the problem

It might be beneficial to retrace the major cornerstones of the envisioned research architecture. Indeed, the discussion stemmed from the overall concern surrounding the survivability of the coupled human-natural system. In this context, the Social-Ecological Panarchy model suggests that the human component of the complex system should exhibit a resilient and sustainable attitude. The key role and equal priority of resilience and sustainability led to their identification as *cores* of the overall discussion. Against this background, a first quantitative approach was adopted in order to provide a preliminary assessment of the conditions of the Social-Ecological System. The proposed methodology that was developed, that is a Combined Assessment of Resilience and Sustainability (CARES) encompassed two phases, one taking advantage of the *attributes* of the *cores* in order to operate a *classification* based on the behaviour manifested in case of critical events, and the other populating the *dimensions* of the *cores* in order to perform a *characterisation* in terms of most relevant traits that moulded that behaviour (Table 12.1).

Table 12.1 – Attributes *and* dimensions *of resilience and of sustainability.*

CORE	*ATTRIBUTES*	*DIMENSIONS*
resilience	absorb	demographic
	recover	social
	learn	economic
		health
		infrastructural
sustainability	services	ecosystem integrity
	functions	ecosystem benefits
	integrity	physical processes state
		external pressures

Although the discussion provided insights on the development path of local communities in terms of resilience and sustainability, the discourse relied only on numerical estimations over an extensive, yet partial representation of the multifaceted essence of local Social-Ecological Systems. Later, it emerged that a possible strategy to compensate such potential weakness consists in questioning local populations on the events and dynamics that occur in their communities. For this purpose, questionnaires appeared the most appropriate tool. Nevertheless, there is not a pre-established survey means to investigate these topics. Consequently, the Social-Ecological Panarchy model was retrieved once more as a conceptual foundation of an additional effort, intended to expand the proposed methodology in terms of qualitative assessment, thus leading to the Combined Assessment of Resilience and Sustainability+ (CARES+) methodology. The following lines will explore the adoption of this further perspective on the resilience and sustainability of local communities.

12.2 Proposed Combined Assessment of Resilience and Sustainability+ (CARES+)

12.2.1 Development of the qualitative methodology

A manifold of strategies is available to gather the voices of local populations. As previously mentioned, although they are considered qualitative techniques on the whole, in order to distinguish them from those approaches relying on quantitative, objective metrics, a significant divide exist among the viable methods. In particular, a relevant difference lies in the extent and typology of the involvement of the individual. The viewpoint of a person might be derived from their narration of personal thoughts, experiences and expectations. In this case, intensive discussions and exchanges between the interviewer and the respondent are the means to convey personal beliefs and stories. At the same time, those ideas might be elicited through numerical evaluations. That is, attitudes might indeed be captured through estimated quantities (Sjöberg, 2000). In other words, it is possible to employ numbers in order to grasp the perceived status of specific issues: in this case, more structured means are needed to standardise the form to be disseminated to a more extensive public. As suggested, in order to identify the most appropriate strategy, it is necessary to pinpoint the main intent of the investigation: is it the demand to draw a wide and detailed picture or rather to let common traits to emerge? In this case, the aim focuses on an overall understanding on the local perceptions concerning resilience and sustainability. In other words, there is the need to simplify an inherently particularised picture in order to grasp the general attitudes towards those issues. Hence, the second category of research methodologies appears more suitable in this case. In addition, the positivist paradigm that has been proposed relies on quantitative assessments: if it was possible to derive metrics from this further effort, it would be possible to facilitate a possible comparison among the respective outcomes.

In order to define the features of the tool to be employed, it might be beneficial to identify the overarching targets to be pursued. Stemming from the research hypotheses and questions, some major points might be identified:

- Evaluate the perceived level of resilience and sustainability;
- Identify the perceived most crucial functions of the Social-Ecological System;
- Identify the perceived critical thresholds in the neighbourhood of the collapse;
- Collect information on the dynamics of the local territories from the vantage point of the local populations;
- Investigate the role socio-demographic features among the possible relevant variables.

As suggested above, quality-quantitative techniques, such as questionnaires, appear to be especially suitable to gather data and outline insights for the identified issues, in the present case. Nonetheless, when delivering questionnaires, it might happen that the respondent wanted to provide some additional information or to share some personal experiences. Even though such contributions might not adhere to the structure of the questionnaire, they would represent especially valuable information, as spontaneity might allow some peculiar facts or dynamics to arise from the standardised set of questions. Consequently, those disclosures should be recorded as well, and considered as peculiar and unique insights of the place.

A further aspect to establish concerns the typology of sampled population to be involved. Although experts and local authorities might be more informed and aware of the events occurring in a community, in this case the aim points towards the perception of the community that laypeople experience. Professionals might be aware of what is happening in a place, but it is laypeople that are living those happenings. In this perspective, the sampling method should tend towards the highest representativeness, hence probabilistic techniques should be favoured. That is, the composition of the sample should not be influenced by biases imposed by the investigator, since the objective is to capture the overall local viewpoint.

Established these preliminary cornerstones, it was possible to identify the overarching structure of the questionnaire. In particular, 55 questions were arranged in three major conceptual sections, addressing the three driving themes:

1. resilience and sustainability perception

2. critical functions and thresholds
3. socio-demographic features

All questions were explicitly referred to a local community, highlighting the exclusion of the dynamics occurring in the wider regional or national territory. Evidently, in order to maintain consistence with the previous parts of the operative framework, the discourse focused on flood events and related management activities. In might be interesting to bear in mind that as a general rule, open-ended questions were limited as far as possible, in order to maintain the highest standardisation of the answers. Nonetheless, with the aim of allowing respondents to freely share their thoughts, a final area was left blank to be spontaneously filled in.

At this point, it might be relevant to put back together the pieces that have been modelled throughout the present discussion and thus give shape to the overall methodological frame that comes as a result. In particular, it might be noteworthy to unearth the parallel and complementary discourse carried by the qualitative and quantitative assessments that compose the proposed enhanced methodology (Fig. 12.1).

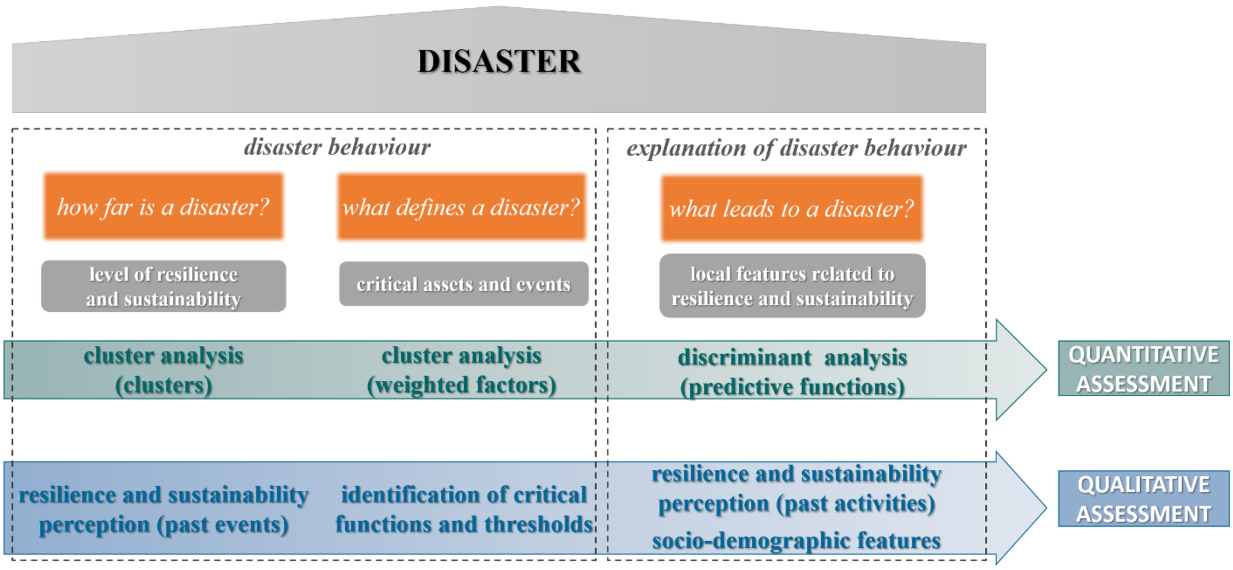


Figure 12.1 — Structure of the proposed enhanced methodology

Indeed, it might be especially significant to observe how the quantitative and the qualitative metrics are intended to develop one along the other, in order to provide completing information on the dynamics that surround a disaster and on the features that define the response of a community to adverse events. Although this approach might appear redundant, the different perspectives that it addresses might reveal potential flaws in quantitative measurements as well as critical misconceptions of local populations, or on the contrary consolidate a shared outcome. At the same time, it might ne noteworthy that such an approach is not intended to demean the inherent value of each other assessment strategy. On the contrary, it is acknowledged that both quantitative and qualitative metrics hold an intrinsic meaning and provide insights that are valuable as stand-alone outcomes. Precisely on the strength of this potential, within the proposed enhanced methodology the two assessment strategies might be considered as one constantly testing and questioning the other, potentially adding data when lacking and providing insights when opaque, or strengthening analogous results. Additionally, this dual combination might converge to a balance in terms of reference. Indeed, while the quantitative assessment roots in the consolidated literature, the qualitative assessment brings in the hands-on calls of local people: one assures theoretical accuracy, the other provides anchorage to reality. Nevertheless, it might be noteworthy that in some domains one assessment approach might be more significant compared to the other, especially if considering the potential further implementation. For instance, the definition of "*disaster*" within the Social-Ecological Panarchy lies in the failure of critical functions. Accordingly, in order to define a "*disaster*", it turns essential to preliminarily identify those critical assets of a community and the tipping point of their functioning. Even though the literature and the practice might be highly informative of those that are commonly assumed as critical infrastructures, it also holds true that local communities might have a rather clear and accurate idea of which services are fundamental for their daily lives. At the same time, those essential necessities might vary depending on local conditions and capacities, in spite of generalisations and standardisations. Consequently, in this domain, the voices and judgements of local communities might be assumed more meaningful than other kinds of judgements, especially if the overarching aim is to tailor local disaster management and development plans to local needs.

Now that the overarching architecture of the proposed enhanced methodology has been presented, the following lines will further focus on the newly introduced qualitative assessment. Hence, a brief exploration of each conceptual section of the questionnaire will be provided, whereas the throughout questionnaire will be available in the Appendix (III). Afterwards, the enhancement of this tool will be presented, stemming from the introduction of the identified case study.

12.2.2 Structure of the qualitative methodology

Resilience and sustainability perception

The first block of questions (n° 1-29) was dedicated to the primary objective, that is identifying the level of resilience and of sustainability of a Municipality (namely, the *sub-unit* of the previous phases of the proposed methodology), as perceived by the local population. To this end, questions were included that mirrored the indicators employed in the previous cluster analysis in order to allow for a direct comparison of the results. Then, further questions concerned other capacities related to the *attributes* (*learn*, *absorb*, *recover*; *services*, *functions*, *integrity*) of the two *cores* (see Table 5.3): for instance, enhancement of flood management activities (*learn*), typology of assets that would suffer flood damages (*absorb*), return to everyday life (*recover*); use of natural water (*services*), extension of green areas (*functions*), protection of natural areas (*integrity*). In order to allow for the association of a level of resilience and of sustainability (see Table 5.4) to each available option, the answers were designed as Likert and Likert-type scales with three viable preferences. Following the requirements of the Likert and Likert-type scales, each answer was assigned a growing numerical value, corresponding to the Level: 1 – LR/LS ; 2 – MR/MS; 3 – HR/HS. It might be interesting to note that, where 1 was related to a "decrease" and 3 to an "increase" in the surveyed variable, 2 was related to unaltered conditions, thence not influenced by flood and flood-related dynamics. This might mean that no chances occurred in the area, but also that a variation indeed occurred (e.g. family income), yet it was not due to flooding events. Nonetheless, in some cases (n° 28-29) four options were envisioned so as to include a more appropriate range of perspectives on the current situation, although later they were reduced to three Levels as well. The correspondence among options and levels was interpreted by the author, following the rationale of considering whether the expressed preference would represent a higher or lower level or resilience and of sustainability. For instance, if the respondent declared that the influence of flood risk led to tighter social bonds, this was assumed as a sign of increased resilience (question n°1). Similarly, if the respondent affirmed an observed worsening of landscape scenery in the past years, this was considered as a sign of decreased sustainability (question n° 25). Nevertheless, in some cases the association worked in the opposite direction: for example, a perceived low number of species in dangerous conditions was assumed as a sign of higher sustainability (question n°26). Within this structure, some space was dedicated to explore the peculiar point of view of the local population on the transformations of their territory: for instance, respondents were asked whether they knew some official plans (e.g. Municipal Civil Protection Plan) and how they first came to know them. In these cases, answers were necessarily arranged as multiple choices, although open-ended questions were kept limited, as previously mentioned.

Critical functions and thresholds

The second section (n° 30-37) was designed with the purpose of investigating the most jeopardising *phase* of the *adaptive cycle*, that is the section of the *cycle* surrounding the potential *collapse*. To this end, a couple of questions solicited the identification of the assets that are considered as fundamental for the survivability of the community (n° 30, 34). Then, it was required to express some preferences on the maintenance of such functions in those crucial times, that is in case of potential heavy damages (n° 31-33, 35-37). In order to achieve this result, it was necessary to preliminary select some proxies for those thresholds. In other words, some significant quantities that could discriminate among different *phases*. The overarching rationale was based on the concept of "rate of tolerance". For the resilience *core*, first of all it was questioned how long it would be possible to live without the critical functions, in case they were interrupted. That is, how long is it possible to tolerate their absence before considering the functions critically lost, thus signalling the collapse (*conservation* to *release phase*)? Then the focus shifted towards the recovery time. In particular, the question concerned how much it would be acceptable to wait until the recovery of such functions (*release* to *reorganisation phase*), thus identifying the maximum tolerance of the permanence in the *back-loop*. Eventually, the last concern related to the quality of the critical functions after recovery (*release* to *exploitation*). For the sustainability *core*, the approach was analogous, except for the first issue that was quantified in terms of acceptability of loss of the ecosystem services. This difference was introduced in order to mirror the previous idea of suspension in the delivery of critical functions, although in a fashion that could be more easily associated to the environment: for instance, living without "clean air" would be impossible *a priori*, hence the answer might be obvious, whereas questioning "how much is it acceptable to lose of those services" might better unravel different levels of tolerance over environmental issues. Overall, the questions of this section needed to be a multiple-choice type. It might be significant to bear in mind that when time spans were concerned, different preferences were available for the two *cores*, because dynamics related to human processes were associated to shorter time scales (few hours to one month) compared to the dynamics associated to natural processes (5 years to 20 years).

Socio-demographic features

The last section (38-55) of the questionnaire was designed to gather information concerning the basic features of the population (e.g. nationality, age, gender, education), as well as other variables that are commonly recognised as potentially significant factors influencing resilience and sustainability attitudes (e.g. participation in local civic organisations, time of residence in the Municipality). In particular, some variables were selected in order to correspond to those included in the previous discriminant analysis, in order to substantiate the parallels between these two research paths. In this section, questions were necessarily multiple-choice and yes/no type. The only open-ended question concerned the Municipality: the respondent was allowed to add their own if it was not included among those of interest listed. By doing so, even though the answer would not be acceptable for the present analysis, it would still be possible to avoid losing potentially interesting points of view.

13. The further case to study

Once the major features of the quali-quantitative investigation were outlined, the further step turned towards the operative enhancement of such tool. In other words, the questionnaire was ready to be employed. In this case, the matter shifts to the population to be involved. Ideally, the questionnaire should be delivered to the case studies that were addressed by the previous phases of the proposed methodology. Unfortunately, resource constraints limited the implementation of this approach, hence it was necessary to scale down the case study. It is acknowledged here that an evident further improvement of the present study would envisage the removal of such limitations, thus extending the application of the thorough proposed methodology to the case studies in their entirety.

In this case, the focus was pointed to the Marche Region. In particular, when examining the distribution of the (quantitively) assessed Levels of Resilience and Sustainability (see Fig. 8.7), it was possible to observe a predominance of the most desirable Levels, whereas the lowest ones were a minority. Furthermore, the highest Levels appeared to be more frequent along the coastal line, while the lowest were more present in the inner areas. Nonetheless, the distribution was not homogeneous throughout the territory of the Region, but rather highly scattered. When overlapping the distribution of the river basins, though, the condition of the Esino basin appeared especially interesting. Differently from the others, in this river basin it was possible to locate all the possible Levels (except for the LR-LS, not appearing among the Marche Region Municipalities). Overall, the Levels would increase moving from the mountains to the coast (approximately West to East). The issues posed by floods are especially relevant to the Esino basin. Overall, the territory of the Esino basin is dotted by critical areas in terms of flood risk. The Italian Law (*D.P.C.M. 29/09/1998*, n.d.) recognises four classes of flood risk, depending on the return time of the probable flood: moderate – medium – high – very high (R1 to R4, respectively). Per each class, the expected damages grow consistently, from irrelevant nuisances to loss of lives, natural assets and socio-economic structures. The Esino river basin presents several areas bounded for the different risk classes (*Piano Stralcio Di Bacino per l'Assetto Idrogeologico Dei Bacini Di Rilievo Regionale (PAI) 21.01.2004*, 2004). Among those, the most part fall under the classes R2 (35.50%) and R4 (25.80%), respectively representing the 0.7% and the 0.4% of the total territory of the basin. Although the values are overall in line with the means related to the Marche Region, the relative wight of the R4 flood risk class holds a higher detrimental potential than in the remaining Region.

Table 13.1 — Extension and percentage of the territory concerned by flood risk, differentiated for the four risk classes, for the Esino river basin, the cumulative and mean values for the Marche Region.

	territory concerned by flood risk									
	number of areas					relative percentage				
	R1	R2	R3	R4	TOT	R1	R2	R3	R4	TOT
Esino	7	11	5	8	31	22.6%	35.50%	16.10%	25.80%	100%
	cumulative number of areas					mean relative percentage				
	R1	R2	R3	R4	TOT	R1	R2	R3	R4	TOT
Marche	161	160	61	50	432	37.30%	37.00%	14.10%	11.60%	100%

	extension (ha)					percentage				
	R1	R2	R3	R4	TOT	R1	R2	R3	R4	TOT
Esino	190.22	855.69	294.02	497.76	1837.69	0.20%	0.70%	0.30%	0.40%	1.60%
	cumulative extension					mean percentage				
Marche	6286.62	6066.63	2102.61	2288.21	16744.07	0.80%	0.70%	0.30%	0.30%	2.00%

Source: Piano Stralcio Di Bacino per l'Assetto Idrogeologico Dei Bacini Di Rilievo Regionale (PAI) 21.01.2004.

As a matter of facts, in the last years a series of events have affected the Municipalities that concern this river basin (Table 13.2).

Table 13.2 — Number of flood events occurred in the Municipalities of the Esino river basin in the period 2011-2015.

Municipality	Number of flood events in 2011-2015 (5 years)
Agugliano	4
Ancona	4
Apiro	4
Arcevia	5
Belvedere Ostrense	2
Camerata Picena	1
Cantiano	5
Castelbellino	4
Castelplanio	3
Castelraimondo	2
Cerreto D'esi	4
Chiaravalle	3
Cupramontana	3
Esanatoglia	1
Fabriano	4
Falconara Marittima	4
Fiuminata	2
Frontone	5
Gagliole	2
Genga	4
Jesi	3
Maiolati Spontini	4
Matelica	2
Mergo	1
Monsano	2
Monte Roberto	2
Monte San Vito	2
Montecarotto	5
Montemarciano	4
Morro D'alba	1
Osimo	3
Ostra	2
Poggio San Marcello	0
Poggio San Vicino	0
Polverigi	1
Rosora	0
San Marcello	4
San Paolo Di Jesi	3
San Severino Marche	2
Santa Maria Nuova	0
Sassoferrato	4
Senigallia	5
Serra San Quirico	1
Serra Sant'abbondio	3
Staffolo	3
mean events	*2.73*

Overall, a mean of 2.73 events occurred in these Municipalities in the studied period, although nearly 38% suffered from a flood event almost once a year, estimation that grows to the point of including more than half of the Municipalities when considering a recurrence of at least three times in that five years period (Table 13.3).

Table 13.3 — Number of municipalities of the Esino river basin and overall incidence of flood events.

NUMBER OF MUNICIPALITIES THAT IN 2011-2015 SUFFERED				
5 events	4 events	3 events	at least 4 events	at least 3 events
5 (11.11%)	12 (26.67%)	8 (17.78%)	17 (37.78%)	25 (55.56%)

All these considerations appear to confirm that not only the suitability of the Esino river basin as a case study to investigate the impact of floods on the development of the local territories and thence communities. Indeed, the distribution of the Levels of Resilience and Sustainability are evenly represented within such boundaries, the flood risk scenario is far from marginal and, additionally, river basins have been suggested as a significant basic unit when discussing the sustainability of local territories (Chaves & Alipaz, 2007). Eventually, it might be interesting to note that by assuming the Esino river basin as the present case study, it would mirror the ideal model previously discussed as a possible archetype (see Ch. 2), hence the application of the Social-Ecological Panarchy model would be immediate.

At this point, it was possible to identify the Municipalities that would be the effective target of the quali-quantitative investigation. The distribution of the Levels of Resilience and Sustainability (Fig. 8.7) was consulted once more to select the appropriate representative for the river basin. Overall, the possible Levels are nine: the LR-LS Level was excluded because of its absence in the Marche Region territory, the HR-LS and the LR-HS Levels were excluded as well, because they have been postulated to represent *traps*, that is rather peculiar conditions that might need to be treated as a separate matter and be discussed more thoroughly. Consequently, a total of six Municipalities were needed in order to exemplify all the remaining Levels (Table 13.4).

Table 13.4 — Combined levels (high H, medium M, low L) of resilience (R) and of sustainability (S) along with the selected Municipalities of the Esino river basin.

Level of Resilience and Sustainability	Municipality
HR-HS	Jesi
HR-MS	Serra San Quirico
MR-HS	San Marcello
MR-MS	Fabriano
MR-LS	Falconara Marittima
LR-MR	Genga
LR-LS	/
LR-HS	/
HR-LS	/

Thence, the questionnaire targeted the population of these Municipalities: Fabriano, Falconara Marittima, Genga, Jesi, San Marcello, Serra San Quirico. These Municipalities are arranged throughout the basin, from upstream towards downstream until the coast, following the course of the Esino river (Fig. 13.1). Except for Serra San Quirico, which was affected just once, all these Municipalities regularly suffered from flood impacts, at least 3, but more frequently 4 times (4 out of 6 Municipalities) in 5 years (Table 13.2).

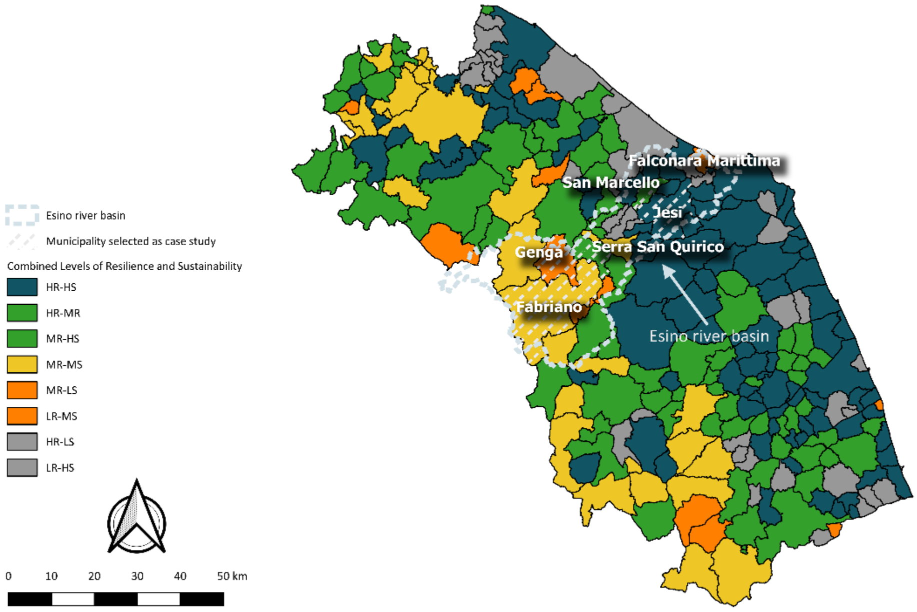


Figure 13.1 — The Esino river basin and the selected Municipalities within the Marche Region.

The questionnaire was thence designed following the structure outlined above (see Ch. 12). Consequently, the variables that echoed the preliminary quantitative phases of the proposed methodology were adjusted to the version tailored to the Marche Region case (see Ch. 6.5). The tool was made available in both Italian and English languages, in order to facilitate the filling in of the potential respondent, addressing the possible linguistic preferences. In this case, an issue of translation emerged: although in English the term "flood" is common and easily understood to describe water-related events, in Italian such a term does not exist, or rather, is usually associated only with river-related events. Consequently, the general term "*inondazione*" was employed and a brief premise on the intended meaning was included in the questionnaire.

Eventually, the process turned to the population. As previously mentioned, the population sampling attempted to adhere as far as possible to the probability-driven techniques, since the present objective focuses on the general perception of the Level of Resilience and Sustainability of a Municipality. In particular, questionnaires were administered thorough a double channel: telephone contacts and in an online format. In the first case, the telephone directory was consulted. The first and the last name of each column was selected, excluding same surnames, as they might lead to members of the same family and thence introduce a possible bias, while if there were not enough columns, the selection proceeded along the available ones. Approximately 10 names per each letter were the first target, though when the telephone number resulted not active, a substitute was included, avoiding a far as possible to repeat surnames also in this case. Only telephone numbers that referred to households were admitted. Telephone numbers were dialled at least twice when it was not possible to obtain an answer in the first attempt. When reaching a respondent, the questionnaires was read and the answers registered manually. In these cases, it often happened that further discussions and thoughts were shared, hence they were recorded as well. Nonetheless, before starting, in case it would have been more convenient for the respondent, it was offered the option to receive via e-mail the link to the online questionnaire. More in general, the online questionnaire was publicised through social media (Facebook shares in personal profile and groups relevant to the local communities). In addition, some key persons related to cultural associations relevant for the local territories were contacted and they assisted in spreading the link among their networks of acquaintances, although the assumption of voluntariness of the participation was not hindered. In spite of the effort to maximise the representativeness of the sample, it is acknowledged here that some biases might be introduced. For instance, the historical socio-demographic features of the Region might lead to a prevalence of women that stay at home and take care of the housework, hence the probability to interact with an unbiased public might be limited. At the same time, although extremely common, the registration to the telephone directory is not mandatory, hence the list might not include the whole population. Similarly, although the employed social media is highly popular, it might not reach the entirety of the local communities. Though it is evident that these restrains might hamper the reliability of the sampling, the mixed technique and the extension of the outreached sought to compensate for those drawbacks.

In the following lines, the discussion will progress towards the outcomes of those endeavours and how they settle in the overarching picture delineated by the findings of the previous phases of the enhanced methodology proposed for this research study.

14. Results

Throughout the above lines, the matter of engaging local population in the comprehension and management of their communities led to the emergence of the need to gather their perspectives in terms of disaster resilience and environmental sustainability. Consequently, a positivist approach was adopted to guide the design of a qualitative methodology to investigate the local perception of resilience and sustainability, thus yielding to the CARES+ (Combined Assessment of Resilience and Sustainability) methodology. At that point, the further step involved the identification of suitable case studies to implement such research method: based on the output of the previous quantitative assessment, six Municipalities were selected in the Marche Region that would be enclosed within the same river basin (i.e. Esino river basin) and would represent a different combined level of resilience and sustainability each. Thence, in the coming paragraphs the results deriving from the delivered questionnaires will be presented. Following the introduction of the overall gathered responses, the discussion will be divided into two main parts: first, some considerations pertaining the Municipalities as a whole, thence the information could be considered as an averaged value over the Municipal population; then, some considerations associated to the answer of each respondent, thence the information could be assumed as an averaged value over the level, perceived or assessed, of resilience, sustainability or combined.

14.1 Introduction of the local responses

As previously mentioned, questionnaires were delivered through a double channel, that is via phone administration and through an online form. The collected information concerned resilience and sustainability themes as well as demographic variables. In addition to providing information for the discussion to come, the latter allows also to delineate the main characteristics of the respondent population. The overall results, distinguished per Municipality, will be thoroughly presented: here, the discussion will proceed following the thematic sections of the questionnaire. Later, the focus will be directed only towards the analyses of the responses that held a peculiar or unexpected meaning.

14.1.1 Assessment of the perceived level of resilience

The first section of the questionnaire held a primary role, as it was intended to draw the level of resilience from the unique viewpoint of the local communities. For this purpose, the questions and the available choices were selected in order to mirror as far as possible the conceptualisation laid out for the previous quantitative assessment (see Ch. 5). In general terms, respondents were questioned on themes related to resilience capacities, as well as their observed implementation in critical conditions (Table 14.1).

Table 14.1 — Number of preferences per each question and each related level (low L, medium M, high H) of resilience (R), per each Municipality.

ANSWERS	OPTIONS	CORRESPONDING LEVEL	MUNICIPALITY					
			FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*
Effect of flood risk on:								
			1. social cohesion					
valid	worse	LR	3	4	0	2	1	3
	as usual	MR	14	16	7	19	16	12
	better	HR	2	2	6	5	0	1
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16
			2. household income					
valid	worse	LR	5	8	4	10	3	2
	as usual	MR	13	13	8	15	13	14
	better	HR	0	1	1	1	1	0
	total		18	22	13	26	17	16
missing			1	0	0	0	0	0
total			19	22	13	26	17	16
			3. infrastructural development					
valid	worse	LR	4	6	1	4	4	0
	as usual	MR	11	13	6	16	12	13
	better	HR	3	2	6	6	1	3
	total		18	21	13	26	17	16
missing			1	1	0	0	0	0
total			19	22	13	26	17	16
			4. flood management activities					
valid	less activities	LR	5	7	5	5	7	5
	as usual	MR	8	9	6	15	9	8
	more activities	HR	6	5	1	6	1	3
	total		19	21	12	26	17	16
missing			0	1	1	0	0	0
total			19	22	13	26	17	16
			5. number of flood-proof buildings and infrastructures					
valid	lower	LR	3	6	2	6	2	2
	as usual	MR	12	13	8	19	14	14
	higher	HR	3	2	3	1	1	0
	total		18	21	13	26	17	16
missing			1	1	0	0	0	0
total			19	22	13	26	17	16
			6. my fellow citizens have become more aware of flood risk					
valid	disagree	LR	6	11	5	7	5	1
	uncertain, neutral	MR	4	4	4	13	6	5
	agree	HR	9	7	4	6	6	10
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16

			7. I have become more aware of flood risk					
valid	disagree	LR	4	1	2	3	4	0
	uncertain, neutral	MR	4	6	2	11	2	1
	agree	HR	11	15	9	12	11	15
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16
			8. the citizens of my Municipality have enough means and sources to manage a flood emergency					
valid	disagree	LR	13	17	6	16	4	8
	uncertain, neutral	MR	2	3	4	7	9	5
	agree	HR	4	2	3	3	4	3
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16
Effect of last flood on:								
			9. population growth in flooding areas					
valid	less people	HR	7	4	6	9	2	2
	as usual	MR	11	14	6	15	15	14
	more people	LR	1	3	1	2	0	0
	total		19	21	13	26	17	16
missing			0	1	0	0	0	0
total			19	22	13	26	17	16
			10. economic welfare					
valid	worse	LR	8	9	1	10	4	1
	as usual	MR	10	13	12	15	13	15
	better	HR	0	0	0	1	0	0
	total		18	22	13	26	17	16
missing			1	0	0	0	0	0
total			19	22	13	26	17	16
			11. amount of damage					
valid	low	HR	13	9	2	11	9	7
	not high not low	MR	3	6	6	10	5	5
	high	LR	3	7	5	5	3	4
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16
			12. recovery of social life and public services					
valid	absent	LR	1	2	2	3	0	1
	partial	MR	10	13	3	14	4	6
	complete	HR	8	7	8	9	13	9
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16
			13. duration of recovery of social life and public services					
valid	long	HR	4	5	3	2	1	3
	not long not short	MR	5	10	7	13	7	9
	short	LR	10	7	3	11	9	4
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16
			14. return to everyday life					
valid	absent	LR	1	0	1	0	0	0
	partial	MR	5	12	3	15	4	6
	complete	HR	13	10	9	11	13	10
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0

total			19	22	13	26	17	16
16. local authorities have become able to effectively manage a flood emergency								
valid	disagree	LR	6	10	5	8	2	5
	uncertain, neutral	MR	7	7	5	13	9	2
	agree	HR	6	5	3	5	6	9
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16
17. my fellow citizens have become able to effectively manage a flood emergency								
valid	disagree	LR	7	12	3	10	2	7
	uncertain, neutral	MR	7	7	7	15	9	3
	agree	HR	5	3	3	1	6	6
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16
18. I have become able to effectively manage a flood emergency								
valid	disagree	LR	8	8	4	10	3	5
	uncertain, neutral	MR	7	8	5	13	7	4
	agree	HR	4	6	4	3	7	7
	total		19	22	13	26	17	16
missing			0	0	0	0	0	0
total			19	22	13	26	17	16

The participation to this section was rather high, with few missing responses. Similarly, preferences were distributed throughout the available options, with few cases of no selected option (e.g. question *1. Social cohesion*, option "*better*" for respondents from San Marcello), even though the distribution was generally not homogenous.

14.1.2 Assessment of the perceived level of sustainability

This section was complementary to the previous one and thus completed the first part of the questionnaire, pursuing the aim of drawing the perceived level of sustainability of the selected Municipalities from the perspective of the local communities. Consequently, also in this case themes mirrored those included in the previous quantitative assessment (see Ch. 5), as well as introduced topics concerning the impact of anthropic activities on the surrounding environment (Table 14.2).

Table 14.2 — Number of preferences per each question and each related level (low L, medium M, high H) of sustainability (S), per each Municipality.

ANSWERS	OPTIONS	CORRESPONDING LEVEL	MUNICIPALITY					
			FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*
			19. transformation of green areas					
valid	smaller	LS	6	2	0	4	4	1
	as usual	MS	9	15	10	16	12	8
	wider	HS	4	4	3	6	1	7
	total		19	21	13	26	17	16
missing			0	1	0	0	0	0
total			19	22	13	26	17	16
			20. land use change					
valid	low	HS	8	8	5	6	10	10
	average	MS	7	9	5	12	5	6
	high	LS	4	4	3	8	2	0
	total		19	21	13	26	17	16
missing			0	1	0	0	0	0
total			19	22	13	26	17	16
			21. quantity of urban and industrial use of water					
valid	lower	HS	8	1	1	3	2	4
	as usual	MS	9	13	7	17	8	9
	higher	LS	1	7	5	6	6	3
	total		18	21	13	26	16	16
missing			1	1	0	0	1	0
total			19	22	13	26	17	16
			22. characteristics of the river area					
valid	worse	LS	5	6	3	3	6	5
	as usual	MS	8	10	6	20	11	9
	better	HS	6	4	4	2	0	2
	total		19	20	13	25	17	16
missing			0	2	0	1	0	0
total			19	22	13	26	17	16
			23. soil fertility					
valid	lower	LS	5	5	4	9	3	5
	as usual	MS	11	12	8	14	6	9
	higher	HS	2	4	1	2	6	2
	total		18	21	13	25	15	16
missing			1	1	0	1	2	0
total			19	22	13	26	17	16
			24. wildlife catches					
valid	lower	LS	8	7	1	7	4	2
	as usual	MS	7	10	3	15	7	5
	higher	HS	3	3	9	3	2	8
	total		18	20	13	25	13	15
missing			1	2	0	1	4	1
total			19	22	13	26	17	16
			25. landscape scenery					
valid	worse	LS	4	11	5	5	4	1
	as usual	MS	11	9	5	17	8	9
	better	HS	4	1	3	3	5	6
	total		19	21	13	25	17	16
missing			0	1	0	1	0	0
total			19	22	13	26	17	16
			26. number of species in dangerous conditions					

valid	low	HS	6	7	6	4	7	4
	average	MS	10	9	6	18	7	11
	high	LS	3	4	1	3	1	1
	total		19	20	13	25	15	16
missing			0	2	0	1	2	0
total			19	22	13	26	17	16
27. effects of human activities on rivers and streams								
valid	negative	LS	9	12	2	8	9	4
	not negative not positive	MS	5	4	8	11	2	3
	positive	HS	5	5	3	6	3	9
	total		19	21	13	25	14	16
missing			0	1	0	1	3	0
total			19	22	13	26	17	16
28. protection of natural areas								
valid	insufficient	LS	4	7	4	4	2	2
	inadequate and no possibility of changes	LS	5	2	1	5	5	5
	inadequate, but changes are happening	MS	5	8	0	7	2	3
	significant	HS	3	3	6	9	6	6
	total		17	20	11	25	15	16
missing			2	2	2	1	2	0
total			19	22	13	26	17	16
29. initiatives to reduce pollution								
valid	insufficient	LS	4	13	4	10	5	4
	inadequate and no possibility of changes	LS	5	4	2	1	3	5
	inadequate, but changes are happening	MS	5	3	4	11	4	5
	significant	HS	3	1	3	3	3	2
	total		17	21	13	25	15	16
missing			2	1	0	1	2	0
total			19	22	13	26	17	16

Similarly to the previous case, the participation to this section was rather high in terms of responses. The distribution of preferences was rather diverse, although not particularly even.

14.1.3 Critical functions and thresholds of resilience and of sustainability

The themes presented in this section of the questionnaire aimed at gathering the perception of the local communities on the characterising traits of their local Social-Ecological System. In other words, the purpose was to allow local populations to identify and possibly quantify the most significant functions (Table 14.3) and thresholds (Table 14.4) related to the adaptive cycles composing their local Social-Ecological Panarchy.

Table 14.3 — Number of preferences per each question concerning the critical functions of resilience and sustainability, per each Municipality.

ANSWERS		OPTIONS	MUNICIPALITY						
			FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*	*total*
		30. most important functions for resilience							
valid		productive system	13	7	5	12	4	1	42
		banking/financial services	2	0	0	1	0	0	3
		energy system	5	4	2	5	4	7	27
		transportation system	5	3	4	4	1	7	24
		water system	9	6	2	6	5	6	34
		sewage system	4	7	0	3	1	1	16
		waste disposal system	7	8	1	5	5	4	30
		health system	8	12	7	14	12	9	62
		police service	1	5	2	6	4	1	19
		education system	7	12	5	7	4	0	35
		communication system	1	1	0	1	0	1	4
		social life	1	2	2	3	1	0	9
	total		18	21	13	25	15	15	107
missing			1	1	0	1	2	1	6
total			19	22	13	26	17	16	113

ANSWERS		OPTIONS	MUNICIPALITY						
			FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*	*total*
		34. most important functions for sustainability							
valid		food production	12	7	7	18	11	10	65
		raw materials production	3	5	2	7	4	4	25
		soil formation	3	5	1	3	3	1	16
		clean air supply	13	21	9	13	5	10	71
		clean water supply	16	19	12	20	11	11	89
		precipitation regulation	0	1	0	1	0	1	3
		scenery	2	4	4	4	3	3	20
	total		18	21	13	25	15	14	106
missing			1	1	0	1	2	2	7
total			19	22	13	26	17	16	113

Table 14.4 — Number of preferences per each question and the main critical thresholds of resilience and sustainability, per each Municipality.

ANSWERS	OPTIONS	MUNICIPALITY					
		FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*
Resilience							
	31. maximum acceptable duration of recovery						
valid	up to 1 day	2	7	4	5	5	2
	up to 1 month	1	3	0	5	1	1
	up to 1 week	4	4	6	5	3	4
	few hours	11	7	3	10	6	8
	total	18	21	13	25	15	15
missing		1	1	0	1	2	1
total		19	22	13	26	17	16
	32. acceptable quality after recovery						
valid	worse	1	1	0	1	0	0
	as before	4	4	4	12	9	8
	better	13	16	9	12	6	7

	total	18	21	13	25	15	15
missing		1	1	0	1	2	1
total		19	22	13	26	17	16
33. duration of alternative sources to cope with critical function interruption							
valid	up to 1 day	4	6	5	4	3	3
	up to 1 month	3	2	3	1	3	2
	up to 1 week	5	10	4	13	5	5
	few hours	6	3	1	7	3	5
	total	18	21	13	25	14	15
missing		1	1	0	1	3	1
total		19	22	13	26	17	16
Sustainability							
35. maximum acceptable duration of recovery							
valid	20 years	0	0	0	0	2	0
	10 years	0	3	0	1	0	2
	5 years	16	17	13	21	12	12
	impossible	0	1	0	2	0	0
	no need	1	0	0	1	0	0
	total	17	21	13	25	14	14
missing		2	1	0	1	3	2
total		19	22	13	26	17	16
36. acceptable quality after recovery							
valid	worse	1	0	1	0	0	0
	as before	3	5	3	10	6	5
	better	14	16	9	15	8	9
	total	18	21	13	25	14	14
missing		1	1	0	1	3	2
total		19	22	13	26	17	16
37. acceptable loss							
valid	until you can compensate for them	6	7	4	5	3	6
	until you can make use of them	0	2	2	4	1	2
	none	12	12	6	16	11	4
	all	0	0	1	0	0	1
	total	18	21	13	25	15	13
missing		1	1	0	1	2	3
total		19	22	13	26	17	16

Also in this section of the questionnaire, the missing cases are rather low, when considering both functions and thresholds of the complex Social-Ecological System. in the case of resilience functions, all options received preferences, except for the case of *banking and financial services* and the *communication system* that were chosen only 3 and 4 times (out of the 107 total expressed preferences), respectively. Conversely to the rather dispersed distribution of preferences for the resilience function, the case of sustainability was more consistent, with *water*, *air* and *food* received the wide majority of the preferences, while *precipitation regulation* gathered the lowest consensus (3 total preferences out of the 106 expressed).

A similar trend might be observed when examining the preferences concerning the thresholds. Indeed, the thresholds concerning resilience were less defined than those pertaining to sustainability, where preferences were evidently polarised towards the lowest tolerance of loss and endangerment.

14.1.4 Socio-demographic features

The last section of the questionnaire was devoted to the characterisation of the responding population. Consequently, themes concerned the common demographic and social features, as well as economic traits and available assets (Table 14.5).

Table 14.5 — Number of preferences per each question related to the socio-demographic features of the responding population, per each Municipality.

ANSWERS	OPTIONS	MUNICIPALITY					
		FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*
38. place of birth							
valid	Africa	0	0	0	0	0	0
	America	0	0	0	0	0	1
	Asia	0	0	0	0	0	0
	Europe (other than Italy)	1	0	1	0	1	0
	Italy	18	21	12	25	14	15
	Oceania	0	0	0	0	0	0
	total	19	21	13	25	15	16
missing		0	1	0	1	2	0
total		19	22	13	26	17	16
39. gender identified with							
valid	female	15	9	9	15	7	11
	male	4	13	4	11	10	5
	total	19	22	13	26	17	16
missing		0	0	0	0	0	0
total		19	22	13	26	17	16
40. class of age							
valid	less than 18 years old	0	0	0	0	0	0
	18-24 years old	1	2	1	4	2	1
	25-34 years old	3	4	1	3	1	2
	35-44 years old	0	5	1	0	1	0
	45-54 years old	4	3	4	7	2	0
	55-64 years old	5	2	3	6	4	6
	65-79 years old	6	5	2	5	5	5
	over 80 years old	0	0	1	0	2	2
	total	19	21	13	25	17	16
missing		0	1	0	1	0	0
total		19	22	13	26	17	16
41. highest level of education							
valid	primary school	1	1	1	1	1	3
	middle school	2	2	0	2	4	5
	high school	7	9	7	9	6	5
	Bachelor’s degree or equivalent	0	2	2	3	1	1
	Master’s degree or equivalent	7	6	3	7	3	2

	post-graduate degree, Doctoral degree or equivalent	2	1	0	3	0	0
	total	19	21	13	25	15	16
missing		0	1	0	1	2	0
total		19	22	13	26	17	16
42. municipality of residence							
valid	Fabriano	19	0	0	0	0	0
	Falconara Marittima	0	22	0	0	0	0
	Genga	0	0	13	0	0	0
	Jesi	0	0	0	26	0	0
	San Marcello	0	0	0	0	17	0
	Serra San Quirico	0	0	0	0	0	16
	total	19	22	13	26	17	16
missing		0	0	0	0	0	0
total		19	22	13	26	17	16
43. permanence in municipality of residence							
valid	1 year or less	0	1	0	1	0	0
	2-5 years	0	1	0	0	0	0
	5-10 years	1	0	0	0	1	0
	more than 10 years	18	19	13	24	14	16
	total	19	21	13	25	15	16
missing		0	1	0	1	2	0
total		19	22	13	26	17	16
44. number of cohabitants							
valid	1	1	4	1	4	0	2
	2	6	6	5	7	4	7
	3-4	11	10	5	9	7	6
	more than 4	1	1	2	4	4	1
	total	19	21	12	24	15	16
missing		0	1	1	2	2	0
total		19	22	13	26	17	16
45. presence of minors among cohabitants							
valid	no	14	19	10	19	10	15
	yes	5	2	3	6	5	1
	total	19	21	13	25	15	16
missing		0	1	0	1	2	0
total		19	22	13	26	17	16
46. local civic organisation participation							
valid	no	15	12	10	13	10	13
	yes	4	9	3	12	5	3
	total	19	21	13	25	15	16
missing		0	1	0	1	2	0
total		19	22	13	26	17	16
47. national election participation							
valid	no	0	0	0	4	2	2
	yes	19	21	13	21	13	14
	total	19	21	13	25	15	16
missing		0	1	0	1	2	0
total		19	22	13	26	17	16
48. current employment							
valid	no	8	6	3	11	6	8
	yes	11	15	10	14	9	8
	total	19	21	13	25	15	16
missing		0	1	0	1	2	0
total		19	22	13	26	17	16
49. class of income							
valid	0-15 000€	6	1	5	6	4	11

	15 001-30 000€	10	13	5	9	5	3
	30 001-50 000€	2	3	3	4	2	2
	more than 50 000€	0	0	0	4	1	0
	total	18	17	13	23	12	16
missing		1	5	0	3	5	0
total		19	22	13	26	17	16
50. ownership of phone							
valid	no	2	0	0	0	3	1
	yes	17	21	13	25	12	15
	total	19	21	13	25	15	16
missing		0	1	0	1	2	0
total		19	22	13	26	17	16
51. ownership of personal means of transportation							
valid	no	3	2	1	2	0	2
	yes	16	19	12	23	14	14
	total	19	21	13	25	14	16
missing		0	1	0	1	3	0
total		19	22	13	26	17	16
52. internet access at home							
valid	no	3	1	1	2	1	4
	yes	16	20	12	23	13	12
	total	19	21	13	25	14	16
missing		0	1	0	1	3	0
total		19	22	13	26	17	16
53. average data speed at home							
valid	less than 2 Mb/s	1	0	5	1	0	1
	more than 2 Mb/s	2	4	6	4	5	2
	more than 20 Mb/s	3	5	1	5	1	1
	more than 50 Mb/s	5	4	0	5	2	1
	more than 100 Mb/s	2	4	0	6	0	0
	total	13	17	12	21	8	5
missing		6	5	1	5	9	11
total		19	22	13	26	17	16
54. ownership of house							
valid	no	5	4	2	6	3	1
	yes	14	16	11	18	11	15
	total	19	20	13	24	14	16
missing		0	2	0	2	3	0
total		19	22	13	26	17	16
55. age of house							
valid	1918 or before	3	0	0	4	4	0
	1919-1945	0	4	1	0	0	1
	1946-1960	2	2	0	0	5	3
	1961-1970	1	6	4	5	0	2
	1971-1980	2	6	0	5	1	4
	1981-1990	5	3	3	6	1	6
	1991-2000	3	0	2	3	1	0
	2001-2005	1	0	2	2	1	0
	2006 or after	1	0	0	0	0	0
	total	18	21	12	25	13	16
missing		1	1	1	1	4	0
total		19	22	13	26	17	16

Although even in this case the rate of response was high, some themes raised some diffidence, hence the willingness to answer resulted lower. In particular, this happened for economic themes, especially when related to the *class of income* (question *49*). At the same time, *internet speed* (question *53*) was rarely addressed, although this might be due to an authentic unawareness of the actual capacity of their network.

14.1.5 Additional information

Throughout the questionnaire, some additional questions were enclosed, with the aim of collecting further information on the dynamics occurring in the selected Municipalities, soliciting the point of view of those who experienced such processes (Table 14.6, 14.7, 14.8, 14.9 and 14.10). It might be noted that not all of these questions were mandatory, hence the rate of response was expected to be lower than in the other cases. Furthermore, conversely to the overall setting, some of these questions allowed a multiple choice of the available options.

Table 14.6 — Number of preferences per most common flood management activity, per each Municipality.

ANSWERS	OPTIONS	MUNICIPALITY						
		FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*	*total*
4.1 most common management activities								
valid	construction and management of embankments	3	5	3	8	1	6	26
	river management	4	6	5	11	1	4	31
	drainage system management	4	4	3	6	4	2	23
	coastal defence	0	7	0	0	0	0	7
	coastal maintenance	1	9	0	2	0	0	12
	urban development planning	2	2	0	6	1	1	12
	flood-related maps	1	0	0	1	0	1	3
	early warning systems	5	3	2	6	1	0	17
	total	20	36	13	40	8	14	131
total respondents		12	16	8	20	4	7	67
missing respondents		7	6	5	6	13	9	46
total		19	22	13	26	17	16	113

When questioned on the most frequent activity implemented to reduce flood risk, the majority of the preferences was gathered by activities pertaining the river (31 preferences out of total 131) or its embankments (26 preferences out of total 131), followed by the management of the drainage system (23 preferences out of total 131). On the contrary, the design and adoption of flood maps was not particularly witnessed (3 preferences out of total 131).

It might be noted that respondents were demanded to indicate only the activities performed within their own Municipality, hence it should be expected that the preferences to the options related to the sea coasts (*coastal defence* and *coastal maintenance*) were more rarely selected, given that only one Municipality (Falconara Marittima) lies on the sea side. Nevertheless, in this case, such options were indicated by 7 and 9 respondents, respectively, out of the 36 total expressed preferences.

Table 14.7 — Number of preferences per asset that would suffer more damages due to a flood, per each Municipality.

ANSWERS	OPTIONS	MUNICIPALITY						
		FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*	*total*
	11.1 which would suffer more damages							
valid	public buildings	0	0	3	3	2	2	10
	private buildings	8	13	8	16	2	8	55
	productive system	5	9	6	10	6	6	42
	energy system	2	0	2	3	1	0	8
	banking/financial services	1	1	0	0	0	0	2
	communication system	3	1	1	0	2	0	7
	transportation system	5	6	6	8	4	2	31
	health system	0	0	1	0	0	0	1
	water system	4	7	1	3	1	1	17
	sewage system	6	6	1	6	2	2	23
	waste disposal system	0	0	1	2	0	2	5
	none	0	0	0	0	2	0	2
	total	34	43	30	51	22	23	203
total respondents		14	17	13	24	14	10	92
missing respondents		5	5	0	2	3	6	21
total		19	22	13	26	17	16	113

In the context of the potential impact of a flood, respondents were surveyed on the perceived susceptibility of local assets (Table 14.7). The expressed concern converged towards *private buildings* and the *productive system* (55 and 42 preferences out of total 203), whereas *banking and financial services* received the lowest preference. It might be relevant to observe that it was extremely rare that respondents assumed that no assets would be damaged by the impact of a flood event (option *none*, 2 preferences out of the total 203) and when this occurred, it pertained only one Municipality (San Marcello).

Table 14.8 — Number of preferences per each question concerning awareness of local flood management plans, per each Municipality.

ANSWERS	OPTIONS	MUNICIPALITY						
		FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*	*total*
	15. knowledge of local and regional flood management plans							
valid	Municipal Civil Protection Plan	6	10	4	8	1	1	30
	Flood Risk Management Plan	2	4	1	3	1	0	11
	River Contract	0	1	1	4	0	1	7

	none of the above	13	12	9	16	16	14	80
	other	0	1	2	0	0	0	3
	total	21	28	17	31	18	16	131
total respondents		19	22	13	26	17	16	113
missing respondents		0	0	0	0	0	0	0
total		19	22	13	26	17	16	113
15.1 level of knowledge of local and regional flood management plans								
valid	I have read it/them	2	4	1	2	1	2	12
	I have attended discussions about it/them	2	4	0	6	0	0	12
	I have heard about it/them	2	4	2	3	0	0	11
total respondents		6	12	3	11	1	2	35
missing respondents		13	10	10	15	16	14	78
total		19	22	13	26	17	16	113
15.2 source of knowledge of local and regional flood management plans								
valid	by word of mouth among acquaintances	1	3	2	3	0	0	9
	television and/or radio	1	0	0	0	0	0	1
	books and/or magazines and/or newspapers	1	0	0	3	0	0	4
	websites and/or social media	0	3	0	1	0	1	5
	websites and/or social media of public authorities	1	4	0	2	0	0	7
	mails and/or e-mails from public authorities	0	1	0	0	0	0	1
	activities and/or flyers of public authorities	1	1	1	1	1	1	6
total respondents		5	12	3	10	1	2	33
missing respondents		14	10	10	16	16	14	80
total		19	22	13	26	17	16	113

Within the main section of the questionnaire, it was possible to investigate the awareness on the local plans and strategies to manage flood risk and emergency (Table 14.8). In general terms, it appears that the familiarity with this kind of strategic planning is rather limited, as most of the respondents admitted of not being knowledgeable of any (question *15*, option *none of the above*, 80 preferences of the total 131). In the remaining cases, local Civil Protection Plans (question *15*, option *Municipal Civil Protection Plan*, 30 preferences of the total 131) were most commonly acknowledged, although the level of detail was heterogeneous (question *15.1*), whereas it appeared that the most common means of first information was a discussion with relatives or acquaintances, followed by official communications delivered by the local authorities through their websites and social media (question *15.2*, option *by word of mouth among acquaintances* and *websites and/or social media of public authorities*, 9 and 7 preferences of the total 33 respectively).

Table 14.9 — Number of preferences per personal capacities in dealing with flood emergency, per each Municipality.

ANSWERS	OPTIONS	MUNICIPALITY						
		FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*	*total*
18.1 reason of personal efficacy in flood emergency management								
valid	I learnt the emergency procedures	2	6	2	7	1	2	20
	I survived the last flood	0	1	1	1	0	0	3
	I am sure that I will get help	5	4	3	4	1	2	19

total respondents	7	11	6	12	2	4	42
missing respondents	12	11	7	14	15	12	71
total	19	22	13	26	17	16	113

A further question (*18.1*) related to flood events concerned the personal capacity to face an emergency (Table 14.9), conditioned by a positive response to the previous question (*18. I have become able to effectively manage a flood emergency*). In this case, almost equally confidence was attributed to acquired abilities and to provided assistance (option *I learnt the emergency procedures* and *I am sure that I will get help*, 20 and 19 preferences of the total 42 respectively), whereas it appears that the last flood event did not leave any positive effect in this context (option *I survived the last flood*, 3 preferences of the total 42 respectively).

Table 14.10 — Number of preferences per typology of land use change, per each Municipality.

ANSWERS	OPTIONS	MUNICIPALITY						
		FABRIANO	*FALCONARA MARITTIMA*	*GENGA*	*JESI*	*SAN MARCELLO*	*SERRA SAN QUIRICO*	*total*
20.1 most frequent type of land use change								
valid	urbanisation	9	11	3	15	6	2	46
	industrialisation	1	4	1	2	0	2	10
	naturalisation	2	2	3	5	1	3	16
	total	12	17	7	22	7	7	72
missing		7	5	6	4	10	9	41
total		19	22	13	26	17	16	113

Along with the previous questions surveying specific resilience themes, a side question was included also for the sustainability domain (Table 14.10). In this case, the theme concerned the alteration of the surrounding landscape. It emerged that anthropic activities appeared to cause the most frequent transformations, especially in terms of urban settlements (46 preferences out of total 72). It might be noteworthy that even though limited, also the conversion to natural areas was reported by a significant share of respondents (16 preferences out of total 72).

14.2 Analysis of the Municipal response

As previously mentioned, a strategy to investigate the meaning of the responses might be based on an aggregation carried on at a Municipal level. The present section is aimed at delving into the local perception from such standpoint, beginning from questioning the structure of the responding population (Table 14.11).

Table 14.11 — Number of collected questionnaires and main characteristics of the respondent population of the surveyed Municipalities, including the respective assessed combined level of resilience and sustainability.

		Municipality					
		Fabriano	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*
combined assessed level of resilience and sustainability		MR-MS	MR-LS	LR-MS	HR-HS	MR-HS	HR-MS
population (2018)		30809	26063	1748	40210	2036	2744
number of questionnaires (TOT = 112)		19	22	13	26	17	16
gender	*female*	15	9	9	14	7	11
	male	4	13	4	11	10	5
most frequent class of age		65-80 years old	35-44 years old 65-80 years old	45-54 years old	45-54 years old	65-80 years old	55-64 years old
most frequent class of education		high school Master's degree or equivalent	high school	high school	high school	high school	middle school high school
most frequent class of income		15 001-30 000€	15 001-30 000€	15 001-30 000€	15 001-30 000€	15 001-30 000€	0-15 000€
most frequent class of residence in the Municipality		more than 10 years	more than 10 years	more than 10 years	more than 10 years	more than 10 years	more than 10 years

In particular, the survey campaign allowed to retrieve a total of 113 questionnaires, almost evenly distributed among the Municipalities (Fig. 14.1), with Jesi holding the highest portion (26 questionnaires, 23% of the total) and Genga the lowest one (13 questionnaires, 12% of the total). This corresponds to the different dimension of the corresponding populations (Table 14.11), as Municipality of Jesi hosts the largest population (40210 residents) all through Municipality of Genga, which hosts the smaller (1748 residents).

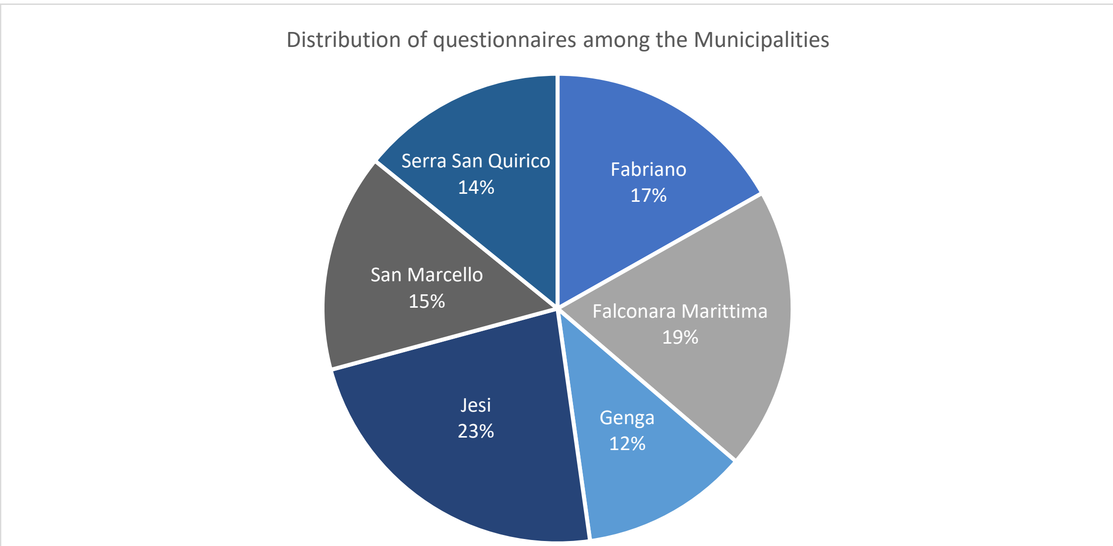


Figure 14.1 — Portion of the collected questionnaires per each surveyed Municipality.

Overall, the majority of the respondents declared a female gender, except for the Municipalities of Falconara Marittima and of San Marcello, whose respondents were mainly of a male gender (Fig. 14.2). it might be interesting to observe that even though the option outside the gender binarism was proposed, none of the respondents selected it, hence it is not present in the presentation of these outcomes.

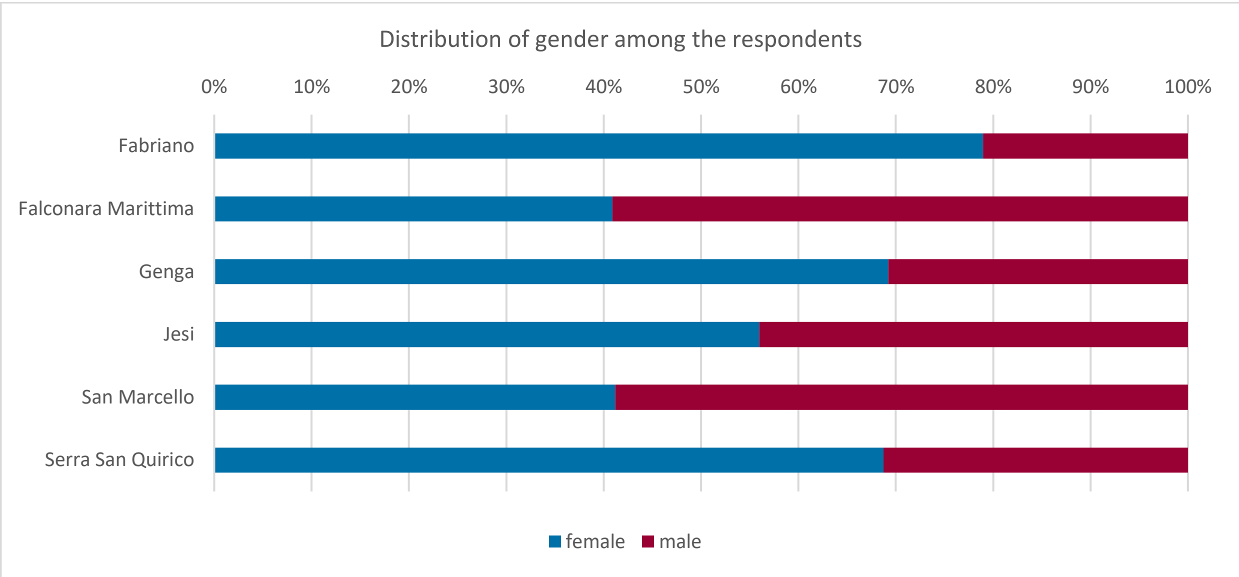


Figure 14.2 — Portion of each gender among the respondents per each surveyed Municipality.

The respondents were distributed among all the classes of age, although in some cases not all classes were represented (Fig. 14.3). The respondents of the Municipalities differed also in terms of most frequent class, although in general the more adult classes were dominant (45-54 to 65-80 years old), except for Falconara Marittima, which showed an equally relevant component in the class 35-44 years old.

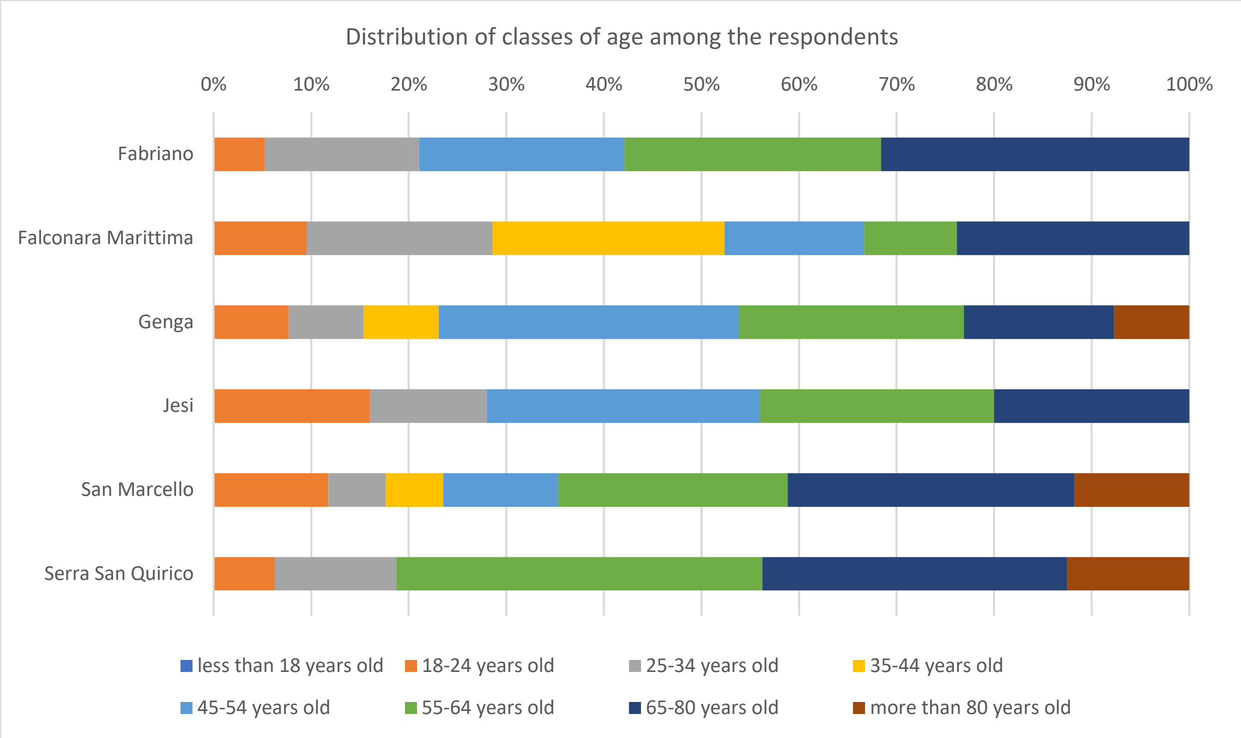


Figure 14.3 — Portion of each class of age among the respondents per each surveyed Municipality.

In general terms, most of the respondents declared to have achieved a level of education corresponding to high school, although the respondents of Fabriano municipality equally declared a Master's degree (or equivalent) and those from Serra San Quirico a middle school level (Fig. 14.4).

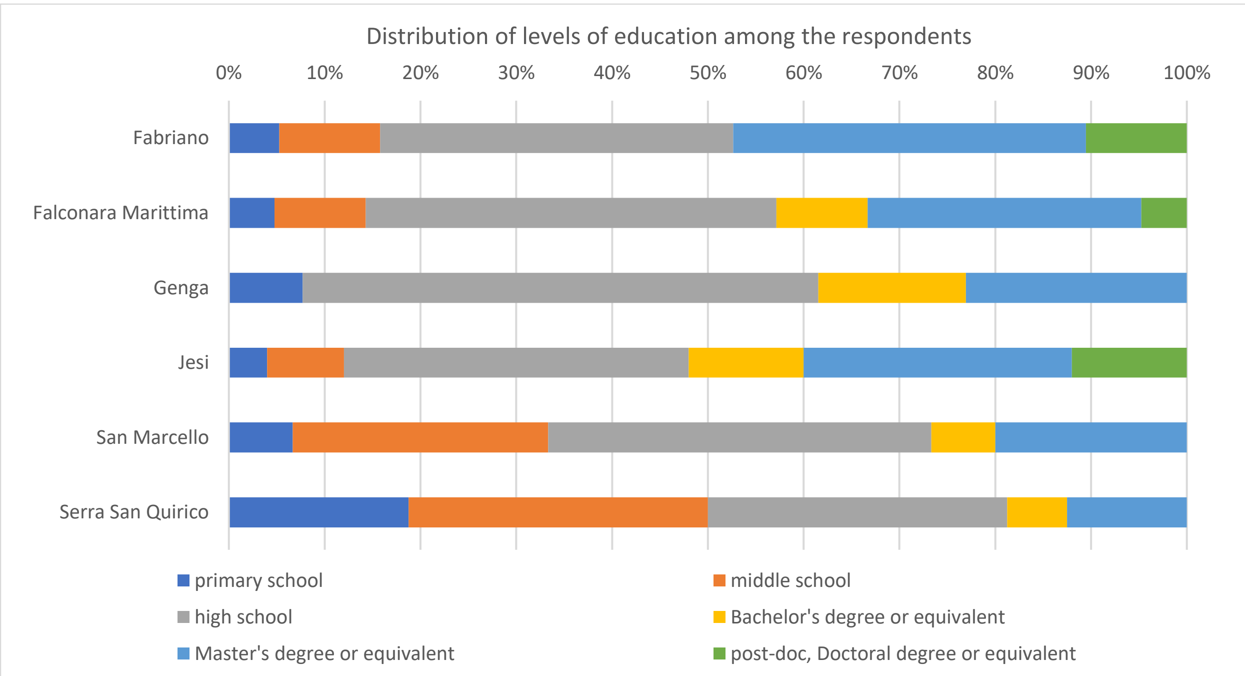


Figure 14.4 — Portion of each level of education among the respondents per each surveyed Municipality.

The respondent population resulted rather homogeneous in terms of income, as the majority was distributed between the first two levels (0-15000€ and 15001-30000€), almost reaching a cumulative 90% of the collected answers for two Municipalities, Fabriano and Serra San Quirico (Fig. 14.5).

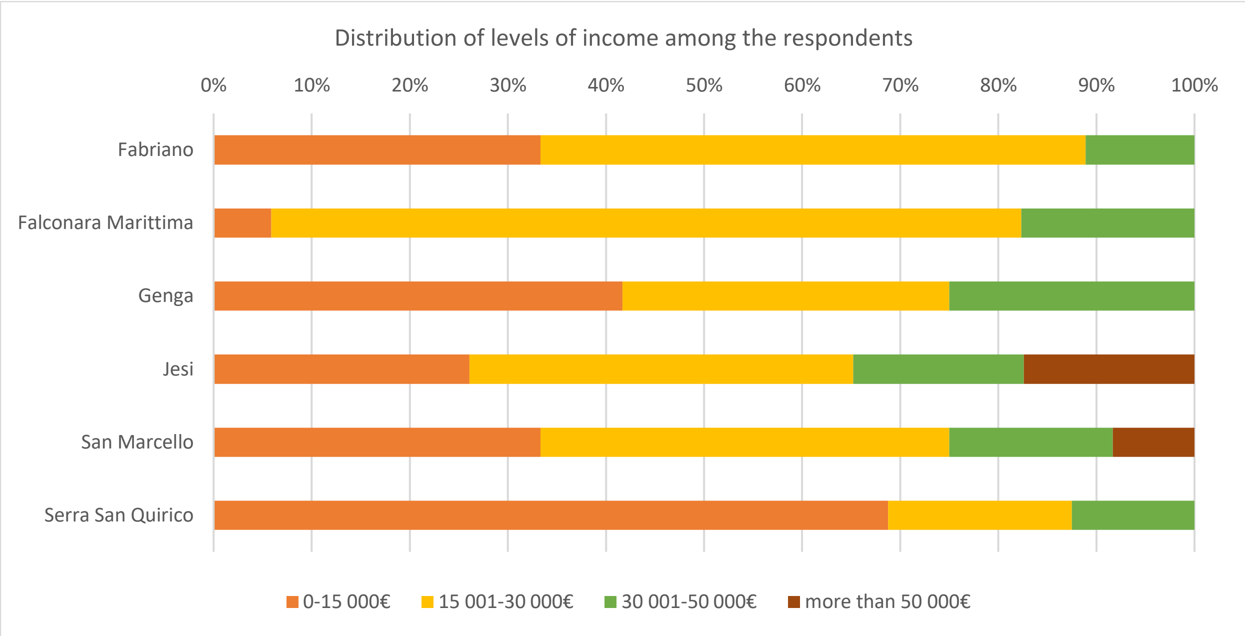


Figure 14.5 — Portion of each level of income among the respondents per each surveyed Municipality.

Similarly, almost all respondents affirmed to have spent in their Municipality an extensive period of their life, generally estimating it as over 10 years long (Fig. 14.6). Only the respondents related to the Municipality of Falconara Marittima proposed a slightly higher variance, although still rather limited.

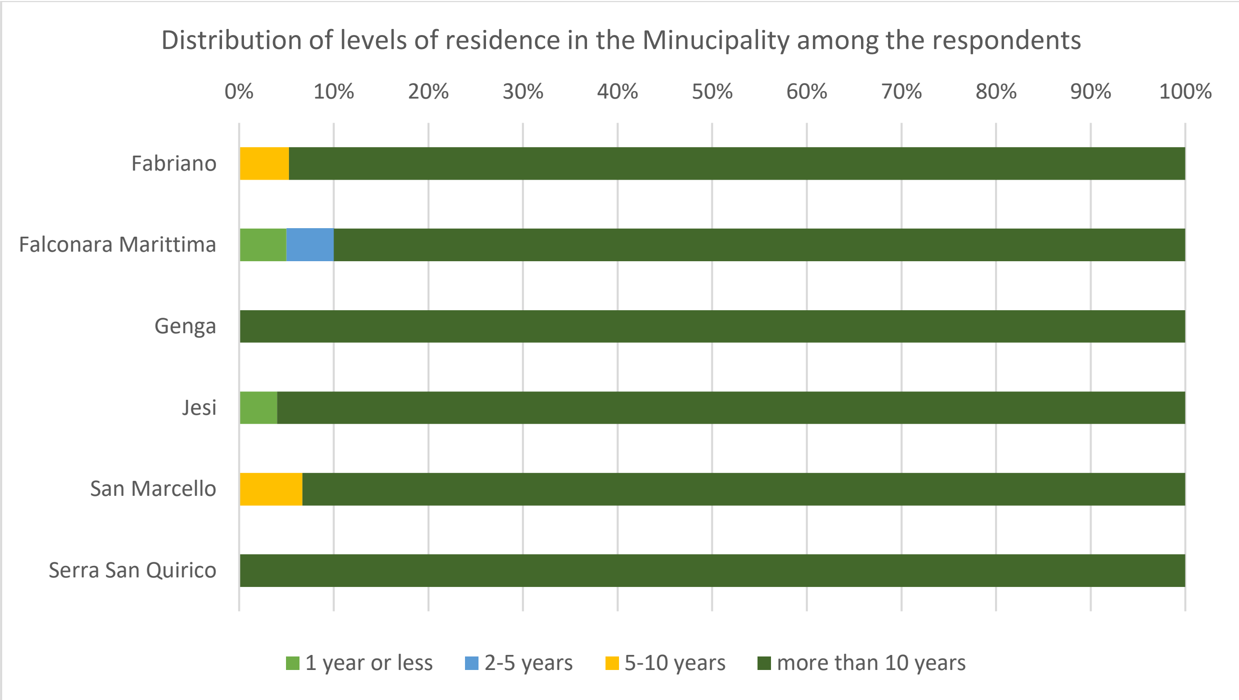


Figure 14.6 — Portion of each level of residence among the respondents per each surveyed Municipality.

Along with the general characteristics of the respondent population sketched above, a primary objective of this analytical step revolved around the identification of the local perception of the levels of resilience and of sustainability, as well as the emergence of the definition of critical functions and related thresholds, concerning both the resilience and the sustainability *core* (Table 14.12).

Table 14.12 — Main outcomes from the collected questionnaires: perceived levels (low L, medium M, high H) of resilience (R) and of sustainability (S), perceived critical functions, identified thresholds of recovery and of collapse, preferred quality after recovery of the critical functions, per each surveyed Municipality.

		Municipality					
		Fabriano	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*
Level of	*resilience*	MR	MR	MR	MR	MR	MR
	sustainability	MS	MS	MS	MS	MS	MS
resilience	*Critical functions*	productive system water system health system	health system education system waste disposal system	health system productive system education system	health system productive system education system	health system waste disposal system water system	health system energy system transportation system
	Threshold of recovery	few hours	few hours up to 1 day	up to 1 week	few hours	few hours	up to 1 week

	Quality after recovery	better	better	better	same better	same	same
	Threshold of collapse	few hours	up to 1 week	up to 1 day	up to 1 week	up to 1 week	up to 1 week few hours
sustainability	*Critical functions*	clean water supply clean air supply food production	clean air supply clean water supply food production	clean water supply clean air supply food production	clean water supply food production clean air supply	food production clean water supply clean air supply	clean water supply food production clean air supply
	Threshold of recovery	5 years	5 years	5 years	5 years	5 years	5 years
	Quality after recovery	better	better	better	better	better	better
	Threshold of collapse	none	none	none	none	none	until you can compensate for them

When considering the cumulative responses per each Municipality, the perceived levels of resilience and of sustainability result homogeneous throughout the case studies. Indeed, the most common assessment identified a medium level of resilience (MR) and a medium level of sustainability (MS), regardless of the Municipality. Similarly, some common trends might be evidenced through the examination of the other investigated pivotal factors, both for resilience (Fig. 14.7) and sustainability (Fig. 14.8).

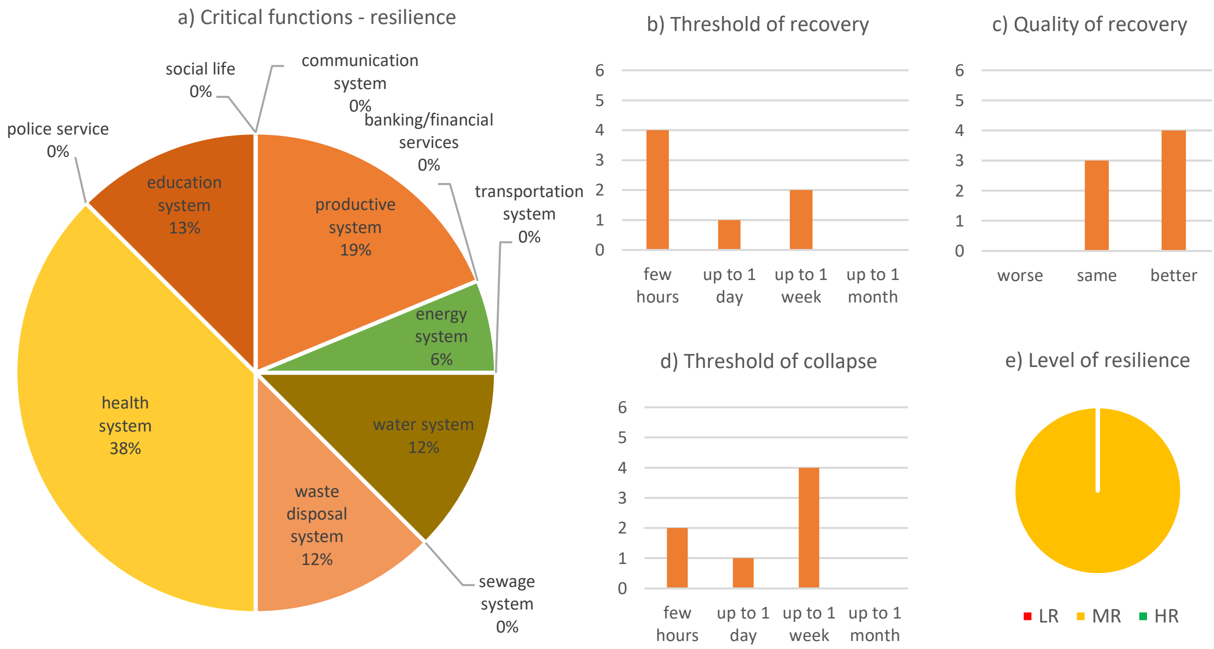


Figure 14.7 — Most common preferences in terms of critical functions (a), threshold (b) and quality (c) of recovery, threshold of collapse (d) and level (e) of sustainability throughout the surveyed Municipalities.

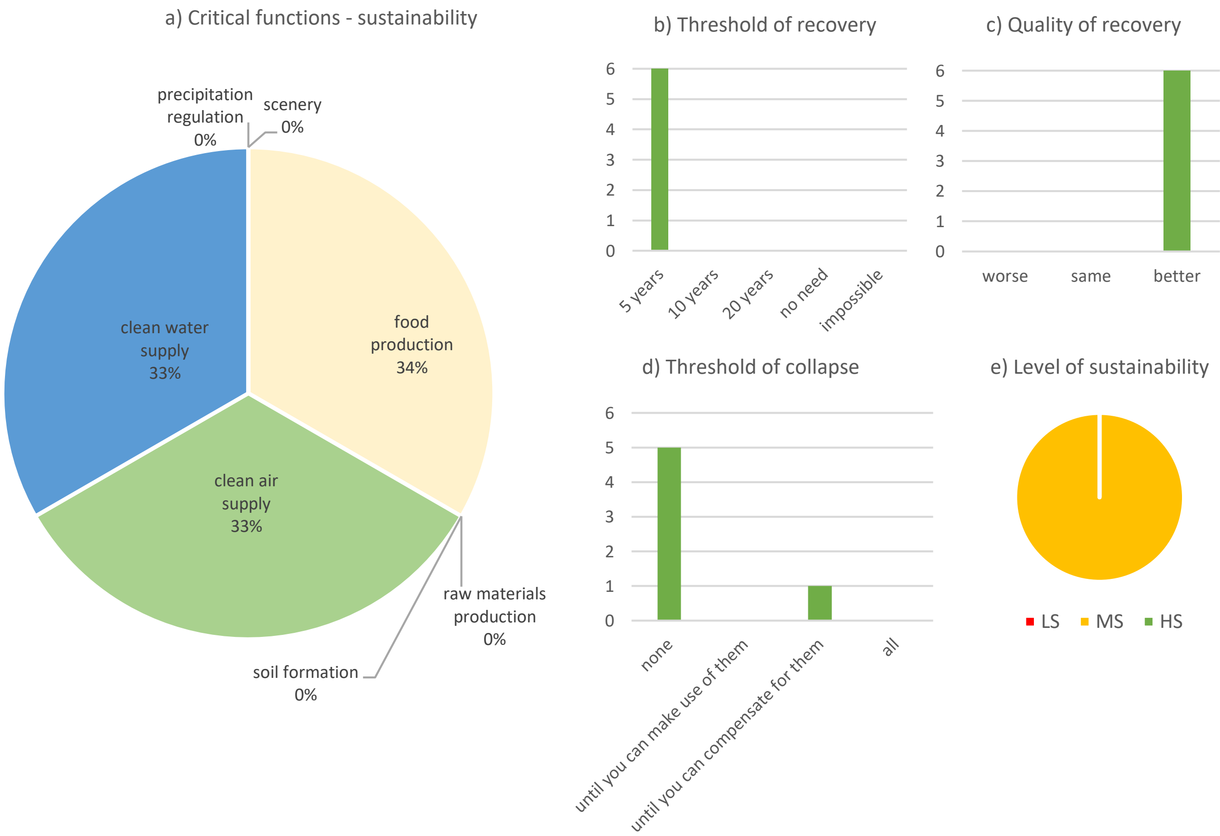


Figure 14.8 — Most common preferences in terms of critical functions (a), threshold (b) and quality (c) of recovery, threshold of collapse (d) and level (e) of resilience throughout the surveyed Municipalities.

In terms of critical functions, when referring to disaster resilience the highest preferences were shared among the health system (38%), productive system (19%) and education system (13%), although some other functions emerged as significantly valued. On the contrary, when considering environmental sustainability the expressed preferences converged towards three critical functions, food production, clean air supply and clean water supply, that equally shared the perceived priority. In a similar vein, the responses in terms of threshold (of recovery and of collapse) were rather distributed among the available options for the resilience *core*, whereas they were strictly focused for the sustainability *core*. Nevertheless, the majority of the responses recognised the shortest periods of time (few hours or 5 years) as most desirable for both thresholds and both *cores*, except for the collapse of the resilience-related functions, whose loss could be generally tolerated for a longer time (up to 1 week). The preferences for the desired (or expected) quality of the critical functions after their recovery adhered to this same trend of difference between the *cores*. Indeed, when questioned about resilience, the agreed quality of the identified pivotal assets could be at least the same as before but also better, while only an ameliorative recovery process could be accepted for the sustainability domain.

At this point it might be significant to delve into the investigation of the differences among Municipalities in terms of perceived level (of resilience and of sustainability) and the preferred option per each question. Nevertheless, as all the surveyed Municipalities were associated to a medium level of resilience (MR) and of sustainability (MS), evidently the most preferred option, and consequently the corresponding most frequent level, was the intermediate one for the majority of the questions, regardless of the Municipality. In other words, on average, the majority of the respondents, regardless of their Municipality, preferred the intermediate option per each question. Consequently, such a comparing the Municipalities in terms of preferences per each question would not contribute with any additional insight to the discussion and it will not be further explored. On the contrary, it might be interesting to identify which questions, if any, challenge such homogenous pattern (Table 14.13).

Table 14.13 — Most preferred option per each level (low - L, medium - M, high - H) of resilience (R) and of sustainability (S) per each question and each surveyed Municipality. The highlighted rows correspond to the questions where the cumulative preferences for low (L) and high (H) levels are more than those for the medium (M) level among the Municipalities.

		Municipality																	
		Fabriano			*Falconara Marittima*			*Genga*			*Jesi*			*San Marcello*			*Serra San Quirico*		
(corresponding) level → **question ↴**		L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
resilience	*1*		x			x			x			x			x			x	
	2		x			x			x			x			x			x	
	3		x			x			x	x		x			x			x	
	4		x			x			x			x			x			x	
	5		x			x			x			x			x			x	
	6			x	x			x				x			x	x			x
	7			x			x			x			x			x			x
	8	x			x			x			x				x		x		
	9		x			x			x	x		x			x			x	
	10		x			x			x			x			x			x	
	11			x			x		x				x			x			x
	12		x			x				x		x				x			x
	13	x				x			x			x		x				x	
	14			x		x				x		x				x			x
	16		x		x			x	x			x			x				x
	17	x	x		x				x			x			x		x		
	18	x			x	x			x			x			x	x			x
sustainability	*19*		x			x			x			x			x			x	
	20			x		x			x	x		x				x			x
	21		x			x			x			x			x			x	
	22		x			x			x			x			x			x	
	23		x			x			x			x			x	x		x	
	24	x				x				x		x			x				x
	25		x		x			x	x			x			x			x	
	26		x			x			x	x		x			x	x		x	
	27	x			x				x			x		x					x
	28	x			x					x	x		x	x		x	x		
	29	x			x			x			x	x		x			x		

Indeed, the response to some themes resulted in an outcome conflicting with the overall trend (Fig. 14.9). In particular, such critical topics were conveyed by five questions concerning disaster resilience ("*6. my fellow citizens have become more aware of flood risk*", "*7. I have become more aware of flood risk*", "*8. the citizens of my Municipality have enough means and sources to manage a flood emergency*", "*11. amount of damage*", "*14. return to everyday life*") and four questions related to environmental sustainability ("*20. land use change (natural and cultivated areas in urban and industrial areas)*", "*27. effects of human activities on river and streams*", "*28.*

protection of natural areas", "*29. initiatives to reduce (water, air, soil) pollution*"). In general terms, the most divisive or polarising arguments were connected with the awareness of flood risk in the community and the consequences of a flood event, along with the direct consequences of anthropic activities and the efforts to preserve natural integrity.

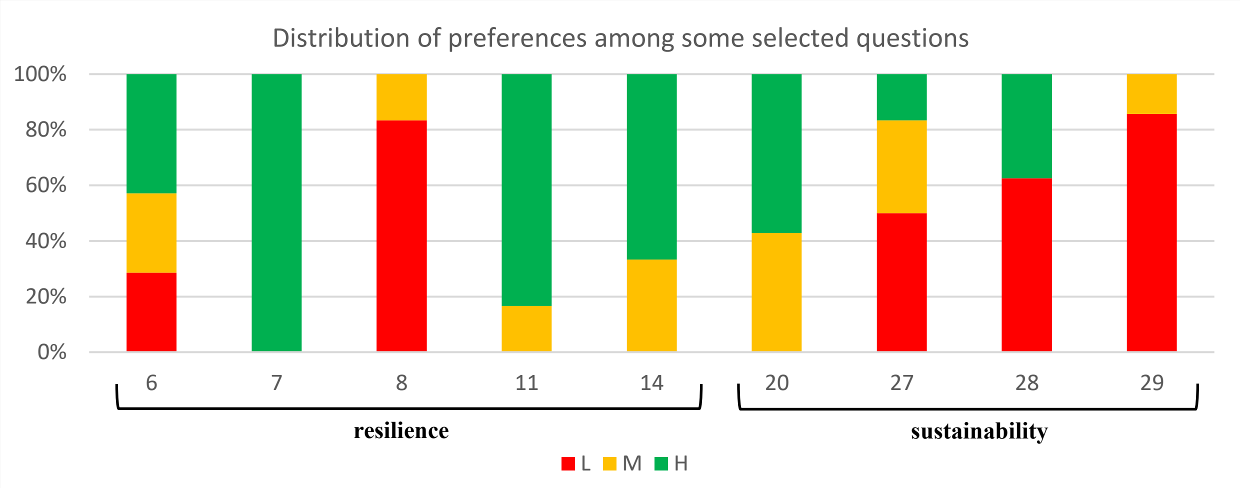


Figure 14.9 — Distribution of preferences among some selected questions (n) per each level (low - L, medium - M, high - H) and per each core *(resilience and sustainability).*

In particular, questions 6 ("*my fellow citizens have become more aware of flood risk*") and 27 ("*effects of human activities on river and streams*") presented the most distributed response over all the available options. Questions 11 ("*amount of damage*"), 14 ("*return to everyday life*") and 20 ("*land use change (natural and cultivated areas in urban and industrial areas)*") exhibited a preference over the medium-high levels, with a sensible inclination towards the highest end. Questions 8 ("*the citizens of my Municipality have enough means and sources to manage a flood emergency*") and 29 ("*initiatives to reduce (water, air, soil) pollution*") tended over the medium-low levels, with an evident preference of the extreme end of the interval. On the contrary, question 28 ("*protection of natural areas*") distributed the preference between the lowest and highest extreme, with a predominance of the low level. Lastly, for question 7 ("*I have become more aware of flood risk*") all responses converged to the highest level. In a few words, questions 6 and 27 were related to the most divisive topics, while the remaining questions portrayed themes that more effectively polarised the expressed preferences of the respondents towards the (perceived) extreme levels of resilience and of sustainability.

14.3 Analysis of the individual response

The previous analysis focused on the perceived level of resilience and of sustainability as the result of the most frequent preferences expressed by the respondents per each Municipality. In other words, the discussed levels could be considered the (perception-derived) assessment as most of the residents would assert for their Municipality. That is, a general overlook of the conditions of resilience and sustainability from the average voice of the local residents. Nonetheless, taking into account the overall homogenous outcome of the previous investigation, it might be especially relevant to explore how each respondent approached the proposed themes and thence the resulting levels (of resilience, of sustainability and combined) that could be derived from their specific answers. Similarly to the previous case, the identification of the level (of resilience and of sustainability) per each respondent was based on the majority of the preferences expressed throughout the questions, following the same decoding employed for the cumulative assessment (see Ch. 12). In this case, though, it happened that a respondent provided the same frequency of preferences to two distinct (decoded) levels. In other words, it occurred that a respondent would be associated with a double level of resilience (or of sustainability), because they had selected the options corresponding to those distinct levels for the same number of times. In such cases, given the impossibility to resolve the ambiguity and in order to avoid the introduction of any external judgement or biases, the process was suspended. As a consequence, some respondents are associated to either a level of resilience or of sustainability, and to none combined level. Nevertheless, they still appear in the presented results as part of the collected information and are labelled as “[NO]”.

14.3.1 Distribution of the perceived levels

The first aspect that is significant to investigate is the frequency per each level, of resilience, of sustainability and combined (Fig. 14.10 and 14.11).

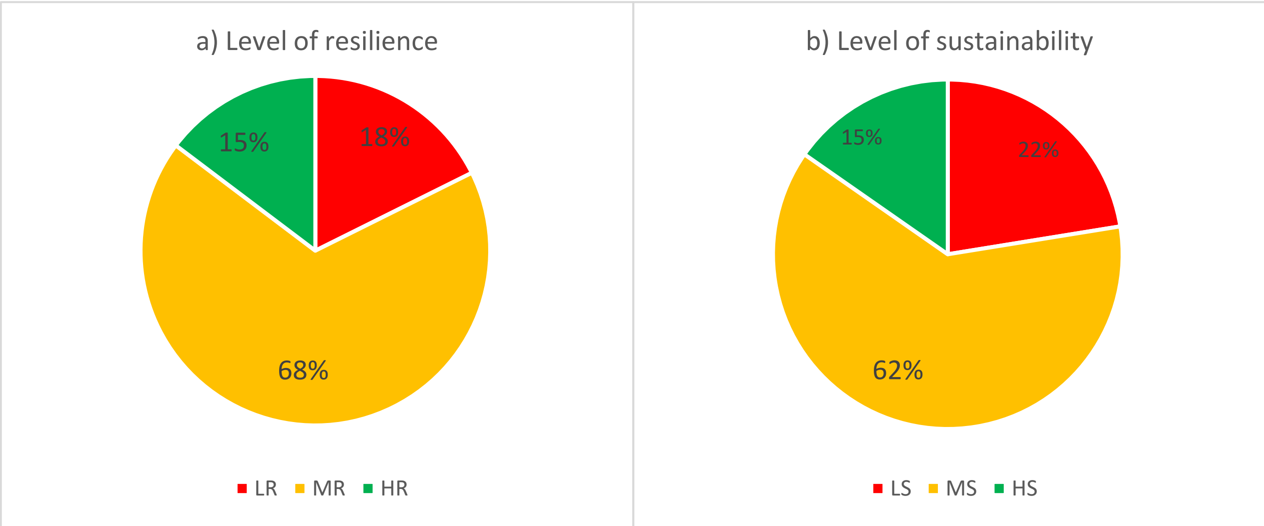


Figure 14.10 — Distribution of the respondents among the perceived levels (low L, medium M, high H) of resilience (R) (a) and of sustainability (S) (b).

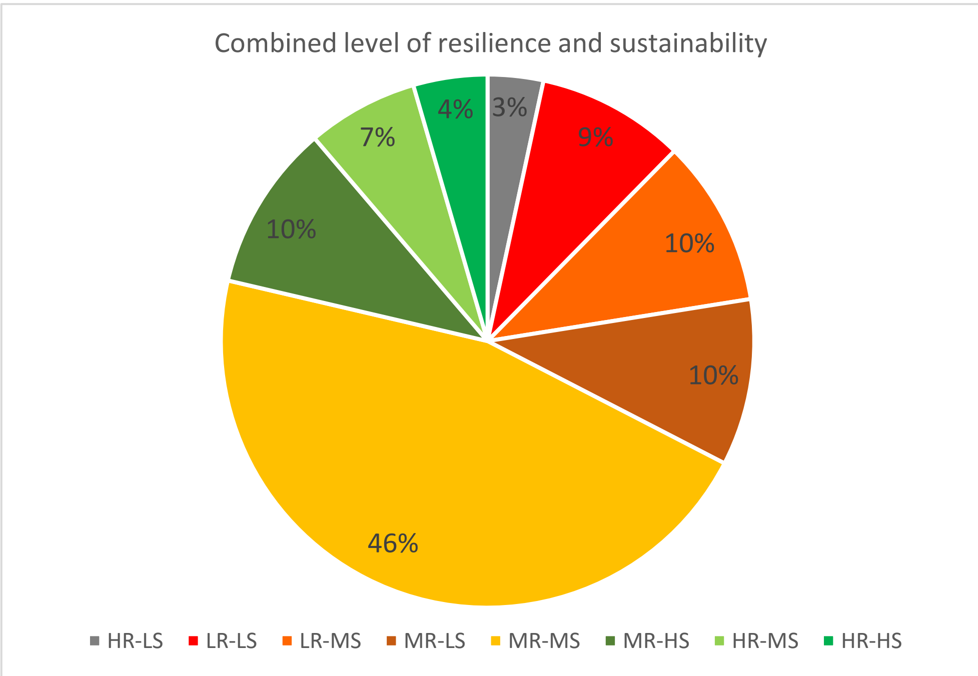


Figure 14.11 — Distribution of the respondents among the combined perceived levels(low L, medium M, high H) of resilience (R) and sustainability (S).

For both *cores*, the most frequent level was the medium one (MR 68%, and MS 62%), whereas the extremes shared almost equally the remaining preferences, with a slight prevalence of the lower levels (LR 18%, LS 22%). In terms of combination, the association of the medium levels retains the wider preference (MR-MS 46%), followed by the combinations of the medium with the lower levels and with the highest level of sustainability (LR-MS 10%, MR-LS 10%, MR-HS 10%). Among the other possibilities, the only significant one is represented by the combination of the lower levels (LR-LS 9%).

14.3.2 Demographic traits

Apart from this basic outcome, when delving into this approach of analysis, a preliminary exploration might involve the demographic characteristics of the respondents, similarly to the previous discussion (Table 14.14, 14.15 and 14.16).

Table 14.14 — Contingency table: perceived level (low L, medium M, high H) of resilience (R) and gender.

			39. gender identified with		*Total*
			female	*male*	
perceived level - resilience	*[NO]*	count	7	4	11
		% within perceived level - resilience	63.6%	36.4%	100.0%
		% within 39. gender identified with	10.6%	8.5%	9.7%
	HR	count	12	3	15
		% within perceived level - resilience	80.0%	20.0%	100.0%
		% within 39. gender identified with	18.2%	6.4%	13.3%
	LR	count	7	11	18
		% within perceived level - resilience	38.9%	61.1%	100.0%
		% within 39. gender identified with	10.6%	23.4%	15.9%
	MR	count	40	29	69
		% within perceived level - resilience	58.0%	42.0%	100.0%
		% within 39. gender identified with	60.6%	61.7%	61.1%
Total		count	66	47	113
		% within perceived level - resilience	58.4%	41.6%	100.0%
		% within 39. gender identified with	100.0%	100.0%	100.0%

Table 14.15 — Contingency table: perceived level (low L, medium M, high H) of sustainability (S) and gender.

			39. gender identified with		*Total*
			female	*male*	
perceived level - sustainability	*[NO]*	count	9	6	15
		% within perceived level - sustainability	60.0%	40.0%	100,0%
		% within 39. gender identified with	13.6%	12.8%	13,3%
	HS	count	11	4	15
		% within perceived level - sustainability	73.3%	26.7%	100,0%
		% within 39. gender identified with	16.7%	8.5%	13,3%
	LS	count	11	11	22
		% within perceived level - sustainability	50.0%	50.0%	100,0%
		% within 39. gender identified with	16.7%	23.4%	19,5%
	MS	count	35	26	61
		% within perceived level - sustainability	57.4%	42.6%	100,0%
		% within 39. gender identified with	53.0%	55.3%	54,0%
Total		count	66	47	113
		% within perceived level - sustainability	58.4%	41.6%	100.0%
		% within 39. gender identified with	100.0%	100.0%	100.0%

Table 14.16 — Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and gender.

			39. gender identified with		Total
			female	*male*	
perceived level - combined	*[NO]*	count	15	9	24
		% within perceived level - combined	62.5%	37.5%	100,0%
		% within 39. gender identified with	22.7%	19.1%	21,2%
	HR-HS	count	4	0	4
		% within perceived level - combined	100.0%	.0%	100,0%
		% within 39. gender identified with	6.1%	.0%	3,5%
	HR-LS	count	2	1	3
		% within perceived level - combined	66.7%	33.3%	100,0%
		% within 39. gender identified with	3.0%	2.1%	2,7%
	HR-MS	count	5	1	6
		% within perceived level - combined	83.3%	16.7%	100,0%
		% within 39. gender identified with	7.6%	2.1%	5,3%
	LR-LS	count	2	6	8
		% within perceived level - combined	25.0%	75.0%	100,0%
		% within 39. gender identified with	3.0%	12.8%	7,1%
	LR-MS	count	4	5	9
		% within perceived level - combined	44.4%	55.6%	100,0%
		% within 39. gender identified with	6.1%	10.6%	8,0%
	MR-HS	count	4	5	9
		% within perceived level - combined	44.4%	55.6%	100,0%
		% within 39. gender identified with	6.1%	10.6%	8,0%
	MR-LS	count	7	2	9
		% within perceived level - combined	77.8%	22.2%	100,0%
		% within 39. gender identified with	10.6%	4.3%	8,0%
	MR-MS	count	23	18	41
		% within perceived level - combined	56.1%	43.9%	100,0%
		% within 39. gender identified with	34.8%	38.3%	36,3%
Total		count	66	47	113
		% within perceived level - combined	58.4%	41.6%	100.0%
		% within 39. gender identified with	100.0%	100.0%	100.0%

Overall, it is possible to observe that the highest levels (of resilience, sustainability and combined) were generally associated to a majority of female respondents, to the point that the most desirable combined level (HR-HS) was completely related (100%) population of female respondents. The other levels provided a more scattered response among the genders, with percentages varying through the levels around the point of equal distribution. Nevertheless, it might be interesting to notice that the lowest level of sustainability (LS) presented the only case of same number of preferences among female and male respondents, whereas the least desired combined level (LR-LS) was mainly associated (75%) to male respondents.

Table 14.17 — Contingency table: perceived level (low L, medium M, high H) of resilience (R) and age.

			40. class of age								
				18-24 years old	*25-34 years old*	*35-44 years old*	*45-54 years old*	*55-64 years old*	*65-80 years old*	*over 80 years old*	*Total*
perceived level - resilience	*[NO]*	count	0	1	1	0	3	3	2	1	11
		% within perceived level - resilience	.0%	9.1%	9.1%	.0%	27.3%	27.3%	18.2%	9.1%	100,0%
		% within 40. class of age	.0%	9.1%	7.1%	.0%	15.0%	11.5%	7.1%	20.0%	9,7%
	HR	count	0	0	1	0	1	8	4	1	15
		% within perceived level - resilience	.0%	.0%	6.7%	.0%	6.7%	53.3%	26.7%	6.7%	100,0%
		% within 40. class of age	.0%	.0%	7.1%	.0%	5.0%	30.8%	14.3%	20.0%	13,3%
	LR	count	0	2	1	3	6	4	1	1	18
		% within perceived level - resilience	.0%	11.1%	5.6%	16.7%	33.3%	22.2%	5.6%	5.6%	100,0%
		% within 40. class of age	.0%	18.2%	7.1%	42.9%	30.0%	15.4%	3.6%	20.0%	15,9%
	MR	count	2	8	11	4	10	11	21	2	69
		% within perceived level - resilience	2.9%	11.6%	15.9%	5.8%	14.5%	15.9%	30.4%	2.9%	100,0%
		% within 40. class of age	100.0%	72.7%	78.6%	57.1%	50.0%	42.3%	75.0%	40.0%	61,1%
Total		count	2	11	14	7	20	26	28	5	113
		% within perceived level - resilience	1.8%	9.7%	12.4%	6.2%	17.7%	23.0%	24.8%	4.4%	100.0%
		% within 40. class of age	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14.18 — Contingency table: perceived level (low L, medium M, high H) and of sustainability (S) and age.

			40. class of age								
				18-24 years old	*25-34 years old*	*35-44 years old*	*45-54 years old*	*55-64 years old*	*65-80 years old*	*over 80 years old*	*Total*
perceived level - sustainability	*[NO]*	count	1	3	4	0	2	4	1	0	15
		% within perceived level - sustainability	6.7%	20.0%	26.7%	.0%	13.3%	26.7%	6.7%	.0%	100,0%
		% within 40. class of age	50.0%	27.3%	28.6%	.0%	10.0%	15.4%	3.6%	.0%	13,3%
	HS	count	0	0	0	0	1	4	7	3	15
		% within perceived level - sustainability	.0%	.0%	.0%	.0%	6.7%	26.7%	46.7%	20.0%	100,0%
		% within 40. class of age	.0%	.0%	.0%	.0%	5.0%	15.4%	25.0%	60.0%	13,3%
	LS	count	0	1	1	1	5	8	6	0	22
		% within perceived level - sustainability	.0%	4.5%	4.5%	4.5%	22.7%	36.4%	27.3%	.0%	100,0%
		% within 40. class of age	.0%	9.1%	7.1%	14.3%	25.0%	30.8%	21.4%	.0%	19,5%
	MS	count	1	7	9	6	12	10	14	2	61
		% within perceived level - sustainability	1.6%	11.5%	14.8%	9.8%	19.7%	16.4%	23.0%	3.3%	100,0%
		% within 40. class of age	50.0%	63.6%	64.3%	85.7%	60.0%	38.5%	50.0%	40.0%	54,0%
Total		count	2	11	14	7	20	26	28	5	113
		% within perceived level - sustainability	1.8%	9.7%	12.4%	6.2%	17.7%	23.0%	24.8%	4.4%	100.0%
		% within 40. class of age	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14.19 — Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and age.

			40. class of age								
				18-24 years old	*25-34 years old*	*35-44 years old*	*45-54 years old*	*55-64 years old*	*65-80 years old*	*over 80 years old*	*Total*
perceived level - combined	*[NO]*	count	1	4	4	0	5	6	3	1	24
		% within perceived level - combined	4.2%	16.7%	16.7%	.0%	20.8%	25.0%	12.5%	4.2%	100,0%
		% within 40. class of age	50.0%	36.4%	28.6%	.0%	25.0%	23.1%	10.7%	20.0%	21,2%
	HR-HS	count	0	0	0	0	0	3	0	1	4
		% within perceived level - combined	.0%	.0%	.0%	.0%	.0%	75.0%	.0%	25.0%	100,0%
		% within 40. class of age	.0%	.0%	.0%	.0%	.0%	11.5%	.0%	20.0%	3,5%
	HR-LS	count	0	0	0	0	0	1	2	0	3
		% within perceived level - combined	.0%	.0%	.0%	.0%	.0%	33.3%	66.7%	.0%	100,0%
		% within 40. class of age	.0%	.0%	.0%	.0%	.0%	3.8%	7.1%	.0%	2,7%
	HR-MS	count	0	0	1	0	1	3	1	0	6
		% within perceived level - combined	.0%	.0%	16.7%	.0%	16.7%	50.0%	16.7%	.0%	100,0%
		% within 40. class of age	.0%	.0%	7.1%	.0%	5.0%	11.5%	3.6%	.0%	5,3%
	LR-LS	count	0	0	0	0	5	3	0	0	8
		% within perceived level - combined	.0%	.0%	.0%	.0%	62.5%	37.5%	.0%	.0%	100,0%
		% within 40. class of age	.0%	.0%	.0%	.0%	25.0%	11.5%	.0%	.0%	7,1%
	LR-MS	count	0	2	0	3	1	1	1	1	9
		% within perceived level - combined	.0%	22.2%	.0%	33.3%	11.1%	11.1%	11.1%	11.1%	100,0%
		% within 40. class of age	.0%	18.2%	.0%	42.9%	5.0%	3.8%	3.6%	20.0%	8,0%
	MR-HS	count	0	0	0	0	0	1	7	1	9
		% within perceived level - combined	.0%	.0%	.0%	.0%	.0%	11.1%	77.8%	11.1%	100,0%
		% within 40. class of age	.0%	.0%	.0%	.0%	.0%	3.8%	25.0%	20.0%	8,0%
	MR-LS	count	0	1	1	1	0	3	3	0	9
		% within perceived level - combined	.0%	11.1%	11.1%	11.1%	.0%	33.3%	33.3%	.0%	100,0%
		% within 40. class of age	.0%	9.1%	7.1%	14.3%	.0%	11.5%	10.7%	.0%	8,0%
	MR-MS	count	1	4	8	3	8	5	11	1	41
		% within perceived level - combined	2.4%	9.8%	19.5%	7.3%	19.5%	12.2%	26.8%	2.4%	100,0%
		% within 40. class of age	50.0%	36.4%	57.1%	42.9%	40.0%	19.2%	39.3%	20.0%	36,3%
Total		count	2	11	14	7	20	26	28	5	113
		% within perceived level - combined	1,8%	9.7%	12.4%	6.2%	17.7%	23.0%	24.8%	4.4%	100.0%
		% within 40. class of age	100,0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

When considering the age distribution throughout the levels, it emerges a significant predominance of the highest classes in all the considered levels, although the distribution did not correspond among the resilience, sustainability and combined levels (Table 14.17, 14.18 and 14.19). Indeed, when considering the extreme levels (high and low, both of resilience and of sustainability), the resilience case appeared to be preferred by the younger class compared to the sustainability level (e.g. HR was preferred by 55-64 years old respondents, whereas HS by 65-80 years old respondents). The medium levels were mainly associated to the same class of age (65-80 years old). In general terms, when combining the same level of the two *cores* (HR-HS, MR-MS, LR-LS), the dominant class of age corresponded to that of the resilience side. It might be interesting to note that only the LR-MS envisioned a significant contribution (22.2%) of the youngest class (18-24 years old), whereas MR-MS included the following class (19.5%, 25-34 years old).

Table 14.20 — Contingency table: perceived level (low L, medium M, high H) of resilience (R) and education.

			41. highest level of education							Total
				Master's degree or equivalent	*Bachelor's degree or equivalent*	*doctoral degree or equivalent*	*elementary school*	*middle school*	*high school*	
perceived level - resilience	*[NO]*	count	0	3	0	0	2	0	6	11
		% within perceived level - resilience	.0%	27.3%	.0%	.0%	18.2%	.0%	54.5%	100,0%
		% within 41. highest level of education	.0%	10.7%	.0%	.0%	25.0%	.0%	14.0%	9,7%
	HR	count	0	5	2	1	0	2	5	15
		% within perceived level - resilience	.0%	33.3%	13.3%	6.7%	.0%	13.3%	33.3%	100,0%
		% within 41. highest level of education	.0%	17.9%	22.2%	16.7%	.0%	13.3%	11.6%	13,3%
	LR	count	1	3	1	1	0	4	8	18
		% within perceived level - resilience	5.6%	16.7%	5.6%	5.6%	.0%	22.2%	44.4%	100,0%
		% within 41. highest level of education	25.0%	10.7%	11.1%	16.7%	.0%	26.7%	18.6%	15,9%
	MR	count	3	17	6	4	6	9	24	69
		% within perceived level - resilience	4.3%	24.6%	8.7%	5.8%	8.7%	13.0%	34.8%	100,0%
		% within 41. highest level of education	75.0%	60.7%	66.7%	66.7%	75.0%	60.0%	55.8%	61,1%
Total		count	4	28	9	6	8	15	43	113
		% within perceived level - resilience	3,5%	24.8%	8.0%	5.3%	7.1%	13.3%	38.1%	100.0%
		% within 41. highest level of education	100%	100%	100%	100%	100%	100%	100%	100%

Table 14.21 — Contingency table: perceived level (low L, medium M, high H) of sustainability (S) and education.

			41. highest level of education							Total
				Master's degree or equivalent	*Bachelor's degree or equivalent*	*doctoral degree or equivalent*	*elementary school*	*middle school*	*high school*	
perceived level - sustainability	*[NO]*	count	1	5	1	1	0	1	6	15
		% within perceived level - sustainability	6.7%	33.3%	6.7%	6.7%	.0%	6.7%	40.0%	100,0%
		% within 41. highest level of education	25.0%	17.9%	11.1%	16.7%	.0%	6.7%	14.0%	13,3%
	HS	count	1	4	0	1	3	2	4	15
		% within perceived level - sustainability	6.7%	26.7%	.0%	6.7%	20.0%	13.3%	26.7%	100,0%
		% within 41. highest level of education	25.0%	14.3%	.0%	16.7%	37.5%	13.3%	9.3%	13,3%
	LS	count	0	4	0	1	0	4	13	22
		% within perceived level - sustainability	.0%	18.2%	.0%	4.5%	.0%	18.2%	59.1%	100,0%
		% within 41. highest level of education	.0%	14.3%	.0%	16.7%	.0%	26.7%	30.2%	19,5%
	MS	count	2	15	8	3	5	8	20	61
		% within perceived level - sustainability	3.3%	24.6%	13.1%	4.9%	8.2%	13.1%	32.8%	100,0%
		% within 41. highest level of education	50.0%	53.6%	88.9%	50.0%	62.5%	53.3%	46.5%	54,0%
Total		count	4	28	9	6	8	15	43	113
		% within perceived level - sustainability	3,5%	24.8%	8.0%	5.3%	7.1%	13.3%	38.1%	100.0%
		% within 41. highest level of education	100,0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14.22 — Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and education.

			41. highest level of education							Total
				Master's degree or equivalent	*Bachelor's degree or equivalent*	*doctoral degree or equivalent*	*elementary school*	*middle school*	*high school*	
perceived level - combined	*[NO]*	count	1	7	1	1	2	1	11	24
		% within perceived level - combined	4.2%	29.2%	4.2%	4.2%	8.3%	4.2%	45.8%	100.0%
		% within 41. highest level of education	25.0%	25.0%	11.1%	16.7%	25.0%	6.7%	25.6%	21.2%
	HR-HS	count	0	2	0	1	0	1	0	4
		% within perceived level - combined	.0%	50.0%	.0%	25.0%	.0%	25.0%	.0%	100.0%
		% within 41. highest level of education	.0%	7.1%	.0%	16.7%	.0%	6.7%	.0%	3.5%
	HR-LS	count	0	1	0	0	0	0	2	3
		% within perceived level - combined	.0%	33.3%	.0%	.0%	.0%	.0%	66.7%	100.0%
		% within 41. highest level of education	.0%	3.6%	.0%	.0%	.0%	.0%	4.7%	2.7%
	HR-MS	count	0	1	2	0	0	1	2	6
		% within perceived level - combined	.0%	16.7%	33.3%	.0%	.0%	16.7%	33.3%	100.0%
		% within 41. highest level of education	.0%	3.6%	22.2%	.0%	.0%	6.7%	4.7%	5.3%
	LR-LS	count	0	1	0	1	0	2	4	8
		% within perceived level - combined	.0%	12.5%	.0%	12.5%	.0%	25.0%	50.0%	100.0%
		% within 41. highest level of education	.0%	3.6%	.0%	16.7%	.0%	13.3%	9.3%	7.1%
	LR-MS	count	1	1	1	0	0	2	4	9
		% within perceived level - combined	11.1%	11.1%	11.1%	.0%	.0%	22.2%	44.4%	100.0%
		% within 41. highest level of education	25.0%	3.6%	11.1%	.0%	.0%	13.3%	9.3%	8.0%
	MR-HS	count	1	1	0	0	2	1	4	9
		% within perceived level - combined	11.1%	11.1%	.0%	.0%	22.2%	11.1%	44.4%	100.0%
		% within 41. highest level of education	25.0%	3.6%	.0%	.0%	25.0%	6.7%	9.3%	8.0%

	MR-LS	count	0	2	0	0	0	2	5	9
		% within perceived level - combined	.0%	22.2%	.0%	.0%	.0%	22.2%	55.6%	100.0%
		% within 41. highest level of education	.0%	7.1%	.0%	.0%	.0%	13.3%	11.6%	8.0%
	MR-MS	count	1	12	5	3	4	5	11	41
		% within perceived level - combined	2.4%	29.3%	12.2%	7.3%	9.8%	12.2%	26.8%	100.0%
		% within 41. highest level of education	25.0%	42.9%	55.6%	50.0%	50.0%	33.3%	25.6%	36.3%
Total		count	4	28	9	6	8	15	43	113
		% within perceived level - combined	3.5%	24.8%	8.0%	5.3%	7.1%	13.3%	38.1%	100.0%
		% within 41. highest level of education	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The characterisation of the respondents per each level in terms of education provided a regular picture (Table 14.20, 14.21 and 14.22). Indeed, regardless of the *core* or of the combination, each level was dominated by the high-school level, equalled by the Master's degree (or equivalent) level in the case of the highest levels (HR and HS). It might be significant to note that the Master's degree (or equivalent) level was the most present both for the most desirable combined level (HR-HS) and for the combined intermediate level (MR-MS).

Table 14.23 — Contingency table: perceived level (low L, medium M, high H) of resilience (R) and income.

			49. class of income					Total
				0 - 15000€	*15001 - 30000€*	*30001 - 50000€*	*more than 50000€*	
perceived level - resilience	*[NO]*	count	1	2	8	0	0	11
		% within perceived level - resilience	9.1%	18.2%	72.7%	.0%	.0%	100,0%
		% within 49. class of income	7.1%	6.1%	17.8%	.0%	.0%	9,7%
	HR	count	2	6	5	2	0	15
		% within perceived level - resilience	13.3%	40.0%	33.3%	13.3%	.0%	100,0%
		% within 49. class of income	14.3%	18.2%	11.1%	12.5%	.0%	13,3%
	LR	count	1	4	8	4	1	18
		% within perceived level - resilience	5.6%	22.2%	44.4%	22.2%	5.6%	100,0%
		% within 49. class of income	7.1%	12.1%	17.8%	25.0%	20.0%	15,9%
	MR	count	10	21	24	10	4	69
		% within perceived level - resilience	14.5%	30.4%	34.8%	14.5%	5.8%	100,0%
		% within 49. class of income	71.4%	63.6%	53.3%	62.5%	80.0%	61,1%
Total		count	14	33	45	16	5	113
		% within perceived level - resilience	12,4%	29.2%	39.8%	14.2%	4.4%	100.0%
		% within 49. class of income	100,0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14.24 — Contingency table: perceived level (low L, medium M, high H) of sustainability (S) and income.

			49. class of income					Total
				0 - 15000€	*15001 - 30000€*	*30001 - 50000€*	*more than 50000€*	
perceived level - sustainability	*[NO]*	count	2	4	7	2	0	15
		% within perceived level - sustainability	13.3%	26.7%	46.7%	13.3%	.0%	100,0%
		% within 49. class of income	14.3%	12.1%	15.6%	12.5%	.0%	13,3%
	HS	count	5	3	6	1	0	15
		% within perceived level - sustainability	33.3%	20.0%	40.0%	6.7%	.0%	100,0%
		% within 49. class of income	35.7%	9.1%	13.3%	6.3%	.0%	13,3%
	LS	count	1	4	11	6	0	22
		% within perceived level - sustainability	4.5%	18.2%	50.0%	27.3%	.0%	100,0%
		% within 49. class of income	7.1%	12.1%	24.4%	37.5%	.0%	19,5%
	MS	count	6	22	21	7	5	61
		% within perceived level - sustainability	9.8%	36.1%	34.4%	11.5%	8.2%	100,0%
		% within 49. class of income	42.9%	66.7%	46.7%	43.8%	100.0%	54,0%
Total		count	14	33	45	16	5	113
		% within perceived level - sustainability	12,4%	29.2%	39.8%	14.2%	4.4%	100.0%
		% within 49. class of income	100,0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14.25 — Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and income.

			49. class of income					*Total*
				0 - 15000€	*15001 - 30000€*	*30001 - 50000€*	*more than 50000€*	
perceived level - combined	*[NO]*	count	3	5	14	2	0	24
		% within perceived level - combined	12.5%	20.8%	58.3%	8.3%	.0%	100,0%
		% within 49. class of income	21.4%	15.2%	31.1%	12.5%	.0%	21,2%
	HR-HS	count	1	2	1	0	0	4
		% within perceived level - combined	25.0%	50.0%	25.0%	.0%	.0%	100,0%
		% within 49. class of income	7.1%	6.1%	2.2%	.0%	.0%	3,5%
	HR-LS	count	0	0	2	1	0	3
		% within perceived level - combined	.0%	.0%	66.7%	33.3%	.0%	100,0%
		% within 49. class of income	.0%	.0%	4.4%	6.3%	.0%	2,7%
	HR-MS	count	0	4	2	0	0	6
		% within perceived level - combined	.0%	66.7%	33.3%	.0%	.0%	100,0%
		% within 49. class of income	.0%	12.1%	4.4%	.0%	.0%	5,3%
	LR-LS	count	0	0	5	3	0	8
		% within perceived level - combined	.0%	.0%	62.5%	37.5%	.0%	100,0%
		% within 49. class of income	.0%	.0%	11.1%	18.8%	.0%	7,1%
	LR-MS	count	1	3	3	1	1	9
		% within perceived level - combined	11.1%	33.3%	33.3%	11.1%	11.1%	100,0%
		% within 49. class of income	7.1%	9.1%	6.7%	6.3%	20.0%	8,0%
	MR-HS	count	4	1	3	1	0	9
		% within perceived level - combined	44.4%	11.1%	33.3%	11.1%	.0%	100,0%
		% within 49. class of income	28.6%	3.0%	6.7%	6.3%	.0%	8,0%
	MR-LS	count	0	4	3	2	0	9
		% within perceived level - combined	.0%	44.4%	33.3%	22.2%	.0%	100,0%
		% within 49. class of income	.0%	12.1%	6.7%	12.5%	.0%	8,0%
	MR-MS	count	5	14	12	6	4	41
		% within perceived level - combined	12.2%	34.1%	29.3%	14.6%	9.8%	100,0%
		% within 49. class of income	35.7%	42.4%	26.7%	37.5%	80.0%	36,3%
Total		count	14	33	45	16	5	113
		% within perceived level – combined	12,4%	29.2%	39.8%	14.2%	4.4%	100.0%
		% within 49. class of income	100,0%	100.0%	100.0%	100.0%	100.0%	100.0%

The overall economic conditions of the respondents were rather similar throughout the levels, with highest frequencies focused on the first two classes (0-15000€ and 15001-30000€), regardless of the considered *core* or combination (Table 14.23, 14.24 and 14.25). Nevertheless, in some of the resilience and sustainability cases, the 15001-30000€ class resulted dominant compared to the others (HS, LR, LS). It might be interesting to notice that the corresponding combined level (LR-LS) confirms this peculiarity, although some respondents associated to this level were related to the next higher level (30001-50000€). Eventually, all the respondents belonging to the highest class (more than 50000€) were related to medium levels, of resilience and of sustainability, and most of them to their combination (MR-MS).

Table 14.26 — Contingency table: perceived level (low L, medium M, high H) of resilience (R) and residence.

			43. permanence in municipality of residence					Total
				1 year or less	2-5 years	5-10 years	more than 10 years	
perceived level - resilience	[NO]	count	0	0	0	0	11	11
		% within perceived level - resilience	.0%	.0%	.0%	.0%	100.0%	100.0%
		% within 43. permanence in municipality of residence	.0%	.0%	.0%	.0%	10.6%	9.7%
	HR	count	0	0	0	0	15	15
		% within perceived level - resilience	.0%	.0%	.0%	.0%	100.0%	100.0%
		% within 43. permanence in municipality of residence	.0%	.0%	.0%	.0%	14.4%	13.3%
	LR	count	1	0	0	0	17	18
		% within perceived level - resilience	5.6%	.0%	.0%	.0%	94.4%	100.0%
		% within 43. permanence in municipality of residence	25.0%	.0%	.0%	.0%	16.3%	15.9%
	MR	count	3	2	1	2	61	69
		% within perceived level - resilience	4.3%	2.9%	1.4%	2.9%	88.4%	100.0%
		% within 43. permanence in municipality of residence	75.0%	100.0%	100.0%	100.0%	58.7%	61.1%
Total		count	4	2	1	2	104	113
		% within perceived level - resilience	3.5%	1.8%	.9%	1.8%	92.0%	100.0%
		% within 43. permanence in municipality of residence	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14.27 — Contingency table: perceived level (low L, medium M, high H) and of sustainability (S) and residence.

			43. permanence in municipality of residence					*Total*
				1 year or less	*2-5 years*	*5-10 years*	*more than 10 years*	
perceived level - sustainability	*[NO]*	count	1	0	0	0	14	15
		% within perceived level - sustainability	6.7%	.0%	.0%	.0%	93.3%	100,0%
		% within 43. permanence in municipality of residence	25.0%	.0%	.0%	.0%	13.5%	13,3%
	HS	count	1	0	0	0	14	15
		% within perceived level - sustainability	6.7%	.0%	.0%	.0%	93.3%	100,0%
		% within 43. permanence in municipality of residence	25.0%	.0%	.0%	.0%	13.5%	13,3%
	LS	count	0	1	0	0	21	22
		% within perceived level - sustainability	.0%	4.5%	.0%	.0%	95.5%	100,0%
		% within 43. permanence in municipality of residence	.0%	50.0%	.0%	.0%	20.2%	19,5%
	MS	count	2	1	1	2	55	61
		% within perceived level - sustainability	3.3%	1.6%	1.6%	3.3%	90.2%	100,0%
		% within 43. permanence in municipality of residence	50.0%	50.0%	100.0%	100.0%	52.9%	54,0%
Total		count	4	2	1	2	104	113
		% within perceived level - sustainability	3.5%	1.8%	.9%	1.8%	92.0%	100.0%
		% within 43. permanence in municipality of residence	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14.28 — Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and residence

			43. permanence in municipality of residence					Total
				1 year or less	*2-5 years*	*5-10 years*	*more than 10 years*	
perceived level - combined	*[NO]*	count	1	0	0	0	23	24
		% within perceived level - combined	4.2%	.0%	.0%	.0%	95.8%	100,0%
		% within 43. permanence in municipality of residence	25.0%	.0%	.0%	.0%	22.1%	21,2%
	HR-HS	count	0	0	0	0	4	4
		% within perceived level - combined	.0%	.0%	.0%	.0%	100.0%	100,0%
		% within 43. permanence in municipality of residence	.0%	.0%	.0%	.0%	3.8%	3,5%
	HR-LS	count	0	0	0	0	3	3
		% within perceived level - combined	.0%	.0%	.0%	.0%	100.0%	100,0%
		% within 43. permanence in municipality of residence	.0%	.0%	.0%	.0%	2.9%	2,7%
	HR-MS	count	0	0	0	0	6	6
		% within perceived level - combined	.0%	.0%	.0%	.0%	100.0%	100,0%
		% within 43. permanence in municipality of residence	.0%	.0%	.0%	.0%	5.8%	5,3%
	LR-LS	count	0	0	0	0	8	8
		% within perceived level - combined	.0%	.0%	.0%	.0%	100.0%	100,0%
		% within 49. class of income	.0%	.0%	.0%	.0%	7.7%	7,1%
	LR-MS	count	1	0	0	0	8	9
		% within perceived level - combined	11.1%	.0%	.0%	.0%	88.9%	100,0%
		% within 43. permanence in municipality of residence	25.0%	.0%	.0%	.0%	7.7%	8,0%
	MR-HS	count	1	0	0	0	8	9
		% within perceived level - combined	11.1%	.0%	.0%	.0%	88.9%	100,0%
		% within 43. permanence in municipality of residence	25.0%	.0%	.0%	.0%	7.7%	8,0%
	MR-LS	count	0	1	0	0	8	9
		% within perceived level - combined	.0%	11.1%	.0%	.0%	88.9%	100,0%
		% within 49. class of income	.0%	50.0%	.0%	.0%	7.7%	8,0%
	MR-MS	count	1	1	1	2	36	41
		% within perceived level - combined	2.4%	2.4%	2.4%	4.9%	87.8%	100,0%
		% within 43. permanence in municipality of residence	25.0%	50.0%	100.0%	100.0%	34.6%	36,3%
Total		count	4	2	1	2	104	113
		% within perceived level – combined	3.5%	1.8%	.9%	1.8%	92.0%	100.0%
		% within 43. permanence in municipality of residence	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Regardless of the level, the absolute majority of the respondents were associated to the longest period of residence (more than 10 years) in their Municipality (Tables 14.26, 14.27 and 14.28).

The medium levels (of resilience and of sustainability) presented the widest variability, with respondents pertaining to all the available periods. Similarly, the combined intermediate levels (MR-MS) mirrored such multifaced characterisation. It might be interesting to notice that when a high level was concerned (either individually or combined), the respondents resulted to have spent the longest period of time in their Municipality.

14.3.3 Assessed vs. perceived levels

A further association that might be worth to be questioned might put side by side the assessed levels (of each Municipality) and the perceived level (by each respondent). In other words, it might be interesting to explore, which was the most frequently perceived level per each assessed level (Table 14.29, 14.30 and 14.31). Indeed, as each assessed level corresponds to a Municipality, the question might be simplified in a few words: "Within this Municipality, how is the perception of resilience and of sustainability distributed among the (responding) population?". Or, similarly: "Within this (assessed combined) level, which is the most common perception of the respondents?".

Table 14.29 — Contingency table: perceived and assessed level (low L, medium M, high H) of resilience (R).

			assessed level						*Total*
			MR-MS	MR-LS	LR-MS	HR-HS	MR-HS	HR-MS	
perceived level - resilience	*[NO]*	count	3	2	2	1	1	2	11
		% within perceived level - resilience	27.3%	18.2%	18.2%	9.1%	9.1%	18.2%	100,0%
		% within assessed level	15.8%	9.1%	15.4%	3.8%	5.9%	12.5%	9,7%
	HR	count	5	2	3	1	2	2	15
		% within perceived level - resilience	33.3%	13.3%	20.0%	6.7%	13.3%	13.3%	100,0%
		% within assessed level	26.3%	9.1%	23.1%	3.8%	11.8%	12.5%	13,3%
	LR	count	3	7	2	4	1	1	18
		% within perceived level - resilience	16.7%	38.9%	11.1%	22.2%	5.6%	5.6%	100,0%
		% within assessed level	15.8%	31.8%	15.4%	15.4%	5.9%	6.3%	15,9%
	MR	count	8	11	6	20	13	11	69
		% within perceived level - resilience	11.6%	15.9%	8.7%	29.0%	18.8%	15.9%	100,0%
		% within assessed level	42.1%	50.0%	46.2%	76.9%	76.5%	68.8%	61,1%
Total		count	19	22	13	26	17	16	113
		% within perceived level - resilience	16,8%	19.5%	11.5%	23.0%	15.0%	14.2%	100.0%
		% within 40. class of age	100,0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14.30 — Contingency table: perceived and assessed level (low L, medium M, high H) of sustainability (S).

			assessed level						Total
			MR-MS	MR-LS	LR-MS	HR-HS	MR-HS	HR-MS	
perceived level - sustainability	*[NO]*	count	1	4	2	2	3	3	15
		% within perceived level - sustainability	6.7%	26.7%	13.3%	13.3%	20.0%	20.0%	100.0%
		% within assessed level	5.3%	18.2%	15.4%	7.7%	17.6%	18.8%	13.3%
	HS	count	4	2	1	2	2	4	15
		% within perceived level - sustainability	26.7%	13.3%	6.7%	13.3%	13.3%	26.7%	100.0%
		% within assessed level	21.1%	9.1%	7.7%	7.7%	11.8%	25.0%	13.3%
	LS	count	7	5	3	3	3	1	22
		% within perceived level - sustainability	31.8%	22.7%	13.6%	13.6%	13.6%	4.5%	100.0%
		% within assessed level	36.8%	22.7%	23.1%	11.5%	17.6%	6.3%	19.5%
	MS	count	7	11	7	19	9	8	61
		% within perceived level - sustainability	11.5%	18.0%	11.5%	31.1%	14.8%	13.1%	100.0%
		% within assessed level	36.8%	50.0%	53.8%	73.1%	52.9%	50.0%	54.0%
Total		count	19	22	13	26	17	16	113
		% within perceived level - sustainability	16.8%	19.5%	11.5%	23.0%	15.0%	14.2%	100.0%
		% within 40. class of age	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14.31 — Contingency table: perceived combined and assessed level (low L, medium M, high H) of resilience (R) and of sustainability (S).

			assessed level						
			MR-MS	MR-LS	LR-MS	HR-HS	MR-HS	HR-MS	*Total*
perceived level - combined	*[NO]*	count	4	5	4	3	4	4	24
		% within perceived level - combined	16.7%	20.8%	16.7%	12.5%	16.7%	16.7%	100,0%
		% within assessed level	21.1%	22.7%	30.8%	11.5%	23.5%	25.0%	21,2%
	HR-HS	count	3	0	0	0	0	1	4
		% within perceived level - combined	75.0%	.0%	.0%	.0%	.0%	25.0%	100,0%
		% within assessed level	15.8%	.0%	.0%	.0%	.0%	6.3%	3,5%
	HR-LS	count	1	1	1	0	0	0	3
		% within perceived level - combined	33.3%	33.3%	33.3%	.0%	.0%	.0%	100,0%
		% within assessed level	5.3%	4.5%	7.7%	.0%	.0%	.0%	2,7%
	HR-MS	count	1	0	1	1	2	1	6
		% within perceived level - combined	16.7%	.0%	16.7%	16.7%	33.3%	16.7%	100,0%
		% within assessed level	5.3%	.0%	7.7%	3.8%	11.8%	6.3%	5,3%
	LR-LS	count	2	3	2	1	0	0	8
		% within perceived level - combined	25.0%	37.5%	25.0%	12.5%	.0%	.0%	100,0%
		% within assessed level	10.5%	13.6%	15.4%	3.8%	.0%	.0%	7,1%
	LR-MS	count	0	4	0	3	1	1	9
		% within perceived level - combined	.0%	44.4%	.0%	33.3%	11.1%	11.1%	100,0%
		% within assessed level	.0%	18.2%	.0%	11.5%	5.9%	6.3%	8,0%
	MR-HS	count	1	1	0	2	3	2	9
		% within perceived level - combined	11.1%	11.1%	.0%	22.2%	33.3%	22.2%	100,0%
		% within assessed level	5.3%	4.5%	.0%	7.7%	17.6%	12.5%	8,0%
	MR-LS	count	3	1	0	2	2	1	9
		% within perceived level - combined	33.3%	11.1%	.0%	22.2%	22.2%	11.1%	100,0%
		% within assessed level	15.8%	4.5%	.0%	7.7%	11.8%	6.3%	8,0%
	MR-MS	count	4	7	5	14	5	6	41
		% within perceived level - combined	9.8%	17.1%	12.2%	34.1%	12.2%	14.6%	100,0%
		% within assessed level	21.1%	31.8%	38.5%	53.8%	29.4%	37.5%	36,3%
Total		count	19	22	13	26	17	16	113
		% within perceived level - combined	16,8%	19.5%	11.5%	23.0%	15.0%	14.2%	100.0%
		% within assessed level	100,0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

In general terms, the perceived levels of resilience and of sustainability do not exhibit comparable tendencies. Indeed, among the respondents associated to a high level of resilience (HR) the majority (27.3%) referred to a Municipality assessed in an intermediate condition (MR-MS), whereas among the respondents associated to a high level of sustainability (HS) the highest frequency (26.7%) was equalled by two assessed levels (MR-MS and HR-MS). Turning to the lowest levels, from the resilience side respondents most frequently (38.9%) belonged to the MR-LS Municipality, while for the sustainability side to the MR-MS Municipality (31.8%). On the contrary, respondents associated to a medium level, either of resilience or of sustainability, most frequently (29.0% and 31.1%, respectively) pertained to the Municipality in the most desirable conditions (HR-HS). It is noteworthy that the proposed values are not affected by the widespread preference over the medium levels, since the percentages are valid within each perceived level. Correspondingly, considering the frequencies of the perceived levels within each assessed level might not add any significant insight to the discussion, because the percentages would be altered by the vast preference for the medium levels (either individually or combined).

Eventually, a comparison among perceived combined levels and assessed levels returns a rather multifaceted picture. Some peculiarities emerged immediately in terms of mismatch: indeed, some respondents were associated to levels (HR-LS and LR-LS) that were not previously detected by the analytical procedure, hence the direct comparison was not possible, while the respondents appeared distributed among the other assessed levels. In particular, it might be noteworthy that within the perceived LR-LS level, the respondents were distributed among four assessed levels (MR-MS, MR-LS, LR-MS and HR-HS), with the majority (37.5%) belonging to the MR-LS Municipality. Then, it might be relevant to observe that among the respondents who perceived to live in the most desirable conditions (HR-HS), none of them actually belonged to the HR-HS Municipality. In contrast, they were distributed between the MR-MS and the HR-MS Municipalities. Turning to the intermediate perceived condition (MR-MS), which was also the most common preference in general terms, the majority (34.1%) belonged to the most performing Municipality. In turn, it might be significant to explore the distribution of combined levels within an assessed level. In this case, it might be interesting to notice that in the HR-HS Municipality, most of the respondents (53.8%) perceived an intermediate condition (MR-MS). At the same time, within the assessed MR-MS Municipality, apart from the majority (21.1%) perceiving the corresponding combined level, a significant portion of respondents was distributed in two other levels, that are HR-HS and MR-LS (15.8% each).

14.3.4 Perceived levels and key indicators

As mentioned above, the questionnaire was designed in order to include themes that most closely resembled the indicators employed in the first phase of the quantitative analytical procedure. In this way, not only it was possible to derive the overall perceived level of resilience and of sustainability (and their combination) per each Municipality and per each respondents, but it also allowed a comparison among such perceived levels and the indicators that were used in the quantitative assessment (Table 14.31 and 14.32). In this case, the outcome will consider only the individually perceived levels, in order to ease the interpretation of the results. In addition, values will be presented in terms of highest frequency.

Table 14.32 — Perceived level (low L, medium M, high H) of resilience (R) and key indicators: most frequently preferred option and related metrics.

			9. population growth in flooding areas	11. amount of damage after flood	10. economic welfare after flood
perceived level - resilience	*[NO]*	option	as usual	low	as usual
		count	6	6	8
		% within perceived level - resilience	54.4%	54.5%	72.7%
	HR	option	as usual	low	as usual
		count	9	7	12
		% within perceived level - resilience	64.3%	46.7%	85.7%
	LR	option	as usual	high	worse
		count	9	7	12
		% within perceived level - resilience	50.0%	38.9%	66.7%
	MR	option	as usual	low	as usual
		count	51	33	52
		% within perceived level - resilience	73.9%	47.8%	75.4%

Table 14.33 — Perceived level (low L, medium M, high H) of sustainability (S) and key indicators: most frequently preferred option and related metrics.

			19. transformation of green areas	21. quantity of urban and industrial use of water	26. number of species in dangerous conditions
perceived level - sustainability	*[NO]*	option	as usual	lower/higher	average
		count	8	5/5	7
		% within perceived level - sustainability	57.1%	37.5%/37.5%	50.0%
	HS	option	wider	as usual/higher	average
		count	9	6/6	7
		% within perceived level - sustainability	60.0%	42.9%/42.9%	53.8%
	LS	option	smaller	as usual/higher	high
		count	10	8/8	8
		% within perceived level - sustainability	45.5%	36.4%/36.4%	36.4%
	MS	option	as usual	as usual	average
		count	50	45	40
		% within perceived level - sustainability	82.0%	75.0%	67.8%

In general terms, the preferences of the respondents associated to the highest levels (HR and HS) often resembled those of the respondents related to mediums levels (MR and MS), regardless of the considered indicator. In such cases the respondents favoured the options related to intermediate judgements (“as usual”, “average”). The respondents associated to the lowest levels (LR and LS) most frequently preferred the options representing extremes (“high”, “worse”, “smaller”, “higher”), except for the high level of sustainability (HS) when addressing the transformation of green areas (the most preferred option was “wider”). The indicator dealing with population growth received the most homogenous response, as in every case the most preferred option was “as usual”, and similarly a significant portion of respondents, throughout the perceived levels of sustainability, selected the option “as usual” when asked about the quantity of water employed for human activities. It might be interesting to observe that the topic of sustainability was sometimes divisive. Indeed, while in all other cases a definite majority of preferences clearly emerged, for one of the sustainability-related indicator (water use for human activities) the respondents were equally distributed among two of the available options (“as usual” and “higher”), although this ambiguity did not involve the respondents associated to MS.

At this point, the available information concerns the perceived levels, of resilience and of sustainability, and the key indicators, mirroring those employed in previous cluster analysis and derived from the questionnaires, along with their association. In particular, it might be significant to bear in mind that each question envisioned three options, each representing a possible variation trend (that is, an increase, a decrease or stability). In a similar vein, the previously drawn clusters divided the Municipalities and thence identified the groups on a comparative basis, meaning that the process evaluated if values were higher or smaller among the Municipalities, per each indicator. In addition, in this phase, per each option of each question, it is possible to retrieve the magnitude of preference among the respondents, hence it is possible to identify the dominant trend per each question (/key indicator). Against this background, it is possible to draw the configuration of clusters of resilience and of sustainability, similarly to the outcome of the previous cluster analysis, but based on the perception of the respondents (Fig. 14.12 and 14.13). In other words, the most preferred option per each key indicator would suggest the definition of the levels of resilience and of sustainability.

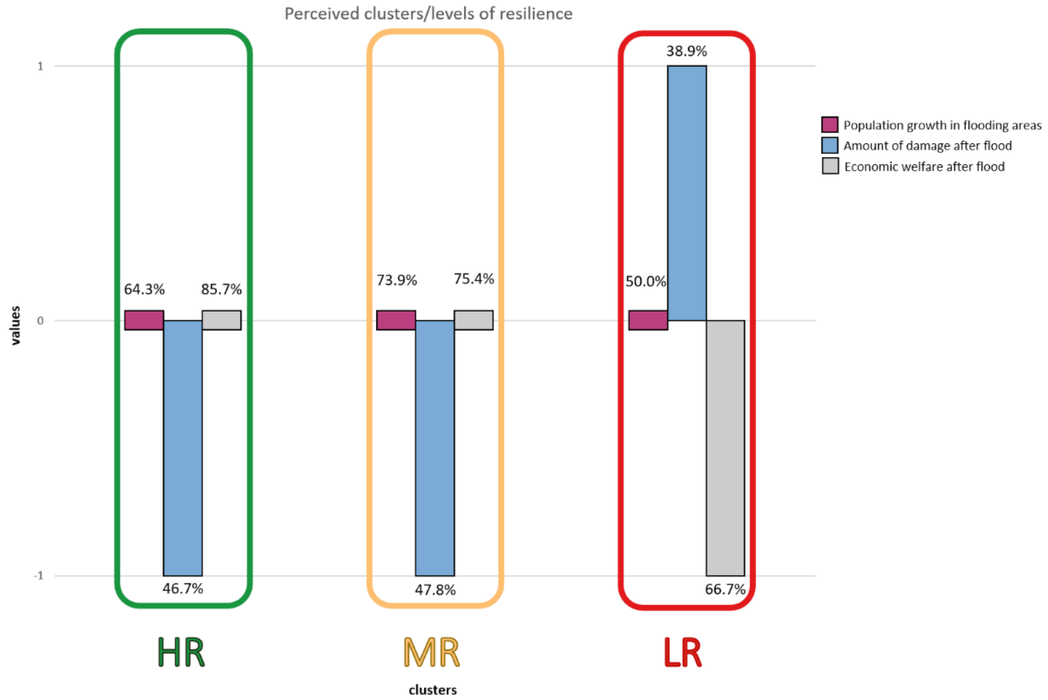


Figure 14.12 — Perceived levels of resilience (low - LR, medium - MR, high - HR) and the most frequently preferred option (and respective percentage of preference) for the key indicators included in the questionnaire.

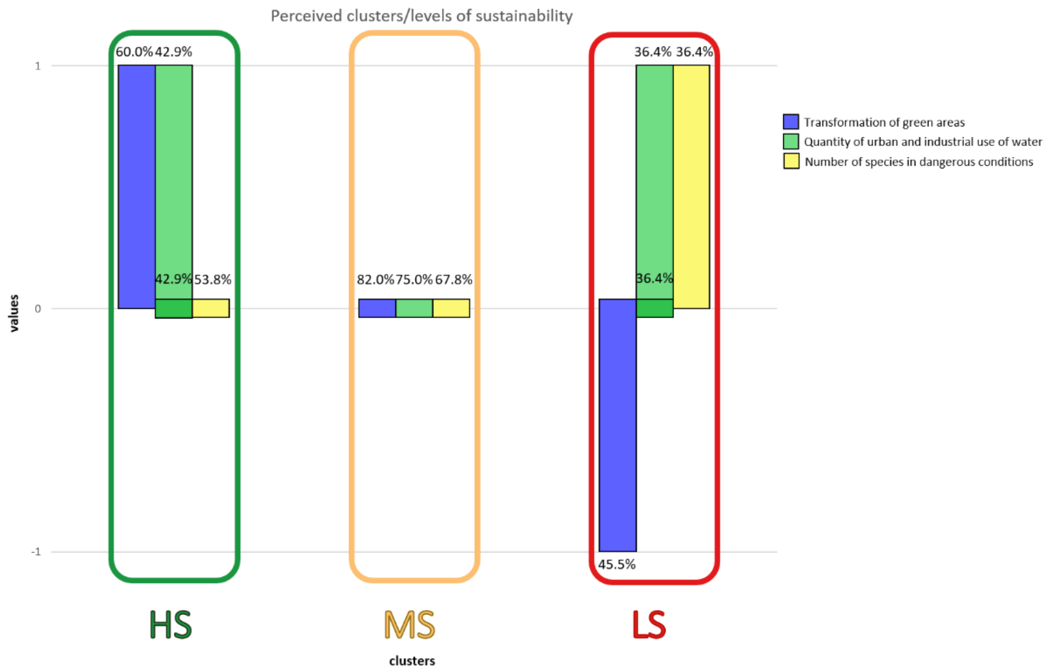


Figure 14.13 — Perceived levels of sustainability (low - LS, medium - MS, high - HS) and the most frequently preferred option (and respective percentage of preference) for the key indicators included in the questionnaire.

Firstly, it might be interesting to observe that in the resilience case, the highest and medium levels/clusters (HR and MR) exhibit the same trends in terms of preferences, whereas for the sustainability case the high and low levels/clusters (HS and LS) reintroduce the ambiguity in the definition of the most common preference for one of the indicators, as anticipated above. Apart from such peculiarities, it is possible to notice that, for the resilience *core*, the high (HR) and medium (MR) levels are perceived as characterised by an invariance in the presence of population in flooding areas, a low amount of damage suffered after a flood event and a general invariance in the local economic welfare. Nevertheless, the entity of preference of the intermediate conditions (that is, the invariance) was more stable for the medium level, with overall higher percentages throughout the indicators, except when dealing with the economic welfare, whose perception of stability was more solid for respondents associated to the higher level. The low level of resilience (LR) was depicted as an invariance of the exposed population to flood, a high magnitude of suffered damages and a decrease in the economic welfare of the community. When turning to the sustainability side, the high level of sustainability (HS) was represented as a condition where green areas are expanding, the quantity of anthropic water use is unvaried/increasing and the number of species in inadequate preservation conditions are on an average level. The medium level (MS) appears perceived as a general invariance of all indicators. Lastly, the low level (LS) is represented by a decreased extension of green areas, a usual/higher quantity of water employed for human activities and a high number of species in dangerous conditions.

14.3.5 Assessed levels and key indicators

A further association that complements the previous investigation combines the assessed levels of resilience and sustainability to the preferences expressed for the questions related to the key indicators (Table 14.34 and 14.35). While the driving questions of the previous chapter (14.3.4) could be summarised as “Among the respondents related to a specific perceived level of resilience and of sustainability, what is the dominant perception of the trends for these key indicators?”, in this case the driving question would become: “Among the respondents related to a specific assessed level of resilience and sustainability, what is the dominant perception of the trends for these key indicators?”. in other words, the above outcomes provide insights on the perception of the transformations of the Municipality, related to the perceived condition of resilience and of sustainability (e.g. “How is generally perceived the variation of exposed population to flood among those who perceive their Municipality as highly resilient?”). The outcomes that are going to be introduced here aim at exploring the perception of the transformations of the Municipality, related to the assessed condition of resilience and sustainability (e.g. “How is generally perceived the variation of exposed population to flood among those who reside in a highly resilient

Municipality?”). In order to focus on such facet, only the dominant preferences will be presented here.

Table 14.34 — Assessed level (low L, medium M, high H) of resilience (R) and key indicators of resilience: most frequently preferred option and related metrics.

			9. population growth in flooding areas	**11. amount of damage after flood**	**10. economic welfare after flood**
assessed level	*MR-MS*	option	as usual	low	as usual
		count	11	13	10
		% within assessed level	57.9%	68.4%	55.6%
	MR-LS	option	as usual	low	as usual
		count	14	9	13
		% within assessed level	66.7%	40.9%	59.1%
	LR-MS	option	as usual/less people	not high not low	as usual
		count	6/6	6	12
		% within assessed level	46.2%/46.2%	46.2%	92.3%
	HR-HS	option	as usual	low	as usual
		count	15	11	15
		% within assessed level	57.7%	42.3%	57.7%
	MR-HS	option	as usual	low	as usual
		count	15	9	13
		% within assessed level	88.2%	52.9%	76.5%
	HR-MS	option	as usual	low	as usual
		count	14	7	15
		% within assessed level	87.5%	43.8%	93.8%

Table 14.35 — Assessed level (low L, medium M, high H) of sustainability (S) and key indicators of sustainability: most frequently preferred option and related metrics.

			19. transformation of green areas	**21. quantity of urban and industrial use of water**	**26. number of species in dangerous conditions**
assessed level	*MR-MS*	option	as usual	as usual	average
		count	9	9	10
		% within assessed level	47.4%	50.0%	52.6%
	MR-LS	option	as usual	as usual	average
		count	15	13	9
		% within assessed level	71.4%	61.9%	45.0%
	LR-MS	option	as usual	as usual	low/average
		count	10	7	6/6
		% within assessed level	76.9%	53.8%	46.2%/46.2%
	HR-HS	option	as usual	as usual	average
		count	16	17	18
		% within assessed level	61.5%	65.4%	72.0%
	MR-HS	option	as usual	as usual	low/average
		count	12	8	7/7
		% within assessed level	70.6%	50.0%	46.7%/46.7%
	HR-MS	option	as usual	as usual	average
		count	8	9	11
		% within assessed level	50.0%	56.3%	68.8%

When exploring the general perception of each assumed characterising trait (that is, the key indicators) of the resilience and sustainability core, a rather homogeneous picture emerges. Indeed, in general terms the intermediate options ("as usual", "average") were preferred, regardless of the related Municipality. In other words, independently of residing in more or less desirable conditions, the perceived transformation was rather an invariance of the *status quo*, thus corresponding to the options decoded as representing medium levels of resilience or of sustainability. Some exceptions can be traced for the LR-MS Municipality, whose respondent exhibited an ambiguity of preference when dealing with the variation of the population exposed to flood hazard and with the number of species in inadequate conditions. In the latter case, also the MR-HS Municipality provided an uncertain outcome. Nevertheless, it might be interesting to observe that in these case the ambiguity revolved around the medium/low options, that related to medium/high levels of resilience or of sustainability (e.g. as previously mentioned, "less people" related to exposed population was interpreted as a perception of high resilience; similarly, "low" related to the number of endangered species was considered as a perceived high level of sustainability).

14.3.6 Perceived levels and other related themes

The last inquiries that might be explored concern the relation among the perceived levels and the proposed questions, in general terms. Although the questions corresponding to the indicators employed in the previous cluster analysis carried a specific meaning and interest for the ongoing investigation, all the questions concurred in delineating the resilience and sustainability level of the Municipalities, as perceived by the respondents. Consequently, it might be significant to consider whether some topics allowed the emergence of peculiar traits. This eventuality might be especially significant, considering the methodology adopted to decode the expressed preferences in perceived levels (of resilience and of sustainability). Indeed, such methodology was based on the association of the options with different levels, hence the most frequently preferred option translated in the overall perceived level, of resilience and of sustainability. As a consequence, the major trend that could be identified, consisting in preferred options matching the final, overarching level (of resilience and of sustainability) could only came naturally. Similarly, considering that the same methodology was applied also on a Municipal, leading to the identification of the overall level associated to the Municipality itself, homogenously identified as MR-MS, it was equally natural that the second major trend consisted in preferences converging towards the options decoded as medium levels. Against such a structured picture of foreseeable behaviour, peculiarities emerge clearly.

In particular, the response to the questions that directly addressed perceived behaviour, on different scales, was distinctive. Indeed, when asked whether they perceived themselves more aware of flood risk ("*7. I have become more aware of flood risk*") all the respondents agreed on a positive reply, regardless of the *core* considered (that is, all respondents, for all levels of resilience and of sustainability converged towards this self-perception). Nevertheless, such solid picture would be promptly dishevelled by the complementary question directed towards the other residents of their Municipality ("*6. my fellow citizens have become more aware of flood risk*"), that caused the preferences to be distributed once again among the available options, generally matching the corresponding level. The third question in this same thematic cluster ("*8. the citizens of my Municipality have enough means and sources to manage a flood emergency*") allowed to evidence a peculiar perception of low resilience among respondents corresponding to the overall MR and MS levels.

The parallel thematic set concerned the efficacy of flood emergency management, considered at different scales: local authorities, fellow citizens and personal (questions *16* to *18*). In this case, the picture matched the expectations, with preferences attributed to the option corresponding to the perceived level of the respondent. Nonetheless, an exception could be still observed: respondents identified with a high level of sustainability showed a significant uncertainty over the increased ability of their fellow citizens to face a flood emergency ("*17. my fellow citizens have become able to effectively manage a flood emergency*"), that was decoded as a medium perceived level (of resilience).

A further peculiar behaviour could be observed when considering the last issues proposed for the sustainability section of the questionnaire, that are protection of natural areas and mitigation of anthropic pollution (questions *28* and *29*). While the association among sustainability levels and preferred options tended to be highly consistent with the expected preferred options, the resilience levels did not agree with such picture. Indeed, the perception about the protection of natural areas ("*28. protection of natural areas*") envisioned mild judgements coming from some HS respondents along with the majority of the LR respondents, whereas the MR respondents tended to favour the most encouraging option. In contrast, the discussion over the efforts to mitigate polluting emissions ("*29. initiatives to reduce (water, air, soil) pollution*") registered a unanimous convergence towards a general disapproval and discouragement of the enacted activities.

Lastly, it might be interesting to notice that when considering the anthropic impact on the riverine area ("*27. effects of human activities on river and streams*"), the respondents were once again polarised around the most severe judgement, that is recognising a general negative effect of humans of the natural water system.

15. Discussion

The lines above explored the further expansion of the initial quantitative methodology that led to the moulding of the enhanced proposed methodology. In particular, the process employed questionnaires in order to investigate the perceived level of disaster resilience and environmental sustainability of the Municipalities from the perspective of the local communities. Hence, the survey involved six case studies of the Marche Region, each representing a distinct combined level of resilience and sustainability as previously quantitatively assessed. At this point it is possible to draw the overall picture and the peculiar traits that emerge from the voices of the local populations.

Consequently, in the following paragraphs the exploration will proceed similarly to the previous section, that is through the characterisation of the overall judgement of each Municipality, later decomposed in the views of the individual respondents, regardless of their community of origin. Eventually, some insights will be drawn concerning the perceived resilience and sustainability capacities of local communities.

15.1 General perception of the resilience and sustainability level

As previously mentioned, the Municipalities were selected in order to satisfy two main criteria: being representative of the combined resilience and sustainability levels identified in the previous analytical process, with the aim of comparing all the possible assessed levels with the perceived ones; belonging to the same river basin, in this case the Esino river basin, so that the physical, social and cultural characteristics would be similar enough, or at least representative of a specific physiographic unit, to allow a comparison among the responses and evidence the peculiarities that might emerge.

The collected questionnaires envisioned similar percentages among the Municipalities, ranging from 13 to 26 forms. Indeed, the response mirrored the magnitude of the population, thus it was reasonable to receive more answers from Municipalities such as Jesi, Falconara Marittima and Fabriano. As the survey was mostly carried on through telephone contact, the willingness to participate in the research resulted a significant factor for the collection of the local perceptions. In light of this consideration, it might be interesting to analyse the responding population. In general terms, the emerging profile of the respondent is a female, aged between 45 and 80 years old (more probably between 65-80 years old), who completed high school, whose income is around 15001-30000€ and has spent most of her life in her Municipality. In other words, when dialling a random number, this kind of answering profile would most probably agree to take part in the survey and thence to provide their view on the local capacities to deal with flood risk and to manage environmental issues. It might be also considered that this kind of answering profile would be the most actively interested in disclosing personal beliefs and ideas, as well as the most engaged and aware of the topics proposed through the questionnaire.

It might be noteworthy that, in spite of the methodological design intended to emphasise the local peculiarities and possibly the unique features of the Municipalities (significantly differing for resilience and sustainable capacities), the local perceptions were strictly homogeneous. That is, the respondents of all six Municipalities converged towards a common assessment of medium resilience and sustainability capacities. As a consequence, MR-MS resulted the perceived combined level resulted for all case studies. This might suggest that, regardless of the efforts (or inactivity) of the Municipalities to foster resilience and sustainability, the population would be generally cautious in their judgements, generally not expressing extreme opinions. Although this might be due to a personal, yet generalised, attitude of not revealing extremist beliefs, but rather to exhibit a moderate approach, such a uniform response might still be informative of the overall perception of the local communities. In particular, it might be reasonable to extend such generalisation at least to the Esino river basin, if not to the whole Marche Region: as previously mentioned, the river catchment presents similar features within its borders by definition, but it is also consolidated that the characteristics of the Marche Region are rather comparable throughout the territory. The first consequence of such generalised prudence is that the perceived level of resilience and sustainability does not match the assessed level. It might be significant to consider that it is reasonably possible that the indicators employed in the quantitative analysis missed some important traits that could be recorded and accounted for only by those living the local communities, resulting in an approximated estimate of the assessed level. Nevertheless, also in light of the comparative methodology enacted in the previous phases, it appears hardly possible that all Municipalities eventually belonged to the MR-MS level. Consequently, such a mismatch could indeed result significant. For instance, it suggests that the higher efforts towards the consolidation of resilience and sustainability capacities were not evident for the local communities or that the effects of such endeavours did not reach the population. Otherwise, when the discrepancy concerns lower levels of either *core*, it might translate into an unfounded confidence in local capacities. Such a condition might be especially concerning in case of a disaster: assuming that the community owns capacities more consistent than they reasonably are might result in an inadequate behaviour compared to actual risk. In light of these considerations, it appears that this kind of comparison as well as the identification of such discrepancies might be informative when planning the dissemination of the achieved results or when foreseeing the local expected attitudes towards specific situations.

Along with the assessment of the Municipal levels of resilience and sustainability, the set of questions aimed at enabling the local communities to indicate which are the assets that they value the most, along with the related acceptability of loss and recovery. These aspects are especially relevant within the context of the panarchy paradigm, which served as the basis of the present research endeavour. Indeed, the developmental phase and especially the collapse of an *adaptive cycle* is determined on the basis of the status of the basic, identifying functions of the system. As a consequence, it is fundamental first, to identify such basic functions and second, to define the thresholds surrounding their loss and their restoration. Within this context, a substantial difference between the resilience and the sustainability *cores* could be identified. Such difference emerges since a preliminary examination of the overall picture: while the preferences expressed for the themes related to resilience show a considerable variation among the respondents, the case of the sustainability-related topics reaffirmed a general homogeneity of the responses. Hence, it appears that while the matters concerning anthropic processes and their preservation might spark discussion and division among the population (at least on a physiographic or regional level), the same does not occur for issues related to the environment. In other words, in general terms, it appears that the preservation of the environment is perceived as a pivotal topic, regardless of the local peculiarities. More in detail, the most valued functions in terms of resilience capacities were identified in the health system, the productive system and the education system, followed by waste management, water and energy systems. Even though the relevance attributed to these assets, and especially to the health system, might be affected by the current unprecedented conjuncture (while these questionnaires were delivered and these lines were written, the COVID-19 pandemic was altering the perspectives of the worldwide population, and Italy made no exception), the expressed preferences portrait communities that prioritise work and education over other commodities. In other words, it appears that the surveyed communities recognise the highest importance to the preservation of the activities that define the individual role and contribution to society, as well as that allow personal self-sufficiency (that is, once that you can work and thus earn an income, you can provide for any other service), along with the welfare system that characterise the Italian national health management. Nevertheless, the communities exhibit a different tolerance of their loss: though the majority could withstand a rather long period (up to one week) before being affected, some communities affirms that would be able to bear only few hours without such basic functions. After a loss actually occurs, though the majority expects them to be recovered in the least time possible, some might accept to wait for more time. It might be noteworthy that such differences are not associated to the levels of resilience. In other words, higher levels of resilience do not necessarily correspond to a higher tolerance of the potential interruption of such functions: for instance, respondents related to the Municipality of Jesi (HR-HS) would tolerate an interruption of one week and a recovery process of few hours, whereas the respondents from Serra San Quirico (HR-MS) would accept both an interruption and a restoration lasting up to one week; nevertheless, the case of Jesi is mirrored by the cases of Falconara Marittima (MR-LS) and of San Marcello (MR-HS), both identified with a lower level of resilience. It might be interesting to notice that the least performing Municipality (that is Genga, LR-MS) exhibit a high tolerance both of loss (up to one day) and recovery (up to one week). Such an inhomogeneity appears to suggest that rather than the quantitatively assessed level of resilience, other factors might be result pivotal in determining the level of acceptability of the potential impact of a disaster. In particular, in this case local characteristics and dynamics might become especially significant. The possibility that the level of resilience might not significantly influence the identification of these thresholds seems confirmed when considering the perceived level: all Municipalities were associated to a medium level, hence this feature does not appear to be a discriminating factor. The only aspect of resilience-related themes that allowed to identify two distinctive groups among the Municipalities concerned the expectations towards the quality of the recovered functions: while the Municipalities associated to a combined level including at least one high extreme (Jesi HR-HS, San Marcello MR-HS, Serra San Quirico HR-MS) would accept the maintenance of the same level of functionality, those in medium-low conditions (Fabriano MR-MS, Falconara Marittima MR-LS, Genga LR-MS) would prefer an increase of the local capacities. In this case, the effect of the quantitatively assessed level of resilience appears to play a significant role in shaping attitudes, although this might be a not emerge on a conscious level. As previously mentioned, environmental issues cancel any kind of differences that could be previously delineated. Indeed, the preservation of natural assets was unanimously asserted as directed towards the ecosystems services related to water, air and food, in an effort to limit as far as possible their degradation and nurture their eventual restoration to the point that any level of loss would be acceptable. Such an attention to environmental themes might be a result of the ongoing environmental changes that are affecting global as well as local systems, altering the familiar landscapes and thus urging a prompt reaction. This kind of attitude might manifest more evidently in those populations that are particularly bonded and devoted to their community, as the sense of belonging might promote a sound engagement in the protection of the local system. Indeed, the communities of the Marche Region generally live in close contact with the natural environment, activities (both economic and recreational) directly dealing with nature are rather common and settlements are generally rather small and circumscribed, surrounded by natural areas. Consequently, it appears reasonable that such a rural (rather than urbanised) identity of the Municipalities of the Marche Region might play a pivotal role in driving the expectation for a significant endeavour in preserving natural landscapes.

When considering in detail the topics that more than others evidenced peculiar attitudes, the question traditionally related to resilience perception emerged as especially insightful. In particular, the common response denoted a confidence in the personal awareness of flood-related issues that was not shared with the fellow citizens, and in general with the potential ability of the overall community to cope with a flood emergency. Consequently, it appears that locals might rather rely on personal than common means and strategies to deal with flood emergency. At the same time, the judgement over the effects of a flood event on their community was rather moderate, thus generally recognising a mild impact of this kind of event on the local activities and everyday life. As a consequence, it seems that according to the collected perceptions, the recognised significant resilience of the Municipality is more due to the capacities of the individual households than of the common efforts. Acknowledging this common standpoint might be significant when designing local plans to deal with flood disasters: for instance, it suggests that a further energies should be spent in giving higher visibility to the local activities of the civil protection authorities, or in promoting the mutual trust within a community. Coming to the sustainability themes, the relevance of environmental issues appears confirmed by the general dissatisfaction in terms of enacted activities to preserve natural areas and reduce human pollution. Nevertheless, it might be interesting to observe that the judgement over the effects of human activities on riverine systems is not unanimously negative: indeed, positive trust in human efforts might suggest that there is a component of the local populations that believe in a nurturing ability of humans towards natural systems. In other words, these traits appear to draw a picture where human activities are considered at the same time highly detrimental and potentially constructive: anthropic processes might destroy natural equilibria and hamper natural ecosystem as well as contribute to their restoration and preservation. This perspective appears rather encouraging when planning environmental strategies, as it suggests that the engagement of local communities might be not only acknowledged but also required by those same communities.

15.2 Individual perception of the resilience and sustainability level

As previously suggested, along with an examination of the outcomes averaged on a Municipal level, it might be interesting to delve into the responses on an individual level, or, rather, averaging the outcomes over the perceived level, of resilience, sustainability and combined.

The first question that should be addressed concerns the distribution of the respondents among the perceived levels. In light of the perceived assessment averaged on the Municipal scale, the predominance of the medium levels (and of their combination) is easily predictable. Nevertheless, at this point the magnitude of such predominance could be explored. Although this prevalence is unquestionable, it might be interesting to observe that the other two levels, that represent the extremes of each *core*, shared a comparable response from the locals. This facet appears to suggest that there is not a commonly agreed opinion on the tendency of the general status of disaster and environmental capabilities: whether it is medium-high or medium-low could not be detected from the partial perceptions. Nonetheless, the examination of the combined levels provides a hint on these themes. Indeed, the levels that reach the second-highest approval among the respondents represented a combination of medium and low levels (MR-LS and LR-MS), along with a preference over high sustainability (MR-HS). Furthermore, the third highest share was achieved by the combination of the lowest levels (LR-LS). Consequently, it seems that while the management of environmental issues does not gather a common consensus among the population, the risk-related themes lead to an overall lack of confidence in the local capacities. Although this might be a symptom of a more generalised distrust in the means and abilities of the local communities (especially local authorities), it might also be influenced by specific issues unravelling in the area. Thence, it might be relevant to trace the origin of such critical conditions and possibly addressed them.

Similarly to the previous case, a further look might be focus on the demographic characterisation of the respondents. In this case, the trend that emerges is a predominant preference of females for the higher levels compared to male respondents, regardless of the *core* or combination considered. Indeed, the female preference was more significant for the higher levels, progressively decreasing towards the lower levels, up to an equal distribution for the case of sustainability (LS) or the reverse male predominating preference for the resilience case (LR). Such trend is mirrored by the combined levels, where the combination describing the most desirable conditions (HR-HS) envisions only female preferences, whereas that depicting the least desirable conditions (LR-LS) exhibits a more significant male preference. This picture appears to suggest that female respondents tend to exhibit a more benevolent cognition of their Municipality, especially compared to the male counterpart, which tend to be associated to a more negative perspective. These peculiarities appear to suggest that the population might show sharply different approaches towards their community and the surrounding environment. Such tendencies might turn informative when trying to anticipate the local attitude towards specific themes. In particular, this kind of information might result beneficial in designing informative and management strategies towards specific public targets, in order to raise awareness where is lacking or promote local capacities where they are not visible.

The other basic characteristics describe a general situation where the younger groups are related to less positive perspectives on their communities, to the point that no young respondent (aged between 18 and 34 years old) indicated either of the highest levels. On the contrary, the eldest groups tended to provide more optimistic views of their surroundings. Thence, it appears that the younger generations are the most discouraged in terms of local capacities to deal with flood risk and environmental issues. At the same time, within each level, the groups with the highest education attainments tend to be more relevant for the highest levels, suggesting that education might positively influence the approach towards the local conditions. Drawing generalisations from the class of income might be inappropriate given the significant concentration in the first two. Nevertheless, it might be noteworthy that the few respondents pertaining to the higher class basically converged towards the medium levels of both *cores*, thus suggesting that income does not significantly influence the conception of the community. Lastly, in terms of knowledge and experience of the local dynamics, it appears that a longer period of residence tends to extremise judgements, whereas residents for intermediate periods of time tend to exhibit more moderate standpoints. In brief, youngsters tend to own more pessimistic representations of the disaster and environmental capabilities of their communities, whereas elderlies and more educated citizens tend towards more encouraging views, and wealthier or less stable residents assume milder positions. As a consequence, it appears that the composition of the population might indeed affect the overall perception of the local disaster resilience and environmental sustainability, thus also shaping expectations or lost hopes when considering the development path of the respective Municipality.

A further significant information might derive from the comparison among assessed and perceived levels. This process would allow to verify if the conceptions of the populations meet the numerical evaluations, that is if the picture drawn by numbers corresponds to that stemming from living the local territories. Also, it might be beneficial to question whether some significant characteristics of the local communities were not addressed by the computations, thus hampering the reliability of the results. It might also inform on the grade of awareness of either local potentials or local issues, both from a resilience and a sustainability perspective. In this case, the most evident feature that emerges is the substantial mismatch between assessed and perceived levels. In other words, in general the conception of the locals does not correspond to the characterisation that numerical indicators would suggest. The general convergence of the preferences towards the perceived medium levels that was already mentioned in the lines above inevitably leads to a discrepancy to the assessed levels (as Municipalities were selected in order to represent each a different level). A rather predictable consequence is that perceived levels of resilience and of sustainability usually do not correspond to the respective *core* in the combined level of the pertaining Municipality: for instance, the respondents associated to the highest level of resilience (HR) mainly belong to Municipalities assessed on a MR-MS or a LR-MS level, thence with a completely different assessed level of resilience. Such divergencies are even more evident when comparing the combined levels, both perceived and assessed. Once again, the exemplification might concern the most desirable conditions: indeed, none of the respondents residing in the most performing Municipality actually perceived these favourable conditions; rather, the local citizens were associated to more dire perceptions, up to diametrically opposite to the assessed level of their community (LR-LS, LR-MS, MR-LS). Furthermore, it might be noteworthy that the combination of perceived levels led to the presence of combined levels that were not detected by the previous quantitative process: LR-LS was not present throughout the Marche Region, while HR-LS was not present among the selected Municipalities for the collection of the local perspectives. These levels are especially meaningful, as they represent some of the most critical conditions, that correspond, respectively, to a crisis of the basic services of the community (*collapse*) and to an unbalanced development that strengthens human capacities in spite of natural equilibria (*resilience trap*). Tracing a similar perception (of the Municipality of belonging lying in such dreadful conditions, especially when it might reasonably not correspond to the actual status) is extremely significant to comprehend the point of view of the local populations. In particular, it might be informative to foster and optimise efforts to raise awareness on the local abilities and assets devoted to risk management and environmental preservation. Indeed, a sounder relation of the population with their communities might influence the overarching attitude towards local processes and everyday life: strengthening a sense of belonging and an overall consciousness of the local issues might be beneficial to foster personal engagement and common proactivity to strengthen the community.

A further area of discussion might revolve around the questions that aimed at most closely mirroring the indicators employed in the first phase of the quantitative assessment. Such exploration brings to the surface a first peculiar trait of the local perception: in general terms, local communities feel like their Municipality is not changing, at least in the features that were assumed as most significant to detect the resilience capacities and the sustainability commitment. This is demonstrated by the overall preference granted to moderate opinions, regardless of the perceived level or of the assessed level of the pertaining Municipality. Furthermore, it appears that the most extreme views were related to the worst perceived status, as if the perception of residing in dire conditions exacerbated the overall judgement. This might be symptomatic of a more diffuse and generalised discontent that might result urgent to address. The only outlier in this picture is represented by the highest level of sustainability, which indeed matches the evaluation of the green area transformation. This appears to suggest that in spite of the other topics, being the anthropic use of water and the conditions of wildlife, the preservation of natural areas is especially significant to identify the appreciation towards endeavours devoted to improving local sustainability. In particular, allowing natural areas to expand seems related to a rather positive conception of the local ability of human communities to coexist with the natural environment. As a consequence, it appears to be a highly appreciable and desirable action to increase local sustainability, that would be supported and advocated by the locals.

The investigation around the association among perceived levels and seemingly quantitative indicators allowed also to draw the definition of the levels of resilience and of sustainability as they emerge from the expressed preferences. In other words, the previous quantitative assessment compared the values of such indicators among all the Municipalities and accordingly delimited groups of homogeneous characteristics (Fig. 15.1 and 15.3): the definition of higher or lower levels proceeded through the interpretation of such groups in terms of trends of the indicators (for instance, if a group was characterised by more exposed population, high amount of damage and disadvantageous economic conditions, this would be translated in a low level of resilience). On the contrary, in this case the perceived level of resilience and of sustainability was already known (as derived from the analysis of the overall questionnaire), hence it was possible to associate each level to the trends of the same indicators, in terms of frequency of preference (Fig. 15.2 and 15.4).

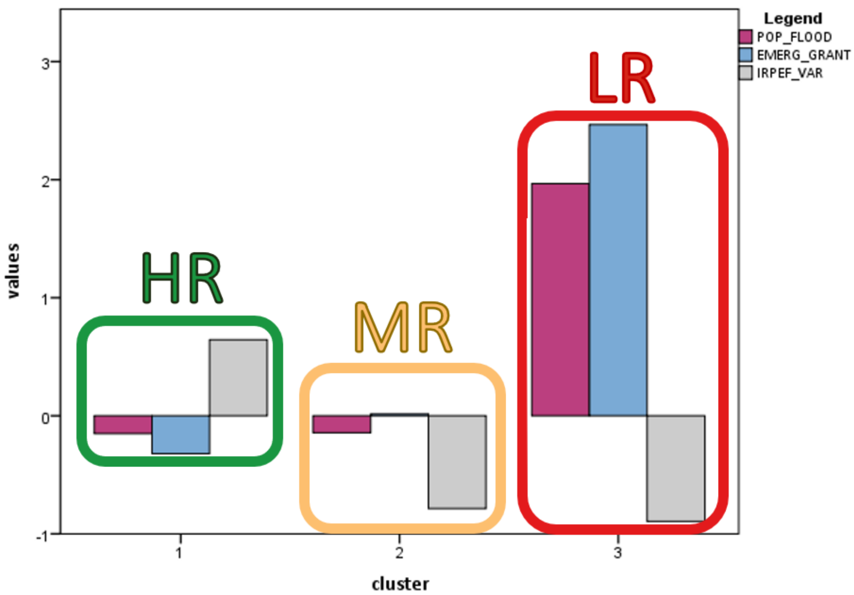


Figure 15.1 — Clusters and levels (low L, medium M, high H) of assessed resilience (R).

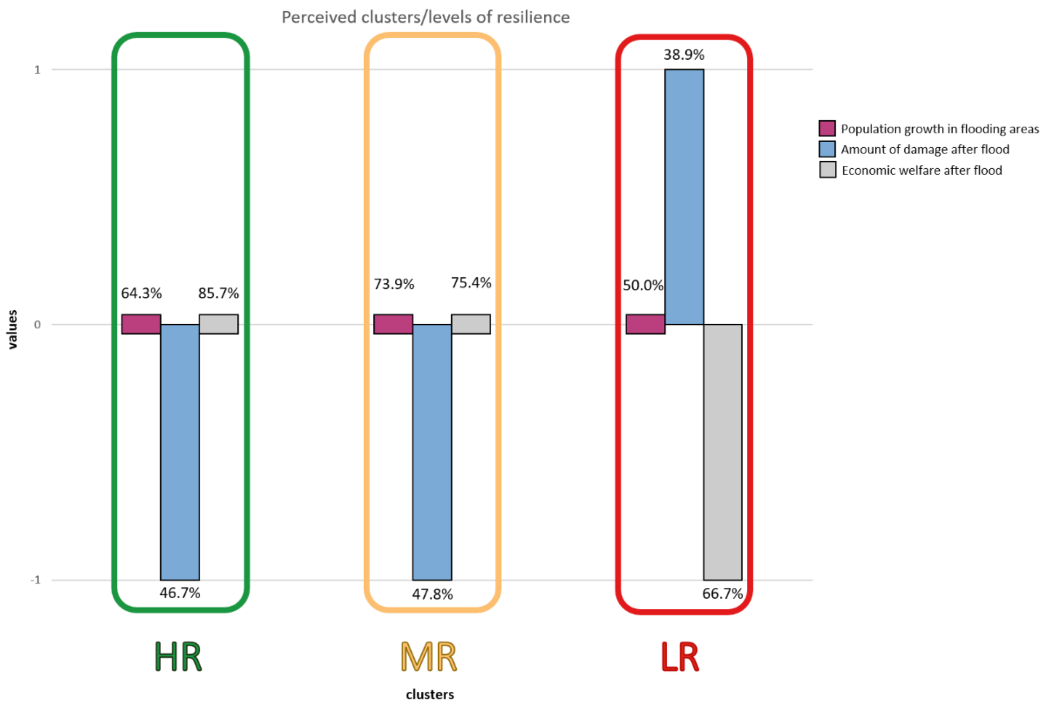


Figure 15.2 — Clusters and levels (low L, medium M, high H) of perceived resilience (R).

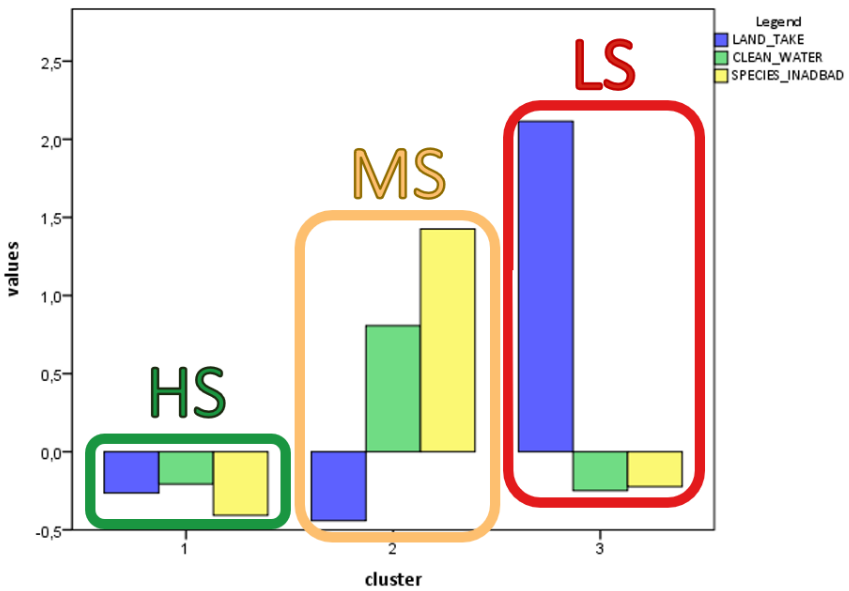


Figure 15.3 — Clusters and levels (low L, medium M, high H) of assessed sustainability (S).

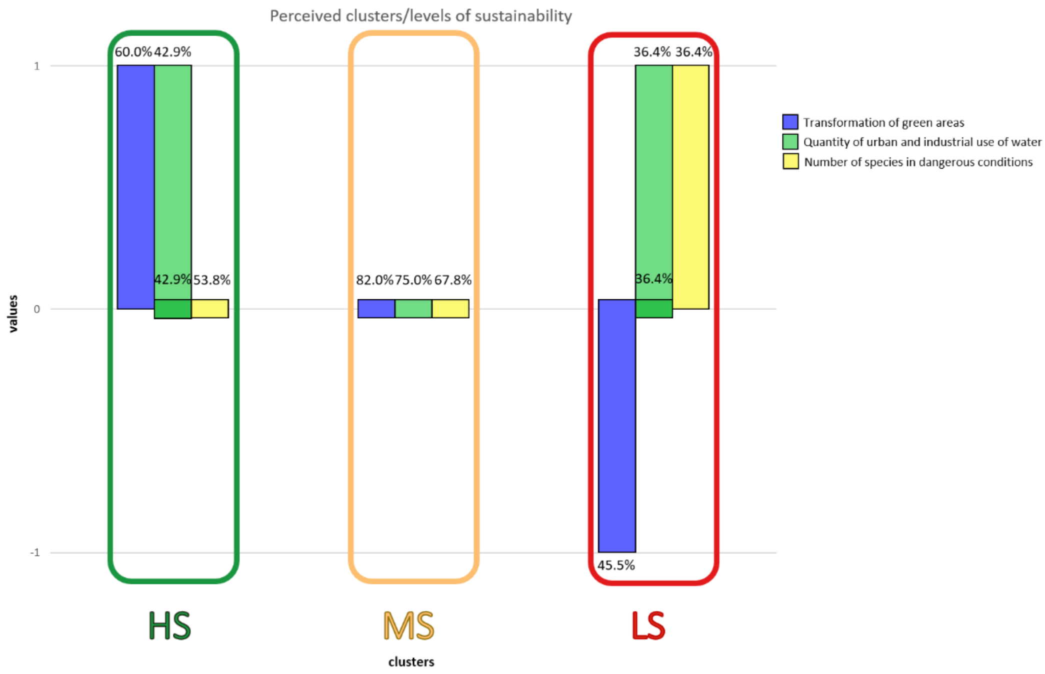


Figure 15.4 — Clusters and levels (low L, medium M, high H) of perceived sustainability (S).

When confronting the drawn clusters it should be bore in mind a couple of differences: first, the quantitative assessment allowed to evidence a grade in the trend (for instance, how extensive is the exposure of population to flood), whereas the perceived clusters show either an increase/decrease or an invariance. Furthermore, the representation of the transformation of green areas holds opposite meaning in the two representations: in the quantitative assessment “more” means an increase in the magnitude of conversion of natural to anthropic areas, while in the perceived assessment “more” translates into wider natural areas. Apart from these differences, the comparison is still conceivable. In particular it appears that neither in this case quantitative and perceived estimations agree. Indeed, the quantified and preferred tendencies generally do not match among the same level, either of resilience or of sustainability. The confrontation is partially more encouraging when considering the high level of resilience (HR), and especially the extreme negative levels (LR and LS), that exhibit a rather high adherence, notably for the resilience *core*. This appears to suggest that the priorities and relative importance of the characterising factors might differ among the considerations that lead to a quantitative paradigm and the views shaped after living a specific area for a long time. In other words, the fundamental features that might be recognised as relevant and significant for an analytical process do not necessarily correspond to the priorities of the local populations. At the same time, the most dire conditions appear to lead towards a convergence of the quantitative assessment and of the qualitative investigation, suggesting that in this case the traits associated to the most negative status are both numerically detectable and individually perceptible, as well as concerning the same issues. In this case, it might be relevant to observe that the most discriminating factors were the effects of flood events for the resilience side and the integrity of natural systems, both in terms of unaltered vegetation and of endangered species, for the sustainability side. This information might provide further insight on the domains that should receive primary attention when planning strategies to address and solve the implicated themes: numbers deliver concerning tendencies, perceptions provide the urgency of action.

Lastly, the exploration of the questions that drove the most peculiar responses draw a picture rather similar to that sketched when considering the averaged level of each Municipality (in the lines above). Indeed, when questioned about flood risk management, it seems confirmed that the locals tend to attribute more substantial reliability and confidence to self-capacities, rather than to the abilities shared within their community. Such a general distrust might turn especially detrimental in times of emergency, when on the contrary social bonds and mutual dedication are pivotal to cope with and overcome the dreadful event and its impacts. When coming to the sustainability themes, though, such a negative view is transferred to the efforts spent to mitigate human impacts in terms of pollution, although the judgement on the role of human activities on the riverine equilibria is ambiguous. Indeed, this appears to confirm that though the effects of anthropic processes on the natural environment is generally acknowledged and despised, there is still some trust in the human capacities to restore, nurture and improve the conditions of the natural environment, owning the potential to positively contribute to the reversal of the current dreading trends. This faith might hint to the willingness to actively contribute to the strategies to be enhanced to foster the local environmental sustainability, rather, those endeavours appear already advocated by the local awareness of such complex issues.

15.3 Emerging traits of the local communities

As previously mentioned, the questionnaire was designed in order to address themes related to the dynamics of the Social-Ecological Panarchy. Consequently, the sections primarily encompassed proxies intended reveal the conditions of resilience and of sustainability, as well as the tolerance of uncertainty yielded by disaster events. Nevertheless, the sections were also dotted with punctual investigations on specific traits of the local capacities, that might contribute in delineating the overall picture on the local perceptions and conditions.

A first topic that was explored concerned how local authorities responded to flood risk, and in particular what kind of strategies were performed to reduce its probability of occurrence. It appears that the most recognised activities are those based on engineered solutions, that affect the built and natural environment, especially in comparison to the kind of measure that conversely are almost non-material, affecting human behaviour and attitudes. It might be noteworthy that the reported frequency of implementation is based on the observations performed by locals. Consequently, while alterations of the built or natural setting might be rather evident and easy to spot, in the absence of a substantial communication effort other measures might pass unnoticed. This might be especially true for strategies that often remain confined to technical offices, as in the case of urban plans and risk maps, although the involvement of communities might be particularly effective in raising their awareness on local critical issues and on the available approaches to cope with them.

When questioned on the susceptibility of local assets, concern appeared to converge towards the private and the productive domains, followed by the transportation system. Although the assumed scenario was hypothetical, thence it was requested to project the known vulnerabilities in a potential condition of disaster impact, the preferences might have been reasonably influenced by the actual experiences suffered by local populations due to the occurred floods. In this case, it appears that flood events hold the potential to significantly and directly affect the most identifying domains of a common daily routine: home, workplace and commuting. This might suggest a priority of action for the development of local emergency plans, as integrating continuity plans for the everyday activities of laypeople might be particularly appreciated by local communities. Whereas the apprehension for the private sphere seem to be consistent, the public domains results rather resistant with regards to flood risk, thus suggesting a sound reliance on public services even during critical events.

The limited participation of local populations in risk management endeavours is corroborated by the low awareness of the enacted planning strategies, thus suggesting a significant margin to improve risk information and communication campaigns. This type of effort might also facilitate the closure of the gap between public authorities and local populations, thus contributing in building that trust that is pivotal to face a disaster emergency with a coherent and effective approach, namely as a cohesive community. It might be noteworthy that respondents reported to be most familiar with Municipal Civil Protection Plans, with various level of detailed knowledge, and that the major source of information were acquaintances or web-based official media of local authorities. Consequently, communication strategies might take advantage of such insights by favouring focus groups of stakeholders and social media when delivering information related to risk prevention and reduction. Additionally, it appears that the higher the level of the local authority and the further it is from the sphere of experience of local populations. Consequently, a more pervasive engagement of local communities in planning and management endeavours performed at higher scales might be particularly informative as well as effective in raising awareness on the proactivity of local authorities at every level, along with potentially contributing in strengthening social trust in the overall governance system.

This kind of trust, at least in the form of confident hope, emerges when considering a hypothetical emergency scenario. In this case, respondents appear equally reliant on personal skills, acquired through a learning process, and on external help, whereas previous flood events did not leave any lesson in this regard, apparently. It might be relevant to note that in this case it is not possible to differentiate if the belief on external support was placed on local authorities or on fellow citizens, although it suggests anyway a mild sense of cohesion.

Along with themes related to resilience, a further topic concerned the sustainability of local communities. In particular, the interest was focused on the perceived changes of the local landscape. In this case, most respondents reported an alteration of natural areas in favour of further urbanisation processes, especially in the Municipalities (Jesi, Falconara Marittima and Fabriano, in order of expressed preferences) already more developed and advantaged from a socio-economic perspective. Nevertheless, it should be bore in mind that this question came as complementary to the information concerning the amount of observed alterations of natural areas, that was most frequently considered limited. Indeed, some of the respondents reported an actual expansion of natural areas. As a consequence, it appears that the dynamics of urbanisation and industrialisation do not significantly affect the surveyed local communities, seemingly lying in a sound equilibrium with their surrounding natural environment.

16. Partial conclusions

The *objective* that drove this further discussion stemmed from the intention to include the unique perspectives and standpoints of the communities that live the examined Municipalities into the quantitative assessment of the Levels of resilience and sustainability. In particular, the involvement of locals sought to incorporate their thoughts in the identification of the fundamental traits that typify their community, thus contributing in the definition of the priorities in terms of disaster and environmental management. In order to pursue this aim, the previous theoretical and analytical paradigms were employed as a base and further expanded. In particular, the analytical methodology was integrated with dedicated questionnaires to form the **CARES+ methodology**, that later was applied to a case study, constituted by six Municipalities of the Marche Region, within the Esino river basin.

In particular, the *first part* of this side of the research focused on the identification of the perceived levels of resilience and of sustainability, from the standpoint of the local populations. When averaging the responses over a specific Municipality, the outcomes delineate a homogeneous picture. Indeed, all the Municipalities were represented as lying in **medium conditions** of disaster resilience and of environmental sustainability. This portrait is in substantial contrast with the assessment provided by the employment of numerical indicators. The emerged homogeneity itself disagrees with the quantitative evaluation, as the Municipalities were selected precisely to represent all the different levels that could be traced in the Region and that punctuate the ideal development cycle of a Social-Ecological System. Delving into the perceived levels on an individual basis, that is losing the information relating to the Municipality of belonging, a more variated picture emerged. Even though the wider preference towards moderate views on the local conditions was still evident, especially when considering judgements concerning either resilience or sustainability, the most preferred combinations hint at a general discouragement in the local capacities to deal with flood risk, whereas opinions on local sustainability were more distributed. Consequently, it appears that **disaster resilience** is the theme most affected by a significant mismatch between assessed and perceived conditions. This facet suggests that it might be beneficial to deepen the investigation regarding the processes that led to such severe views. Indeed, identifying the issues that prevent the local population from acknowledging and being aware of the potential of their communities might be especially important, also in the perspective of strengthening the social bonds and trust that are fundamental for a comprehensive development of the community, as well as for a cohesive response to dire events.

This picture appears confirmed by a *side part* of the analysis that involved the characterisation of the **clusters** (of resilience and of sustainability) based on the expressed preferences. In particular, this further exploration was based on the questions designed to represent as closely as possible the indicators employed in the first part of the quantitative analysis. The general discordance between assessed and perceived metrics is once more affirmed, suggesting that the most significant factors leading especially to positive conceptions of the Municipal conditions were potentially not included in the selected quantitative indicators. The lowest extremes, though, provided an exception, particularly for the resilience side. Indeed, not only the assessed and perceived trends agreed, but they also concerned the same indicators. As well as they resulted more significant in the quantitative analysis, considerations related to the **impacts of flood events** seem to significantly and negatively affect the perception of the locals in terms of resilience, similarly to the **integrity of the natural environment** affects the local perception of sustainability. In other words, this might suggest that memory and experience might indeed significantly contribute in moulding the local perception of disaster resilience, whereas a sound relation with the environment is a valuable virtue for local populations. At the same time, throughout such key topics, preferences were most frequently accorded to moderate views on the changes that underwent in their Municipalities, regardless of the perceived level and scale of assessment. Consequently, it seems that there is a generalised perception of immutability, of permanence of the *status quo* that not even flood events could significantly alter and that pervaded all the proposed foci of discussion.

A further *side part* of the investigation appeared to provide additional insights on this sense of immutability. Indeed, although the few changes of the familiar landscape were frequently reported to pertain the urban settlements, it was possible to trace also the opposite trend, that envisions natural ecosystems successfully reclaiming space, from a multitude of voices. In a few words, it appears that the **processes of transformations** of the local landscapes are perceived as almost **balanced**. In particular, the effects of anthropic activities on the natural environment did not pass unnoticed, also in terms of measures implemented to mitigate flood risk: the **management of the riverine area**, both of the water course and of the pertaining embankments, was frequently reported. It might be interesting to evidence that a similar awareness was not gathered by those risk reduction measures that aim at influencing human behaviour or governance. Indeed, local respondents resulted **scarcely familiar with strategic, management and emergency plans** and even when informed, often the initial hint was provided by **informal means of communication**, such as social media or even by word of mouth, and usually leading to local plans, rather than policies developed at higher scales. Nevertheless, it appeared that the received information was partially effective in educating in the proper disaster behaviour, as in case of emergency equal confidence was entrusted in personal **learnt skills and external help**. In this context, anyway, it emerged a consistent concern surrounding the assets that mould common daily routines: **houses, workplaces and roadways** were depicted as the most susceptible elements of the local communities.

The exploration of the issues surrounding the collapse of a community drove the *second part* of this research section. In particular, locals were asked to identify the most important assets and services, of both human and natural systems, as well as the accepted degree of their loss. In this case, a significant divergence between the *cores* became even more evident. Indeed, the response to the themes related to the environment received an overall agreement: services connected to **food, air and water** were recognised as priorities, while a limited tolerance was exhibited for the entity and duration of damages suffered by natural systems. On the contrary, resilience-related themes induce a more significant division among the population. The prevailing features reveal communities especially caring for **health, work and education**, although a certain degree of loss is sometimes accepted, even for relatively long periods. Consequently, it seems that on one hand, **environmental issues are perceived as compelling** and their solution should not be postponed in any case. On the other hand, local authorities should spend the most significant efforts to grant continuity to the healthcare system as well as to the productive and educational systems, although the accepted degree of loss might be higher (compared to the other *core*). These considerations are particularly informative on the priorities of the communities and on the themes that more than others would rise their endorsement. Consequently, it might be particularly significant to include them in the design of local resilience and sustainability management plans and activities.

Against this background, the *third part* of this section attempted to identify a possible association among some major socio-demographic traits and perceived levels (of resilience, of sustainability and combined). Here, it might be noteworthy that not only the emerging features are associated with the expressed perceptions, but, even before than this, they are related to a willingness to participate and thence to be engaged in the resilience and sustainability issues concerning their community. This might be beneficial in the identification of the population groups that more probably would endorse a further involvement or rather those that would be compel more extensive endeavours. In this case, the typical responding profile was of a middle-aged woman, with a secondary level of education and a medium-low income, who had spent most of her life in her Municipality. When delving into the individual preferences, it emerged that **female** respondents tended to be provide more positive judgements of the overall local conditions compared to the **male** counterpart. Another influencing attribute appeared to be **age**, as younger generations apparently share a more pessimistic view on the local capabilities. On the contrary, achieving the highest levels of education seems to be related to more positive conception of the local territory. Lastly, shorter periods of residence in the area tend to translate into moderate judgements, possibly due to a limited knowledge of the area preventing the expression of extreme opinions. It might be noteworthy that the relevance of gender and age was identified also by the quantitative assessment, while in a similar vein income and education were recognised a less significant influence, at least for the resilience *core*. Hence, it appears that the outcomes validate each other, substantiating the overarching traits. In particular, the overall features that emerge describe a male population more sceptical of the local efficacy in dealing with disaster and environmental themes, similarly to younger generations. It might be considered that at least this latter case might be influenced by the higher awareness of environmental issues that might result in an overall discouragement and pessimism. Anyhow, such facets suggest that where resilience and environmental endeavours are undertaken and result successful in consolidating the local capacities, it might be necessary to promote the engagement and awareness of such efforts to those population groups.

Undoubtedly, the main purpose of the survey intended to provide a tool to collect the points of view of the local communities and shape an evaluation of the local conditions that could represent a term of comparison, and possibly integration, to the quantitative assessment. Consequently, the overall response to the questions was the main focus of analysis. Nevertheless, a further look could be payed to explore the themes that contrasted with the overall picture that could be delineated. Hence, a *fourth part* of the research was dedicated to the identification of the themes that received a peculiar response from the communities. In general terms, such critical topics concerned local **awareness and efficacy in dealing with flood risk**, **flood impacts**, **human effects and endeavours for the environment**, although in some cases discrepancies emerged when considering either the averaged or personal judgements. Nevertheless, awareness to flood risk received a rather consolidated response. Indeed, regardless of the scale of analysis and of the perceived level, there seems to be a significant confidence in the personal knowledge and sensibility towards this themes, whereas a higher scepticism is directed towards the other components of the respective community, that turns into distrust when addressing the potential ability to cope with a flood event on the base of the available resources. At the same time, there appears to be a shared uncertainty over the actual efficacy of the community, at any scale, of actually dealing with a flood event. Nonetheless, in general terms a moderate if not optimistic judgement on the actual consequences of flood event was generally recorded when considering the responses on a Municipal level, thus suggesting an overall conception of limited vulnerability and exposure of the Municipality to flood risk. Other topics of discussion concerned the efforts to mitigate human impacts on the natural environment. Also in this case a general discontent emerged, especially towards the endeavours to reduce pollution, although it was noteworthy that the judgement over the effect of anthropic processes on the environment was not univocal, though often not positive. Against this background, it appears that local residents tend to place the highest confidence in personal abilities and knowledge when pondering themes related to flood risk, discouragement that becomes even more evident when considering the efforts undertaken to preserve the natural environment. Nevertheless, the cautious faith placed on human potential ability to nurture and improve the conditions of natural ecosystems might suggest that indeed it might still be possible to develop strategies and campaigns to engage local communities as a whole in order to, on one hand, strengthen mutual trust and, on the other hand, foster the local sustainability.

vii. Conclusion

A general overview

The funding ground of this study was represented by recognition of the inherent complexity of the coexistence of humans and nature. In particular, the dire consequences that arise when human and natural processes collide led to the assumption that there is a need for gathering more comprehension on the essence of complex Social-Ecological Systems. The overarching purpose lay in contributing, even for a minutest tile, to reconstitute a coexistence between humans and nature that would encourage mutual nurturing and inhibit mutual destruction. In other words, the major drive of this research was to participate in the common endeavour to reduce disaster risk, possibly fostering the survivability of complex Social-Ecological Systems. Consequently, this research intended to develop an interpretivist paradigm that would allow to model those complex dynamics and then to design a positivist methodology that would allow to translate descriptive indicators into insightful information. In order to pursue this aim, the panarchy heuristics served as the starting point to first mould the Social-Ecological Panarchy Model and then settle the Combined Assessment of Resilience and Sustainability Methodology (CARES, then CARES+ methodology).

The ***first part*** of this research focused on adapting the *panarchy* heuristic to the definitions and assumptions of disaster science. Risk and its component, hazard, vulnerability and exposure, could find a further interpretation within the dynamics of complex social-ecological systems. At the same time, it appears inevitable that the discussion had to include environmental issues: what men might suffer, they would also exert on nature, and similarly, what men could benefit, they could also return to nature. In other words, the interaction unavoidably appeared mutual and interlaced, to the point that disaster resilience and environmental sustainability could find their simultaneous definition. The subsequent model then constituted the basis for the analytical methodology.

Thence, the ***second part*** of this research focused on the development of an operative method that would take into account disaster dynamics, as well as be flexible enough to include risk and environmental themes and provide both a classification and a characterisation of the units of analysis, in this case Municipalities. As a consequence, the methodology was composed of two phases. The first phase was based on a *cluster analysis*, in order to group Municipalities into clusters of homogenous behaviour in terms of capacities in dealing with flood risk and environmental issues and thence associating them to different levels of resilience and sustainability. Then, a second phase of analysis employed a *discriminant analysis* in order to identify the most relevant features of the Municipality that would contribute to the determination, and possibly prediction, of that behaviour before critical times took place.

Eventually, a ***third part*** of the research focused on expanding the analytical approach: the adoption of indicators, though varied as far as possible to capture the multifaceted essence of social-ecological systems, would still be unable to account for the perspective of local populations. Consequently, *questionnaires* were designed in order to gather the perceived level of resilience and of sustainability, in analogy with the previous analytical effort. Nevertheless, with the intention of responding to the international calls to engage local populations in the definition of the priorities of their communities, local opinions and perspectives were collected to identify the recognised basic functions of the system, both from the human and the natural side, and the tolerance over the loss of such functions. A comprehensive exploration of the responses to the proposed themes was also expected to bring to light some peculiar traits and views of the local communities.

An overview on the theoretical outcomes

The application of the panarchy heuristics to Social-Ecological Systems allowed to strengthen the intuition that the survival and development of such coupled human-natural systems depend on constant *change*, *transformation* and *adaptation* to internal as well as external forces. At the same time, it also confirmed that the consequences of those shifts might either consolidate the overall hierarchy or trigger the propagation of disruptive disturbances. When the concerned component of the Social-Ecological System are human communities, the question of how to deal with those destructions arise vigorously. In this case, the problem becomes twofold: disruption should not occur to the community, as much as the community itself should not cause disruption to the surrounding environment. That is how resilience and sustainability became the *cores* of the following discussion. Nevertheless, the issue of change provided the stimulus for further insights addressing the theme of risk management. Indeed, the visualisation drawn from the Social-Ecological Panarchy suggests a novel interpretation of *risk* as a potential, vicious interaction among human and natural components of a same system. Here, the concept of risk retains its intrinsic sense of uncertainty and emphasises the requirement of an alignment of susceptibilities for disasters to happen. Indeed, hazards are represented by inherent phenomena unravelling within a component, whereas the vulnerability and exposure of an other component become the necessary counterpart for a destruction to cross different scales and evolve in a disaster, the manifestation of that potential risk. It is noteworthy that such definition might also be considered “component-neutral”, in the sense that anthropic as well as natural components might either be at the starting or at the ending point of the directrix of disruption, thus hinting at a possible, more general interpretation of the concept of risk. Along this perspective, it appears that the proposed theoretical paradigm does not exclude the modelling of different disaster dynamics. Even though natural hazards are easier to identify as external threats to human communities and thus to position where disruptive interactions are triggered, man-made incidents still belong to the overall framework. That is, if such incidents grew into environmental damages, they would be a confirmation of the previously mentioned dual interpretation of risk; on the contrary, if they remained confined within the borders of the anthropic component, they would just require an adjustment in perspective. Indeed, the presented definition of risk would still be valid: it would just be a matter of scale and of transforming a component into a system, in order to retrieve all the factors that compose a risk.

An overview on the quantitative outcomes

The application of the quantitative approach involved two case studies, the Marche Region and Hokkaidō, similar for morphological as well as socio-economic features. The association of the respective Municipalities to the different levels of resilience and sustainability returned rather different pictures. Indeed, the Municipalities of the Marche Region appeared to more extensively lie in *desirable conditions* compared to the Hokkaidō case, where *intermediate conditions* were more common, increasing in the sustainability side. Although Levels were differently populated, they were similarly distributed over the territories of the two case studies. Indeed, the most critical conditions could be commonly traced in the *mountainous and hill areas*, where small clusters of concerning conditions could be found.

The elements that more significantly than other led to this classification were the dire *consequences of flood events* and the direct impact of human processes on the *alterations caused to the natural environment*. While these traits could be interpreted as typifying the local behaviour in case of a critical event, a further look allowed to detect the traits that moulded that behaviour. From the resilience side, in the case of Marche Region *socio-demographic features* as well as the extension of the *volunteer corps* resulted especially significant, whereas for Hokkaidō the robustness of the *welfare system* prevailed on any other facet. From the sustainability side, in both cases the presence and extension of both *natural and cultivated vegetation*.

Recomposing the Social-Ecological Panarchy, it appeared a rather encouraging status for both case studies. Indeed, in both cases the *fore-loop* was extensively populated, with a slight tendency to move towards the *conservation phase*. These considerations suggest a rather sound coexistence between humans and nature in both cases. Nevertheless, the presence of either *resilience* or *sustainability traps* evidence the existence of unbalancing preferences of one *core* over the other, that limit a global effective development. In addition, criticalities could be more easily traced for the sustainability *core*, although the most encouraging performances were less common for resilience *core*, thus suggesting where more urgent issues lie as well as where renovated impetus for improvement should be placed.

An overview on the qualitative outcomes

The application of the qualitative approach involved six case studies in the Marche Region, that are six Municipalities lying within the Esino river basin, distributed from the mountains to the coast and selected in order to represent different Levels of resilience and sustainability. In this case, the emerging picture is extremely homogenous, as all Municipalities were perceived as owning *intermediate levels* of resilience and sustainability. Although this prevalence could be detected also when exploring individual responses, at that scale of analysis the preference to the other levels could arise, whit a slight advantage of the less optimistic views. Indeed, this discouragement could be even more visible when considering the combined perceived levels, in which case the *medium-low evaluations* were more common, with the unique exception of a positive contribution of sustainability. As a consequence, it appears that even though the overall judgement of the local conditions is moderate, the individual response tends to more pessimistic views, especially on matter concerning *disaster resilience*.

The derivation of the clusters, in analogy to the quantitative analysis, evidenced a rather similar representation of high and intermediate levels, whereas the lowest levels were the most distinctively defined. In this case, the most peculiar traits pertained the *impact of flood events*, in terms of dire consequences for the communities and for the households, and the *integrity of natural ecosystems*, in terms of alteration of vegetation and magnitude of endangered species. Nevertheless, in general terms, preference was still devoted to moderate opinions on the key indicators of local resilience and sustainability, associated with a widespread sense of *immutability* of the local features and processes.

When exploring the features that might be most relevant in determining a certain response, it appeared that *gender* and *age* were especially significant on driving the preferences. Indeed, females tended towards more benevolent judgements than males, whereas younger people expressed more sceptical feelings. At the same time, higher educational attainments appeared related to more positive opinions and shorted periods of residence to more moderate standpoints.

At the same time, a general exploration of the responses brought to light peculiar reactions when some specific topics were proposed, that are awareness and efficacy in dealing with flood risk, flood impacts, human effects and endeavours for the environment. In these cases, the answers did not match the associated perceived level. In particular, the question of *self-awareness* to flood risk polarised the opinions towards the highest positive end, on the opposite of the *potential efficacy of the community* in case of a flood emergency. At the same time, discontent emerged when addressing the endeavours fostered to mitigate *anthropic impact* of the environment, especially in the form of pollution.

Lastly, the points of specific interest that dotted the structured discourse revealed consistent apprehension of local populations for those assets related to the most significant domains of daily lives, socially and economically, that are *houses, workplaces and roadways*. When turning to *flood risk reduction,* measures are primarily recognised as affecting the natural riverine system, whereas those strategies that intend to influence and regulate human behaviour were rarely recalled. In particular, a limited awareness of the enacted *policies* emerged evidently, especially when pertaining authorities other than the local Municipalities. In the case of *local emergency plans*, pivotal for the coordination of the community response, *informal ways of communication* appeared to constitute the major means of information, that delivered effective lessons concerning appropriate disaster behaviour, although the reliance on external support was still significant.

An overview on general trends

The positivist paradigm was developed into two research lines, a quantitative and a qualitative one, designed to represent the mirror and at the same time the countercheck each of the other. Hence, the comparison of the respective results might result especially meaningful. Furthermore, the application of the quantitative paradigm to different case studies might provide additional insights on the general tendencies.

The foremost feature that arises is the substantial mismatch among assessed and perceived Levels of resilience and of sustainability. In other words, the evaluation provided by numbers does not comply with the judgements of local population. This might suggest that local phenomena might have affected the local view on the capacities of the communities, phenomena that might not have been appropriately captured through the employed indicators. In particular, perceptions tended towards moderate and eventually pessimistic conceptions of Municipalities that were generally assessed as lying in medium-high conditions. This divergence should not be underestimated: perceiving direr conditions than they actually are might hamper the general trust and endorsement towards the community, whereas perceiving sounder conditions might translate into inappropriate and jeopardising attitudes. Nevertheless, the emerged discrepancy might rise doubts on which are the "real" conditions: in this sense, it might be relevant to delve into the events and processes that led to such incongruities and thence accordingly take action, possibly revising the overall evaluation.

In spite of the different outcome, the investigations converged towards the identification of flood impacts and alterations of the ecosystems as the most significant factors, respectively for disaster resilience and for environmental sustainability, to differentiate through the scale of Levels. At the same time, gender and age emerged as the characteristics of the communities that could influence more considerably the allocation of the Municipality in a specific Level of resilience and sustainability. It should be noticed, though, that these traits are not universally valid, as the other case study suggested the relevance of the soundness of the welfare system as most significant in typifying resilience attitudes, hence specific investigations are required to reveal distinctive features.

On the whole, the positivist paradigm was funded on the interpretivist paradigm centred on the panarchy heuristics. Hence, at this point it might be possible to come back to the origins and recompose the picture through the panarchy metaphor, although only for the case study of the Marche Region. The quantitative assessment describes a Social-Ecological System mainly lying in the most desirable conditions, with a slight tendency towards the more concerning status of consolidated yet rigid processes and assets. Nonetheless, the presence of unbalanced development paths, favouring either resilience or sustainability themes, should not be underestimated. This especially holds true in the light of the overarching assumption of the present research that identifies a balanced equilibrium between resilience capacities and sustainability efforts as the pivotal element for a long-term sound coexistence between humans and nature. A critical point of the development cycle described by the panarchy is the moment of collapse of the fundamental and characterising functions of the social-ecological system. In this regard, local communities that live and mould that system were questioned about the assets that recognising as vital. The preferences were directed towards the health, productive and educational services in order to foster disaster resilience, and food, air and water services to pursue environmental sustainability. Additionally, communities were asked to define the thresholds that surrounded that collapse. For the resilience side, there was a rather high tolerance of service interruption before calling for a disruption, and similarly a relatively long period could be bore before their restoration. On the contrary, for the sustainability side, any grade of loss was considered unacceptable and the recovery of the services was required to be prompt.

Against this background, it appears that local populations tend to underestimate more extensively the resilience abilities of their community, especially expressing scepticism about the local potential to effectively cope with extreme and threatening events. Consequently, it might particularly beneficial to promote strategies and campaigns to consolidate resilience and awareness of the available capacities, engaging the whole community, possibly with direct forms of participation and of contribution, in order to build social trust as well as political endorsement. In this regard, the concentration of the least desirable conditions in the innermost mountainous and hill areas suggests that chronical developmental difficulties might contribute in delineating these undesirable conditions, hence it also suggests where investment should be primarily placed. At the same time, the judgements over the endeavours to foster the sustainability of the community found a generalised discontent, especially in terms of reducing the detrimental effects of human activities on the environment, thus suggesting a common call to improve the relations of the communities with the surrounding natural systems. In this regard, the cautious confidence in the possibility of humans to positively contribute in the preservation of natural equilibria could reassure on the willingness of the local populations to actively engage in projects devoted to the natural environment.

An overview beyond

The present study developed and applied a theoretical framework, the Social-Ecological Panarchy model, and a methodological framework, the Combined Assessment of Resilience and Sustainability methodology. Although the eventual outcomes appear encouraging, certainly improvements need to be fostered in order to strengthen the overall reliability.

For instance, the association among *adaptive-cycle phases* and Levels of resilience and of sustainability could be thorough reconsidered, and possibly more detailed, including a wider range of nuances in the assessment. In this way, it might be possible to capture a more varied range of local capabilities relate to resilience and sustainability. In a similar vein, a broader set of indicators, both for the first and the second phase of analysis might be beneficial to enrichen the portrait on the local conditions. Nevertheless, the difficulties in retrieving relevant information remains a significant limit, hence, possibly, it should be primarily addressed. In this case, it would be particularly meaningful to retain data tailored to the local peculiarities, and thence that would be able to grasp local dynamics. The integration of the opinions and memories of local population might turn especially informative in this regard, as they might provide a unique standpoint on the events and processes unravelling in their territories. At the same time, extending the involvement in the surveys to a wider case study or to other case studies might provide further insights on the common preferences or rather unique traits of the communities. In addition, it should be bore in mind that the design of this methodology is based on comparative considerations. As a consequence, the drawn outcomes are valid only within the considered social-ecological system and they do not allow direct comparisons among different systems. Actually, not only the outcomes, but the assessment structure itself should be considered as context-specific, meaning that indicators as well as questions were designed in order to address local peculiarities. Consequently, while the overarching structure maintains its significance, the operative assessment tools (namely indicators and questions) might not be straightforwardly applied to other case studies, but they should rather be re-considered and re-adapted to local conditions. Additionally, the first analytical phase that employs a cluster analysis is particularly sensible to the change of the indicators, hence though different combinations might be tested in order to optimised the outcome, the foremost priority should be put on the careful identification of the most meaningful indicators to be included.

Although acknowledging the mentioned limitations, the proposed model and the subsequent operative methodology still appear to hold a potential. For instance, the proposed generalisation of the concept of risk might contribute to the current endeavours of bringing together disaster and environmental sciences by providing a possible point of connection, thus stimulating further discussions on how to effectively enhance an integrated development of human communities with the surrounding natural ecosystems. At the same time, the implication that change is inherently necessary and unavoidable poses some questions on how change should be allowed within a complex coupled system. From the perspective of disaster, this theme transforms in a matter of both risk and land-use management. Indeed, where to intervene when dealing with change translates in a preference of resistive or adaptive approaches to disaster management, that is preferring to control nature or advance societies. On the other hand, land-use planning comes into the debate when considering what kind of change to promote within communities, that is optimising assets or promoting flexibility. The proposed theoretical model suggests that in general terms, within coupled human-natural systems, transformations should be favoured for the anthropic components in terms of continuous adjustments to the feedbacks coming from the natural components. What should be privileged, where more efforts should be put, where critical issues lie are all concerns that the assessment methodology tried to address, limited in results to the envisaged case studies but extendable in implementation to any other community. In addition, even though this application was meant to deliver a freeze frame of the actual conditions of some communities and of their surrounding environment, the process could be applied again in the future to monitor the possible variations and thence trace the development path of those same communities. This effort might be especially beneficial to identify in advance circumstances that could lead to concerning conditions, up to hampering the local capabilities of dealing with the unravelling phenomena, both human and natural. At the same time, the insights that both the quantitative and the qualitative processes deliver might be informative for the local development strategies and plans. As commonly and internationally advocated, the expectations and the priorities of the locals that emerge from the investigation should be included when moulding of the perspectives of the whole community, and the proposed methodology was designed specifically to assist in this kind of endeavour. Furthermore, in-depth interviews and more extensive confrontation with local stakeholders might provide invaluable information, that could not only enrichen but also strengthen local development planning. Nevertheless, apart from plans and strategies, the engagement of local communities would promote their direct involvement in moulding of their own future perspectives, addressing behaviours and practices that hinder a thorough resolution of resilience and sustainability issues from their fundamental origins.

In conclusion, this research proposed a theoretical as well as an analytical framework to explore the disaster resilience and environmental sustainability of complex social-ecological systems at a local scale. The framework was designed in order to envisage both quantitative and qualitative evaluations: numbers were intended to provide tendencies, perceptions were intended to indicate the urgency of action. The outcomes suggest that more efforts should be devoted to the strengthening of local capacities, and especially in the engagement of local communities. Nevertheless, the willingness of local populations to actively participate in that enhancing process should be an encouragement for fostering that advancement.

Disaster resilience and environmental sustainability might be considered more attitudes than properties. In this sense, resilience and sustainability should be constantly nurtured and never taken for granted. Panarchy suggests that stillness is detrimental: the only available path for a sound and comprehensive development is that of a tireless and relentless improvement.

viii. References

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ix. Appendix I: Indicators for the quantitative assessment of the Resilience and Sustainability Level of the Marche Region

List of tables

Outline of the indicators

First phase – classification

Table ix.1 — Tested indicators for each core *and each* attribute*, their source and year of reference for the Marche Region case study.*

CORE	*ATTRIBUTE*	INDICATOR	SOURCE	REFERENCE YEAR
resilience	*learn*	variation of population exposed to flood hazard	Italian Institute for Environmental Protection and Research (ISPRA), Italian National Institute of Statistics (ISTAT)	2017
	absorb	grants for extraordinary and emergency interventions	Regional decrees	2019 (last year considered)
	recover	ratio of tax revenue after 2 years and on the year of the last flood event	Ministry of Economy and Finance (MEF)	(depending on Municipality)

sustainability	*functions*	variation of land take	Italian Institute for Environmental Protection and Research (ISPRA)	2012-2018
	services	variation of water intake	Italian National Institute of Statistics (ISTAT)	2012-2015
	integrity	number of species in inadequate or bad conservation status	Italian Institute for Environmental Protection and Research (ISPRA)	2013

Second phase – characterisation

Table ix.2 — Tested indicators for each core *and each* dimension*, their source and year of reference for the Marche Region case study.*

CORE	***DIMENSION***	**INDICATOR**	**SOURCE**	**REFERENCE YEAR**
resilience	*demographic*	immigrants	Italian National Institute of Statistics (ISTAT)	2018
		population over 65 y.o. population over 80 y.o.	Italian National Institute of Statistics (ISTAT) Italian National Institute of Statistics (ISTAT)	2018 2018
		female population	Italian National Institute of Statistics (ISTAT)	2018
		population density	Italian National Institute of Statistics (ISTAT)	2018
	social	population with higher education	Italian National Institute of Statistics (ISTAT)	2011
		territory with UWB internet access	Ministry of Economic Development	2018
		volunteers in no-profit organisations dealing with social welfare and civil protection	Italian National Institute of Statistics (ISTAT)	2011
		public revenues of no-profit organisations dealing with social welfare and civil protection volunteers expenditure of no-profit organisations dealing with social welfare and civil protection	Italian National Institute of Statistics (ISTAT) Italian National Institute of Statistics (ISTAT)	2011 2011
	economic	employment	Italian National Institute of Statistics (ISTAT), Marche Region Statistical Informative System (SIS)	2011
		unemployment	Italian National Institute of Statistics (ISTAT), Marche Region Statistical Informative System (SIS)	2011
		taxable income	Marche Region Statistical Informative System (SIS)	2016
		social expenditure for social welfare	Italian National Institute of Statistics (ISTAT)	2016
		present population difference in present and resident population	Italian National Institute of Statistics (ISTAT)	2017
	health	mental health discharges residence facilities for the elderly beds in residence facilities for the elderly welfare facilities (non-residence) for the elderly	Italian National Institute of Statistics (ISTAT), Ministry of the Interior Italian National Institute of Statistics (ISTAT), Ministry of the Interior Italian National Institute of Statistics (ISTAT), Ministry of the Interior Italian National Institute of Statistics (ISTAT), Ministry of the Interior	2017 2017 2017 2017

		total welfare facilities for the elderly	Italian National Institute of Statistics (ISTAT), Ministry of the Interior	2017
		hospital staff	Regional Health Agency (ASUR), Marche Region Statistical Informative System (SIS)	2018
		hospital beds	Regional decree (DGR 639/2018), Marche Region Statistical Informative System (SIS)	2018
		average time of arrival on place	Firefighters Statistical Yearbook	2017
		average time of arrival on place over the past 5 years	Firefighters Statistical Yearbook	2017
	infrastructural	local expenditure for mitigation	Regional decrees, Italian Institute for Environmental Protection and Research (ISPRA)	2018
		extension of municipal roads extension of non-municipal roads	Ministry of the Interior	2015
		wasted drink water	Italian National Institute of Statistics (ISTAT)	2015
		average building construction year	Italian National Institute of Statistics (ISTAT)	2011
sustainability	*ecosystems integrity*	habitats in inadequate/bad status	European Environment Agency (EEA)	2013
		grassland and pasture	Italian National Institute of Statistics (ISTAT)	2010
		woods owned by farms	Italian National Institute of Statistics (ISTAT)	2010
		geobotanical value	Regional Ecological Network (REM)	2010
	ecosystem benefits	forests for woods	Italian National Institute of Statistics (ISTAT)	2010
		D.O.C. and I.G.P. producers	Italian National Institute of Statistics (ISTAT)	2015
	physical processes state	flood discharge variation	European Environment Agency (EEA)	1960-2010
		PM_{10} average value	European Environment Agency (EEA)	2017
		PM_{10} average difference	European Environment Agency (EEA)	(depending on Municipality)
		PM_{10} average value in most populated cell	European Environment Agency (EEA)	2017
		PM_{10} average difference in most populated cell	European Environment Agency (EEA)	(depending on Municipality)
	external pressures	agricultural area	Italian National Institute of Statistics (ISTAT)	2010
		heads of livestock	Italian National Institute of Statistics (ISTAT)	2010
		heads of cattle	Italian National Institute of Statistics (ISTAT)	2010
		urban-transport fragmentation pressure	European Environment Agency (EEA)	2016

Quantification of the indicators

First phase – classification

Resilience

Table ix.3 — Selected indicators for each attribute *of resilience, per each Municipality.*

MUNICIPALITY	*LEARN* POP_FLOOD	*ABSORB* EMERG_GRANT	*RECOVER* IRPEF_VAR
Acqualagna	-0.112385	358384.32	3.644
Apecchio	-0.650759	159754.55	1.0136
Auditore	-0.194426	272871.88	-0.8196
Belforte all'Isauro	-0.132626	69757.37	-0.4799
Borgo Pace	0	3639.76	1.7463
Cagli	0.219602	347928.19	0.9276
Cantiano	2.567568	592081.97	-4.473
Carpegna	0	105552.65	1.1712
Cartoceto	0.088664	1250100	0.5386
Fano	0.215276	360021.94	2.6998
Fermignano	-0.046713	39994.23	2.9007
Fossombrone	0.146935	59644.64	3.5292
Fratte Rosa	0	95764.69	-5.2926
Frontino	-0.341297	315029.1	-16.1885
Frontone	0	291628.75	2.0553
Gabicce Mare	0.402379	88826.52	-1.1475
Gradara	0	38771.83	4.9247
Isola del Piano	0	79066.66	5.8588
Lunano	-0.131752	71186.01	3.1487
Macerata Feltria	0	111255.92	-2.9628
Mercatello sul Metauro	-0.146199	12490.21	0.9183
Mercatino Conca	-0.095969	103958.44	2.652
Mombaroccio	0	64354.11	-1.0649
Mondavio	0.079051	32016.79	0.6215
Mondolfo	0.498771	255595.07	4.023
Montecalvo in Foglia	0.219378	218409.6	1.8963
Monte Cerignone	0	79302.1	5.5867
Monteciccardo	-0.237671	24404.53	1.4206
Montecopiolo	-0.090416	82294.8	2.4883
Montefelcino	2.495274	70223.35	4.9057
Monte Grimano Terme	0	158027.53	0.0689
Montelabbate	0.131195	34223.26	4.6288
Monte Porzio	-0.034965	13327.85	0.3329
Peglio	-0.275103	28406.96	4.5898
Pergola	0	348938.06	-1.0951
Pesaro	-0.047462	198488.27	3.3767
Petriano	-0.715564	232545.51	4.759
Piandimeleto	0.046361	85454.18	-0.1723
Pietrarubbia	0	15000	1.8091
Piobbico	-0.346535	75997.07	-2.1869
San Costanzo	-0.021057	26894.21	-0.4647
San Lorenzo in Campo	0	115935.36	-2.6966
Sant'Angelo in Vado	0.048924	0	2.6829
Sant'Ippolito	0.129618	178637.45	-2.2835
Sassocorvaro	0	349859	-1.2746
Sassofeltrio	0	122303.38	5.9915
Serra Sant'Abbondio	0	96757.98	1.9822
Tavoleto	0	218002.5	-1.3548
Tavullia	0.01252	52409.29	2.8813
Urbania	0.014142	793	1.283
Urbino	0.013473	880318.71	-1.1185
Vallefoglia	0.00666	414267.03	6.53
Colli al Metauro	0.217742	105515.43	5.5579
Terre Roveresche	0	357279.93	0.0069
Agugliano	0.020513	203432.8	0.4719
Ancona	0.000993	453659.2	0.8514
Arcevia	0.022267	419961.95	-1.5502
Barbara	0	11989.67	3.9062
Belvedere Ostrense	0	43314.4	0.7945
Camerano	0	116550.17	1.7285
Camerata Picena	0	12779.48	0.6786
Castelbellino	0	98807.43	2.7742
Castelfidardo	0.438996	360743.84	3.4961
Castelleone di Suasa	0	19787.47	7.696
Castelplanio	0	112121.37	1.7012
Cerreto d'Esi	0.321199	285994.04	0.3239
Chiaravalle	0.027027	191070.15	1.406
Corinaldo	0.504134	399793.73	-0.5353
Cupramontana	0	124140.55	-0.635
Fabriano	0.089709	400207.42	-1.7536
Falconara Marittima	0.106339	324198.03	-0.2021
Filottrano	0	61373.41	0.1559
Genga	0.336889	966420.31	-1.5941
Jesi	0.044645	393101.12	1.3478
Loreto	0.046838	98478.1	1.2721
Maiolati Spontini	0	36372.34	1.529
Mergo	0.195695	66880	-0.0894
Monsano	0	41936.52	4.6861
Montecarotto	-0.051099	159467.04	-4.6841
Montemarciano	0.050352	193915.79	2.1446
Monte Roberto	0.130081	3083.01	3.4268
Monte San Vito	0	14905.52	3.5869
Morro d'Alba	0	39380.12	2.0475
Numana	0	41986.34	1.8326
Offagna	0	81065.31	4.4783
Osimo	0.057277	422753.49	2.4012
Ostra	8.200824	146607.56	2.4866
Ostra Vetere	2.91616	480404.72	-0.7654
Poggio San Marcello	0	0	-3.117
Polverigi	0	2328.23	4.8987
Rosora	0	0	-2.5629
San Marcello	0	124768.81	-1.8162
San Paolo di Jesi	0	67022.18	6.8733
Santa Maria Nuova	0	0	1.93
Sassoferrato	3.204682	666638.46	-1.5655
Senigallia	14.803382	5152190	2.8041
Serra de' Conti	0	3995.5	2.0816
Serra San Quirico	-0.035575	9602.05	1.8614
Sirolo	0	84799.8	2.0301
Staffolo	0	39129.66	4.2295
Trecastelli	0.706806	351675.87	0.041
Apiro	0	283057.38	0.6554
Appignano	0	22212.61	2.5649
Belforte del Chienti	3.19659	40723.27	2.4354
Bolognola	0	40256.04	1.8279
Caldarola	0	154060.1	-3.4847
Camerino	-0.014271	166786.42	-2.1631
Camporotondo di Fiastrone	0	60580.52	-4.3647
Castelraimondo	0.043821	114553.25	-0.8052
Castelsantangelo sul Nera	0	0	-3.3834
Cessapalombo	0	162172.02	-1.2087
Cingoli	-0.019438	87806.71	0.0658
Civitanova Marche	0.004734	631107.76	3.6463
Colmurano	0	39544.61	-1.8768
Corridonia	0	219848.78	2.7949
Esanatoglia	0.251256	25058.8	-0.2026
Fiastra	0	51519.28	9.544
Fiuminata	1.37881	82841.92	1.8038
Gagliole	-0.15949	30497.39	7.2932
Gualdo	0	139072.62	-0.424
Loro Piceno	0	125872.49	0.6249
Macerata	-0.007107	20000	-0.0345
Matelica	-0.050659	99028.71	1.4352
Mogliano	0.193924	421908.32	2.7134
Montecassiano	3.189994	352288.53	-1.9093
Monte Cavallo	0	6151.51	1.6778
Montecosaro	6.858903	461474.8	5.4265
Montefano	0	225167.49	5.057
Montelupone	1.697273	151062	6.2013
Monte San Giusto	0	90604.46	-1.0315
Monte San Martino	0.938338	359453.85	-2.7543
Morrovalle	14.206897	738362.66	5.0419
Muccia	0	87912.54	-3.5976
Penna San Giovanni	0	185700	-6.4481
Petriolo	0	89875.15	1.8819
Pieve Torina	2.640723	152907.76	-2.0028
Pioraco	-0.258176	15581.6	4.2123
Poggio San Vicino	0	0	-5.9543
Pollenza	-0.030409	39356.92	1.3132

Porto Recanati	3.66717	602251.93	3.2191
Potenza Picena	0.8146	593857.4	2.9138
Recanati	0.240102	1345946.07	1.8937
Ripe San Ginesio	0	17592.4	-2.0887
San Ginesio	0	247616.61	-1.5619
San Severino Marche	0.015835	137583.19	0.2743
Sant'Angelo in Pontano	0	92623.69	-2.2709
Sarnano	0	14311.38	-3.9326
Sefro	-0.238663	145778.84	-2.6929
Serrapetrona	0	160475.49	-2.0609
Serravalle di Chienti	0	427	-6.3718
Tolentino	-0.005043	612352.3	-0.1545
Treia	-0.021302	5086.93	3.6473
Urbisaglia	0	24671.66	-0.7064
Ussita	0.224719	28352.78	-2.7179
Visso	0.45208	24561.29	-3.4233
Valfornace	9.090909	723626.75	-4.3715
Acquasanta Terme	0.105079	920880.67	-2.4966
Acquaviva Picena	0	32822.73	1.4434
Appignano del Tronto	0	201105.62	1.0883
Arquata del Tronto	-0.35057	191416.82	-3.5442
Ascoli Piceno	0.026421	2104816.65	0.1028
Carassai	0.092166	71705.62	-8.5223
Castel di Lama	0.023221	241844.22	0.9506
Castignano	0.072098	509604.74	-0.224
Castorano	-0.085324	31289.27	0.1373
Colli del Tronto	0.109022	49137.33	2.7897
Comunanza	1.886792	229415.3	-3.9492
Cossignano	0	272945.77	-2.2957
Cupra Marittima	-0.055648	292240.04	2.6966
Folignano	0	132390.54	2.2918
Force	0.153728	433908.45	-6.6074
Grottammare	-0.043373	443466.35	2.3786
Maltignano	0	165420.88	-0.0002
Massignano	0.061013	347776.24	-0.6289
Monsampolo del Tronto	0.022148	81231.04	2.9496
Montalto delle Marche	0	156029.69	0.2464
Montedinove	0	64659.22	3.2586
Montefiore dell'Aso	0.047574	108871.94	1.1341
Montegallo	0	277783.21	-5.9584
Montemonaco	0	332448.68	-7.2174
Monteprandone	0.01587	1004536.9	4.5115
Offida	-0.019968	327103.21	0.4139
Palmiano	0	141049.52	-6.401
Ripatransone	0	317412.13	-0.154
Roccafluvione	0.050075	459073.62	0.1614
Rotella	0	422751.89	2.0258
San Benedetto del Tronto	0.151835	824146.18	2.7492
Spinetoli	0.069242	237918.15	2.3335
Venarotta	0	180979.81	1.4429
Altidona	-0.029317	147910	2.6373
Amandola	0.110375	629147.44	-0.9759
Belmonte Piceno	0.159236	11974.8	5.6504
Campofilone	0	182220.37	1.4537
Falerone	-0.029895	21081.16	0.388
Fermo	0.173815	3151244.47	1.1822
Francavilla d'Ete	0.525762	42127.23	0.2284
Grottazzolina	0.088705	74174.91	0.7995
Lapedona	-0.084602	66177.79	4.0468
Magliano di Tenna	0	21745.6	4.7661
Massa Fermana	0.106496	159561.34	0.2803
Monsampietro Morico	0	110164.95	-2.3107
Montappone	0	130174.09	1.6068
Montefalcone Appennino	0.235294	281625.02	-2.8835
Montefortino	0.261324	234748.98	-5.642
Monte Giberto	0.767263	171526.8	0.5774
Montegiorgio	-0.01473	260371.61	2.0368
Montegranaro	0.069632	1193793.13	-1.5714
Monteleone di Fermo	-0.25974	6931.97	0.5625
Montelparo	0	67760.42	-6.4959
Monte Rinaldo	0	39493.4	0.8463
Monterubbiano	7.179015	177278.68	-2.9933
Monte San Pietrangeli	0.655201	170865.71	-2.1611
Monte Urano	0.036232	348129.91	-0.6676
Monte Vidon Combatte	0	52145.1	4.6167
Monte Vidon Corrado	0	96707.38	3.2514
Montottone	-0.408998	131305.4	-6.5698
Moresco	0	6995.46	2.0546
Ortezzano	0.129534	89621.73	2.9296
Pedaso	0.142298	67428.8	-0.0062
Petritoli	2.990897	131553.5	1.6999
Ponzano di Fermo	0.06068	210189.74	1.7623
Porto San Giorgio	9.236898	216634	2.0957
Porto Sant'Elpidio	-0.003807	360547.57	2.3545
Rapagnano	0	151127.5	-6.2884
Santa Vittoria in Matenano	0.0757	139081.75	1.1856
Sant'Elpidio a Mare	1.56973	2840825.9	6.2258
Servigliano	0.043403	250944.23	-2.8217
Smerillo	0.273224	382926.91	2.3242
Torre San Patrizio	0.24777	100819.46	-1.5337

Sustainability

Table ix.4 — Selected indicators for each attribute *of sustainability, per each Municipality.*

MUNICIPALITY	*FUNCTIONS* LAND_TAKE	*SERVICES* CLEAN_WATER	*INTEGRITY* SPECIES_INADBAD
Acqualagna	0.137912	3.587444	11
Apecchio	0.082923	23.873874	24
Auditore	0.07268	17.687075	25
Belforte all'Isauro	0.006509	19.354839	15
Borgo Pace	0.006225	32.8125	22
Cagli	0.052284	2.058111	22
Cantiano	0.012253	9.958506	21
Carpegna	0.035247	64.08046	24
Cartoceto	0.391761	-19.318182	11
Fano	0.415154	-7.965883	8
Fermignano	0.218524	-9.079118	11
Fossombrone	0.234384	23.281787	12
Fratte Rosa	0.097889	-73.626374	3
Frontino	0.054981	46.875	14
Frontone	0.12114	9.032258	17
Gabicce Mare	0.020264	0.916497	11
Gradara	0.312684	-6.798867	10
Isola del Piano	0.166077	28.915663	5
Lunano	0.162512	20.958084	9
Macerata Feltria	0.078854	-7.647059	14
Mercatello sul Metauro	0.018434	-13.714286	16
Mercatino Conca	0.007888	70.815451	24
Mombaroccio	0.409843	4.285714	2
Mondavio	0.017209	0.425532	10
Mondolfo	0.476967	-37.190083	7
Montecalvo in Foglia	0.045487	-12.91866	6
Monte Cerignone	0.017	27.058824	14
Monteciccardo	0.04147	-16.935484	6
Montecopiolo	0.010611	-46.478873	23
Montefelcino	0.069219	5.416667	9
Monte Grimano Terme	0.009179	36.363636	26
Montelabbate	0.432405	1.356589	10
Monte Porzio	0.24115	-27.896996	7
Peglio	0.281826	-10.294118	11
Pergola	0.054184	15.329341	11
Pesaro	0.17883	-4.87655	11
Petriano	0.027503	2.564103	8
Piandimeleto	0.038595	15.517241	14
Pietrarubbia	0	4.444444	9
Piobbico	0.019503	3.144654	18
San Costanzo	0.04965	-11.706349	8
San Lorenzo in Campo	0.418085	2.754821	9
Sant'Angelo in Vado	0.029404	0.330033	11
Sant'Ippolito	0.160497	5.732484	8
Sassocorvaro	0.072787	42.677824	14
Sassofeltrio	0.145647	69.727891	26
Serra Sant'Abbondio	0.021341	12.931034	14
Tavoleto	0.32483	14.563107	14
Tavullia	0.526342	-5.970149	11
Urbania	0.120852	4.042179	17
Urbino	0.059914	5.90892	16
Vallefoglia	0.423563	8.554572	11
Colli al Metauro	0.135809	4.223108	9
Terre Roveresche	0.067789	13.333333	10
Agugliano	0.111923	12.396694	10
Ancona	0.158006	-2.987316	12
Arcevia	0.025637	-12.431444	15
Barbara	0.009059	-29.52381	8
Belvedere Ostrense	0.062139	-21.717172	4

Camerano	0.560385	26.77643	8
Camerata Picena	1.02173	-5.240175	9
Castelbellino	0.674704	-0.456621	8
Castelfidardo	0.433661	2.02381	11
Castelleone di Suasa	0.523248	11.111111	8
Castelplanio	0.493534	-34.577114	14
Cerreto d'Esi	0.989186	8.888889	15
Chiaravalle	0.404499	-1.484716	7
Corinaldo	0.245135	-2.731092	9
Cupramontana	0.018976	16.302187	14
Fabriano	0.057153	-4	35
Falconara Marittima	0.363745	-7.806983	6
Filottrano	0.084408	-12.676056	7
Genga	0.087076	9.663866	14
Jesi	0.116526	-10.298389	11
Loreto	0.18664	-2.143845	7
Maiolati Spontini	0.750967	-8.137715	8
Mergo	0.021986	41.062802	9
Monsano	0.143886	-10.421836	8
Montecarotto	0.025835	-8.75	3
Montemarciano	0.14074	2.729258	7
Monte Roberto	0.135599	-0.367647	9
Monte San Vito	0.08481	-3.137255	3
Morro d'Alba	0.022096	2.873563	4
Numana	0.058528	-0.440141	11
Offagna	0.158036	-6.532663	5
Osimo	0.232064	-6.415539	7
Ostra	0.118091	-2.794411	2
Ostra Vetere	0.036647	-26.62116	8
Poggio San Marcello	0	10.784314	9
Polverigi	0.064043	-15.665796	4
Rosora	0.007442	-30.635838	14
San Marcello	0.096983	-15.656566	8
San Paolo di Jesi	0.051425	-32.258065	9
Santa Maria Nuova	0.013124	-13.356164	8
Sassoferrato	0.095462	-2.475619	33
Senigallia	0.115141	-1.728844	7
Serra de' Conti	0.278695	-8.101852	3
Serra San Quirico	0.016216	-11.23348	16
Sirolo	0.127722	12.408759	8
Staffolo	0.01382	-32.894737	9
Trecastelli	0.17531	-15.29745	9
Apiro	0.074378	3.896104	16
Appignano	0.050723	4.324324	6
Belforte del Chienti	0.030521	21.254355	8
Bolognola	0.019718	-9.090909	7
Caldarola	0.213539	-13.586957	12
Camerino	0.095163	-17.234043	12
Camporotondo di Fiastrone	0.019305	-93.617021	10
Castelraimondo	0.165677	21.760797	14
Castelsantangelo sul Nera	0.040328	6.216216	12
Cessapalombo	0.010152	-32.758621	4
Cingoli	0.184417	-6.549708	12
Civitanova Marche	0.186472	-8.70607	8
Colmurano	0.060721	17.605634	3
Corridonia	0.16445	-2.471042	9
Esanatoglia	0.047173	28.712871	18
Fiastra	0.024148	-2.949853	13
Fiuminata	0.009447	-4.324324	18
Gagliole	0.002911	-5	14
Gualdo	0.00585	26.446281	5
Loro Piceno	0	7.727273	5
Macerata	0.095757	-19.328622	11
Matelica	0.234772	-36.528222	20
Mogliano	0.017089	-12.219451	5
Montecassiano	0.078245	0.707214	9
Monte Cavallo	0.002077	-3.846154	4
Montecosaro	0.395833	14.89726	5
Montefano	0.017088	-0.284091	10
Montelupone	0.171709	-11.326861	8
Monte San Giusto	0.036932	-10.429448	3
Monte San Martino	0.226351	-10.344828	8
Morrovalle	0.073273	1.612903	11
Muccia	0.064458	-1.282051	8
Penna San Giovanni	0.033116	0	6
Petriolo	0.235205	-17.123288	5
Pieve Torina	0.058825	-1.433692	12
Pioraco	0.136745	10.526316	8
Poggio San Vicino	0.316941	-14.285714	13
Pollenza	0.154246	-6.521739	6
Porto Recanati	0.29857	5.410023	11
Potenza Picena	0.101746	-1.918317	9
Recanati	0.139282	-7.893414	11
Ripe San Ginesio	0.009833	-12.222222	3
San Ginesio	0.048449	23.076923	11
San Severino Marche	0.057811	-7.824934	11
Sant'Angelo in Pontano	0.095312	-22.151899	10
Sarnano	0.023589	53.068592	13
Sefro	0	11.547344	18
Serrapetrona	0.014875	3.759398	10
Serravalle di Chienti	0.016981	25	22
Tolentino	0.089047	-9.723461	11
Treia	0.068102	-1.582734	10
Urbisaglia	0.016621	-11.797753	9
Ussita	0.008862	20.508475	13
Visso	0.032764	25.233645	12
Valfornace	0.071586	13.711584	11
Acquasanta Terme	0.008527	7.120743	12
Acquaviva Picena	0.124867	7.334963	6
Appignano del Tronto	0.073725	5.699482	5
Arquata del Tronto	0.217938	28.248588	15
Ascoli Piceno	0.052208	7.255937	12
Carassai	0.005396	9.836066	2
Castel di Lama	0.147592	-9.305374	3
Castignano	0.042016	13.690476	5
Castorano	0.145562	10.546875	3
Colli del Tronto	0.033676	1.404494	3
Comunanza	0.03401	10.227273	8
Cossignano	0.008026	10.714286	2
Cupra Marittima	0.212268	29.98679	5
Folignano	1.253298	-14.214464	6
Force	0.011659	6	4
Grottammare	0.19728	26.481836	4
Maltignano	0.431931	-6.9869	4
Massignano	0.054589	12.365591	4
Monsampolo del Tronto	0.820947	0	4
Montalto delle Marche	0.083972	0	2
Montedinove	0.105587	10.714286	1
Montefiore dell'Aso	0.075867	5.286344	4
Montegallo	0.006603	25.333333	14
Montemonaco	0.00177	41.666667	13
Monteprandone	0.410259	-1.17746	6
Offida	0.355829	14.046823	4
Palmiano	0	0	4
Ripatransone	0.064892	15.913556	5
Roccafluvione	0.004123	-0.995025	9
Rotella	0.012392	26.984127	6
San Benedetto del Tronto	0.258214	34.37367	6
Spinetoli	0.458577	-0.719424	4
Venarotta	0.000662	-3.431373	5
Altidona	0.139526	13.783784	4
Amandola	0.020577	21.505376	12
Belmonte Piceno	0.026586	7.142857	4
Campofilone	0.162146	13.513514	4
Falerone	0.174302	16.959064	6
Fermo	0.258729	12.754247	5
Francavilla d'Ete	0.02548	-9.411765	8
Grottazzolina	0.152238	-4.516129	1
Lapedona	0.173536	9.375	4
Magliano di Tenna	0.001261	-22.689076	1
Massa Fermana	0	-1.587302	3
Monsampietro Morico	0.104481	0	4
Montappone	0.001922	5.555556	3
Montefalcone Appennino	0	16.981132	2
Montefortino	0.000763	18.918919	15
Monte Giberto	0	13.043478	1
Montegiorgio	0.042153	15.384615	6
Montegranaro	0.192563	-16.454456	4
Monteleone di Fermo	0.030435	-4.878049	4
Montelparo	0.063811	15	5
Monte Rinaldo	0.016411	-2.631579	1
Monterubbiano	0.213742	2.92887	3
Monte San Pietrangeli	0.003252	20.141343	6
Monte Urano	0.27938	12.922173	6
Monte Vidon Combatte	0.201487	-2.272727	1
Monte Vidon Corrado	0.159691	-15.517241	6
Montottone	0.025643	10.714286	1
Moresco	0.472411	-3.448276	1
Ortezzano	0.008481	16.129032	1
Pedaso	0.374318	11.074919	4

Petritoli	0.024164	21.311475	1
Ponzano di Fermo	0.027334	-6.329114	3
Porto San Giorgio	0.114861	21.43928	3
Porto Sant'Elpidio	0.184821	-1.066408	4
Rapagnano	0.065635	-9.090909	1
Santa Vittoria in Matenano	0.015279	-3.703704	5
Sant'Elpidio a Mare	0.231604	-9.463148	7
Servigliano	0.035691	0.431034	4
Smerillo	0.014169	13.636364	5
Torre San Patrizio	0.141625	-18.125	4

Second phase – characterisation

Resilience

Table ix.5: Selected indicators for the demographic*,* social *and* economic dimensions *of resilience, per each Municipality.*

MUNICIPALITY	DEMOGRAPHIC				SOCIAL					ECONOMIC			
	IMMIGR	POP_over65	POP_FEM	DENSPOP	HIGH_EDU	UWB_ACCESS	VOLONT	PUBL_REV_CPASS	EXP_CPASS	EMPL_PERC	TAX_INCOME	SOC_EXP	SOC_EXP
Acqualagna	352	958	2207	87.046763	1635	0	52	30039	2993	49.75	9896	0	0.599733
Apecchio	189	530	927	17.640721	719	0	0	0	0	46.05	10754	0	-1.889607
Auditore	161	351	774	74.761374	532	0	0	0	0	50.22	10715	190	-3.435583
Belforte all'Isauro	111	161	378	60.537022	257	0	0	0	0	47.96	10954	82	0.387097
Borgo Pace	87	196	292	10.903186	183	0	0	0	0	40.7	9316	0	-3.405573
Cagli	734	2412	4412	37.737032	3568	42.1	0	0	0	44.68	11667	0	1.838235
Cantiano	145	710	1120	26.498212	915	0	6	0	0	38.31	10847	0	4.323866
Carpegna	200	407	861	58.364347	596	0	0	0	0	48	11564	217	-2.336729
Cartoceto	554	1589	4013	342.020316	2694	62.1	66	7025	13240	53.34	11707	0	1.242079
Fano	4466	14627	31608	500.483839	28996	44.1	824	126755	163144	48.86	14596	22526	5.510973
Fermignano	937	1699	4320	194.08323	3411	0	20	0	0	52.68	12170	2195	-0.162488
Fossombrone	802	2384	4796	88.456493	3829	61.7	145	2556	51031	46.22	12788	5000	4.002031
Fratte Rosa	99	268	472	61.035297	314	0	0	0	0	47.6	10830	516	-3.740157
Frontino	28	87	137	26.91128	93	0	0	0	0	44.89	9621	27	-1.910828
Frontone	134	347	675	35.841996	463	0	0	0	0	44.4	11607	0	-3.409933
Gabicce Mare	572	1486	2919	1157.625985	2238	4.8	32	5097	21033	46.32	12337	6110	-2.820995
Gradara	361	820	2422	278.891964	1816	67.6	11	0	3325	56.14	12054	5084	0.631446
Isola del Piano	62	145	289	25.747979	207	0	0	0	0	50.36	11640	0	-0.629921
Lunano	240	282	733	100.769256	443	0	1	0	0	51.31	11757	190	-1.754386
Macerata Feltria	255	573	1048	50.680102	723	0	73	0	62154	45.43	12460	245	1.254826
Mercatello sul Metauro	64	392	686	19.909799	450	0	0	0	0	44.15	11022	0	1.602787
Mercatino Conca	125	266	526	74.430478	385	0	0	0	0	47.8	11926	136	-1.173285
Mombaroccio	174	463	1041	74.451452	757	0	0	0	0	52.77	12147	200	1.777362
Mondavio	170	1004	1950	129.235151	1416	0	62	0	20110	48.51	12708	2971	3.259486
Mondolfo	1186	3397	7168	625.049294	4286	0	44	0	0	48.33	12341	4792	-0.136321
Montecalvo in Foglia	222	574	1413	150.697318	847	0	0	0	0	51.78	11198	0	18.645949
Monte Cerignone	76	195	340	35.973196	203	0	0	0	0	45.09	10806	81	4.817518
Monteciccardo	97	271	824	63.086759	574	0	0	0	0	56.85	10860	0	-2.645503
Montecopiolo	53	334	537	30.743799	340	0	27	106	0	44.9	10692	136	-1.62116
Montefelcino	106	667	1312	67.346886	902	0	52	0	0	50.02	11988	0	6.890199
Monte Grimano Terme	179	307	566	46.68686	414	0	0	0	0	40.27	9437	136	13.310285
Montelabbate	722	1110	3397	353.431841	2284	4	19	0	12310	57.67	11984	240	1.540302
Monte Porzio	287	612	1416	155.459681	990	0	0	0	0	49.21	11488	1440	1.601423
Peglio	79	143	355	34.127456	287	0	0	0	0	52.72	10856	0	-3.292181
Pergola	549	1877	3213	55.161566	2481	0	71	0	15217	44.67	12295	1729	0.352221
Pesaro	7218	24292	49576	749.054394	43308	95.4	1208	1699489	113953	49.5	15245	25787	2.443135
Petriano	447	578	1382	246.728474	822	0	2	0	0	52.07	11366	0	4.017064
Piandimeleto	265	486	1071	53.555944	668	0	0	0	0	47.08	10881	272	-0.37296
Pietrarubbia	86	176	328	50.267895	179	0	0	0	0	48.18	10329	81	-1.026393
Piobbico	199	516	998	41.433083	819	0	3	0	960	47.84	11209	0	-2.455146
San Costanzo	269	1049	2402	116.713055	1706	0	17	523	0	50.33	11976	7085	4.090064
San Lorenzo in Campo	254	921	1755	116.6037	1133	0	14	7578	6550	45.57	11871	1101	1.924734
Sant'Angelo in Vado	441	980	2046	60.485278	1504	0	79	0	13273	50.27	12131	0	4.794354
Sant'Ippolito	125	338	768	76.423828	486	0	0	0	0	48.92	10743	1000	1.088348

Sassocorvaro	359	867	1742	51.368737	1158	0	1	0	938	50.27	11987	408	-0.202079
Sassofeltrio	208	309	743	67.271063	444	0	0	0	0	46.6	10029	190	-0.138313
Serra Sant'Abbondio	60	336	511	30.515223	338	0	0	0	0	39.4	11306	0	0.3663
Tavoleto	115	206	448	70.205134	293	0	0	0	0	51.97	10372	109	-2.242152
Tavullia	570	1249	3963	189.238979	2568	0	0	0	0	57.72	12839	1351	1.926978
Urbania	782	1552	3637	91.26307	2780	53.2	17	0	0	50.71	12055	2850	-1.383595
Urbino	1384	3875	7458	64.274866	7280	32.9	81	59708	20211	47.96	14029	0	19.441398
Vallefoglia	1385	2622	7503	380.113117	4803	54.1	16	8383	0	55	11586	10400	1.080205
Colli al Metauro	1005	2403	6220	267.908778	4468	0	8	42676	0	51.9	11731	0	0.090312
Terre Roveresche	246	1394	2628	74.751374	1807	0	47	0	31658	48	11849	1000	0.908605
Agugliano	205	969	2453	219.227519	2039	55.3	13	0	0	54.75	13957	0	-1.129363
Ancona	13444	25990	52579	808.416425	48949	96.8	1681	4570270	1530431	47.72	15662	191909	8.409894
Arcevia	401	1488	2303	35.03383	1617	0	0	0	0	42.66	12327	952	11.827297
Barbara	100	363	670	120.937058	479	0	0	0	0	47.75	13914	0	-1.49786
Belvedere Ostrense	192	576	1120	74.80323	696	0	12	0	0	47.87	12066	2633	-0.218818
Camerano	348	1686	3698	360.820619	2802	74.5	159	677	0	51.71	14879	7334	2.75242
Camerata Picena	110	445	1273	214.601658	1041	1.4	0	0	0	57.71	13636	0	3.016529
Castelbellino	479	922	2613	828.317238	1863	76.7	20	0	0	54.21	12922	5793	-1.359264
Castelfidardo	1311	3990	9497	557.072949	6566	99	164	8647	2429	52.64	13370	13190	-0.461571
Castelleone di Suasa	115	420	803	100.816583	476	0	55	0	0	47.41	12015	0	0
Castelplanio	494	833	1799	230.050136	1207	46	0	0	0	48.75	12778	3686	21.616972
Cerreto d'Esi	393	807	1863	218.764042	1405	0	6	11625	0	48.53	12073	896	-1.210287
Chiaravalle	1093	3781	7766	836.997648	5971	84.3	101	34795	19460	46.44	13655	6297	3.918801
Corinaldo	284	1374	2515	100.426748	1733	0	12	0	0	49.31	12699	0	0.725064
Cupramontana	352	1275	2346	168.446251	1625	0	61	0	308	47.41	12434	5804	0.766522
Fabriano	3157	7764	16068	113.234911	13555	62.1	361	51640	25587	46.7	14042	24224	1.718124
Falconara Marittima	2440	7322	13564	1009.555978	11880	96	640	29437	20072	45.68	14853	17091	6.478293
Filottrano	569	2170	4737	131.06263	2640	38.2	96	36169	2220	52.83	13232	10532	2.297297
Genga	125	534	901	23.894307	671	0	10	0	5433	43.36	14197	392	-0.855615
Jesi	4619	10407	21000	369.22122	17624	73.6	600	142154	80847	47.94	14980	43181	6.582253
Loreto	794	3028	6665	715.367379	5036	93.7	131	6520	0	49.5	13117	12000	6.491845
Maiolati Spontini	496	1549	3227	287.866522	2250	2.7	188	8494	56778	49.38	13626	6846	3.274968
Mergo	77	238	526	138.505297	360	0	0	6580	0	48.31	12057	1305	2.022059
Monsano	181	715	1729	230.144497	1441	0	0	0	0	56.67	14531	3686	0.624628
Montecarotto	170	542	1003	78.734668	714	0	0	0	0	47.31	12558	2106	1.300578
Montemarciano	611	2267	4985	442.494139	4377	0.6	109	0	0	49.95	13579	252	3.001486
Monte Roberto	260	624	1557	227.567504	1186	5	0	0	0	53.03	13065	3686	0.229885
Monte San Vito	231	1418	3466	311.131893	2718	1	0	0	0	53.74	13683	1388	-0.609484
Morro d'Alba	130	466	971	96.244759	684	0	10	0	0	49.42	13038	2106	-1.265182
Numana	309	928	1879	344.124371	1781	9.2	0	0	0	51.07	16321	1640	-2.88721
Offagna	61	446	1022	187.381828	754	0	0	0	0	53.3	13526	0	1.112288
Osimo	2367	7530	17859	328.566584	13841	76.4	250	3874	53343	53.01	14110	11829	8.283274
Ostra	637	1599	3458	142.764933	2317	0	13	0	4924	49.35	11867	0	0.10355
Ostra Vetere	199	916	1661	109.07189	1088	0	26	0	0	48.08	12259	0	4.918981
Poggio San Marcello	60	172	346	50.961229	227	0	0	0	0	41.71	11342	527	-1.655172
Polverigi	101	811	2292	182.719864	1773	0	560	1133	277	58.65	14027	0	2.274294
Rosora	193	469	1002	207.945738	686	0	0	0	0	50.56	13390	2554	3.073048
San Marcello	60	462	1024	78.981465	814	0	3	22665	0	53.41	14692	2107	-0.386473
San Paolo di Jesi	120	233	476	89.992979	342	0	0	0	0	49.81	12835	1053	7.675195
Santa Maria Nuova	331	1026	2119	226.715954	1263	0	0	0	0	51.84	11549	4740	0.38059
Sassoferrato	670	1938	3680	51.76556	2698	26.6	0	0	0	44.58	12200	1624	5.734433
Senigallia	3174	11501	23271	378.84172	20142	36.7	890	528906	74483	47.53	14548	26407	4.144856
Serra de' Conti	403	921	1921	153.564706	1276	0	0	0	0	50.13	13057	2637	1.021231
Serra San Quirico	217	757	1466	55.621095	981	0	48	16718	0	47.85	12271	616	4.380054

Sirolo	205	967	2133	244.526926	1719	0	0	19408	0	52.32	15013	0	-0.412371
Staffolo	266	532	1160	81.7186	685	0	77	0	0	48.16	11815	3165	3.282276
Trecastelli	796	1542	3800	192.531792	2553	0	10	0	0	53.2	11394	6115	0.144947
Apiro	169	606	1172	41.539606	800	0	0	0	0	50	11794	2898	1.785714
Appignano	370	1015	2169	185.025912	1249	0	30	500	0	51.51	12514	1384	0.500238
Belforte del Chienti	151	423	966	119.154396	734	0	0	0	0	52.82	12299	1818	-0.429646
Bolognola	4	35	62	5.25805	57	0	0	0	0	46.85	9896	0	55.555556
Caldarola	153	409	888	60.159742	746	0	0	0	0	46.92	11107	1818	-2.829162
Camerino	877	1887	3553	53.555398	3475	67.7	0	0	0	48.01	14322	2785	22.488038
Camporotondo di Fiastrone	69	130	285	60.527601	162	0	0	0	0	47.62	10286	727	-1.194539
Castelraimondo	429	1134	2327	100.56414	1912	66.2	12	85	0	48.64	12567	793	3.945148
Castelsantangelo sul Nera	14	96	119	3.679082	112	0	0	0	0	50.34	12644	0	-0.326797
Cessapalombo	52	136	256	17.802304	163	0	0	0	0	42.31	10699	364	-3.846154
Cingoli	854	2548	5218	68.279675	3285	0	0	8898	0	50.14	12126	14672	-0.315457
Civitanova Marche	4235	9567	22121	919.388276	16837	26.8	752	639308	162150	48.46	12972	34645	4.342746
Colmurano	80	312	622	111.08333	430	0	0	0	0	46.83	10782	1091	2.124312
Corridonia	1522	3353	7835	247.912945	5208	1.7	37	7430	6332	52.23	11920	3521	-0.267101
Esanatoglia	127	543	1041	40.972828	728	0	0	0	0	48.71	12988	265	-1.395998
Fiastra	57	226	325	7.765041	236	0	0	0	0	39	10948	0	-4.148784
Fiuminata	105	433	675	17.47621	582	0	8	0	10124	41.91	12454	265	14.630872
Gagliole	38	144	296	24.822769	239	0	3	0	0	46.96	11003	0	3.058104
Gualdo	87	294	397	35.367489	283	0	0	0	0	46.41	10039	727	-0.230681
Loro Piceno	244	685	1221	72.347662	733	0	47	7081	0	46.36	11644	2182	2.505051
Macerata	3792	11036	22078	451.508939	20387	91.5	1347	1099084	50326	47.87	14902	28000	4.860432
Matelica	626	2616	4967	119.171949	3970	0	16	600	0	48.11	12991	1322	-0.81717
Mogliano	428	1289	2322	156.398461	1513	0	47	0	0	47.12	11596	1000	-1.675042
Montecassiano	541	1660	3600	212.246758	2406	69.1	0	0	0	52.38	12336	0	-1.703837
Monte Cavallo	17	53	62	3.34991	35	0	0	0	0	35.16	10600	0	100
Montecosaro	483	1357	3647	329.367455	2404	0	0	0	0	55.43	12044	2495	0.519406
Montefano	326	824	1748	101.880578	1014	0	3	0	849	50.82	12294	0	-1.154279
Montelupone	327	842	1816	109.420911	1170	0	0	0	0	51.55	11850	1000	1.279608
Monte San Giusto	1154	1800	4042	398.456878	2179	70.7	27	0	0	50.12	11123	4702	1.705599
Monte San Martino	54	189	369	40.341795	253	0	0	0	0	47.02	9221	727	-5.236271
Morrovalle	1128	2254	5041	236.161668	2908	61.9	128	6156	0	51.65	11647	3500	0.234489
Muccia	96	228	471	34.698501	391	0	0	0	0	48.43	11424	0	9.945946
Penna San Giovanni	200	341	561	37.921948	450	0	0	0	0	44.45	9894	1091	-3.55286
Petriolo	140	515	978	125.079093	587	0	0	0	0	46.83	12023	1495	5.395865
Pieve Torina	191	401	701	18.569742	452	0	0	0	0	45.43	11067	0	0.067568
Pioraco	154	315	578	56.856445	444	0	0	0	0	44.13	13641	264	-1.512739
Poggio San Vicino	13	92	124	18.72458	80	0	0	0	0	44.71	10792	0	-3.389831
Pollenza	349	1651	3352	165.586607	2273	65.2	16	0	0	50.25	12277	3664	-1.351967
Porto Recanati	2696	2319	6062	730.990423	4838	100	150	7989	180	49.75	12094	17860	3.061668
Potenza Picena	1247	3624	8126	325.973678	5699	0	63	40605	408	48.19	12215	17186	1.573062
Recanati	1528	5178	10957	204.773803	8367	87.5	72	55514	5499	50.27	13667	4050	4.030109
Ripe San Ginesio	66	228	439	83.386597	274	0	0	0	0	49.45	11064	727	-0.695249
San Ginesio	314	1032	1722	43.270512	1332	0	49	1500	0	44.94	11485	3273	2.455172
San Severino Marche	997	3473	6456	64.120977	5086	0	8	480	0	46.41	12280	1851	-0.807444
Sant'Angelo in Pontano	172	412	724	50.284654	466	0	0	0	0	47.17	10476	1455	8.817498
Sarnano	332	933	1679	50.976065	1373	0	3	0	0	44.22	11389	3273	8.197208
Sefro	76	135	200	9.567983	126	0	0	0	0	37.79	13590	0	2.784223
Serrapetrona	52	227	469	24.676339	377	0	5	0	0	50.63	11156	1091	-3.743842
Serravalle di Chienti	149	331	519	11.000653	376	0	35	3825	0	41.71	10497	0	23.743017
Tolentino	1909	4985	9989	204.048377	7508	94.1	129	15026	15429	48.3	12449	26636	1.284133
Treia	806	2366	4737	99.522008	3027	0	20	8604	1238	50.56	12056	3963	-0.440213

Urbisaglia	122	663	1286	112.711416	925	68.4	54	0	168	50.96	12022	6886	1.959335
Ussita	41	114	213	7.577443	157	0	50	30039	4845	43.32	10455	0	0.719424
Visso	72	335	566	10.71727	462	0	0	0	0	49.67	11460	0	3.914894
Valfornace	94	295		20.878974	387	0	0	0	0	42.3	10912	0	-0.764088
Acquasanta Terme	101	851	1394	20.123777	997	0	0	0	0	42.78	10600	0	-1.116951
Acquaviva Picena	191	853	1924	180.36624	1422	0	2	3354	0	48.67	11091	0	0.182482
Appignano del Tronto	88	478	895	76.181197	613	0	16	0	258	46.39	10751	225	1.520087
Arquata del Tronto	25	386	556	12.089906	398	0	0	0	0	36.46	9441	0	-2.578125
Ascoli Piceno	2966	13407	25261	308.647093	24247	65.5	793	599749	6204	42.77	13863	0	2.817156
Carassai	106	323	544	47.44025	355	0	0	0	0	45.85	10258	0	2.236136
Castel di Lama	659	1734	4358	784.667377	3318	0	1	203846	0	47.53	11298	1350	-1.458995
Castignano	124	733	1387	70.548874	1058	0	0	0	0	45.89	11572	450	-2.272727
Castorano	246	591	1182	166.434718	753	0	3	0	1905	46.23	11360	225	-0.646831
Colli del Tronto	244	757	1874	622.243173	1421	0	13	0	0	49.2	11665	450	0.897868
Comunanza	262	710	1542	56.639882	1111	0	7	4549	591	49.37	11862	0	-1.187871
Cossignano	52	281	492	63.675096	292	0	0	0	0	49	10845	0	0
Cupra Marittima	438	1354	2774	309.053574	2167	38.2	4	0	215	48.63	11769	1020	-2.60902
Folignano	363	1817	4572	617.921195	4048	0.3	0	0	0	49.2	11837	8600	-1.063487
Force	87	349	639	37.251113	434	0	0	0	0	46.95	10565	0	-0.703235
Grottammare	1070	3665	8444	898.360656	6778	2.8	59	500	9803	46.9	12260	7383	0.01923
Maltignano	110	515	1193	288.916898	961	0	0	0	0	46.05	11069	0	-1.207729
Massignano	183	411	819	100.588196	545	0	0	0	0	50.17	11021	0	1.024714
Monsampolo del Tronto	498	949	2282	294.609304	1541	0	0	0	0	48.7	11099	0	-2.327624
Montalto delle Marche	108	639	1128	61.22461	782	0	35	230	151	47.46	11020	0	6.557377
Montedinove	41	160	226	41.731261	188	0	0	0	0	49.35	10404	0	-4.142012
Montefiore dell'Aso	177	604	1049	72.781029	698	0	73	0	0	48.29	11368	0	21.372998
Montegallo	32	196	236	10.399343	170	0	0	0	0	31.95	11324	0	-1.401051
Montemonaco	45	170	291	8.376827	204	0	0	0	0	47.23	10202	0	-4.107425
Monteprandone	1058	2491	6401	480.667885	4031	0	28	343458	0	49.48	10592	4000	-2.182978
Offida	343	1478	2544	100.033667	1825	41.9	11	0	0	45.27	11314	675	-0.403769
Palmiano	10	47	98	14.490585	54	0	0	0	0	45.64	10173	0	-5.633803
Ripatransone	266	1130	2169	56.974764	1558	0	173	4057	0	51.04	11223	0	2.881512
Roccafluvione	72	512	978	32.770987	681	0	40	0	1250	42.84	10696	0	2.679006
Rotella	58	267	440	31.708197	306	0	0	0	0	48.93	10982	0	-2.457265
San Benedetto del Tronto	3341	11976	25059	1863.720987	21642	56.8	598	146289	43723	44.63	12885	29144	2.572087
Spinetoli	678	1495	3664	566.764942	2663	50.5	12	0	747	49.08	11077	1125	1.619946
Venarotta	78	535	1025	67.19607	740	0	0	0	0	44.29	11922	0	-3.313112
Altidona	293	654	1762	266.097266	1309	0	224	0	3204	52.97	11620	0	-1.638331
Amandola	341	977	1826	51.356139	1429	0	19	7498	0	47.25	11887	0	-1.082837
Belmonte Piceno	36	190	323	59.247444	185	0	0	0	0	45.24	10688	0	-2.424242
Campofilone	169	463	958	157.066348	716	0	0	0	0	49.15	10913	0	-1.129363
Falerone	426	878	1678	135.295456	1084	0	1	0	0	46.98	10741	0	0.118168
Fermo	3694	9378	19247	299.018742	15142	84.5	272	1358577	34411	46.84	12472	11858	11.609878
Francavilla d'Ete	119	259	469	92.608018	277	0	0	0	0	50	11135	0	0.596421
Grottazzolina	481	778	1759	359.861368	1125	1.5	0	0	0	49.65	11560	0	-2.125076
Lapedona	75	331	601	79.664458	411	0	0	0	0	51.86	12081	0	-2.730375
Magliano di Tenna	192	299	729	186.644807	424	0	3	0	0	49.59	11095	0	-2.236198
Massa Fermana	143	255	482	118.796506	266	0	0	0	0	45.45	9570	0	-4.785643
Monsampietro Morico	55	178	316	65.249012	195	0	0	0	0	46.53	10998	0	-2.011494
Montappone	212	439	884	161.645284	545	0	0	0	0	48.65	11378	0	-2.863688
Montefalcone Appennino	45	130	210	25.949988	183	0	0	0	0	36.78	10823	0	-2.449889
Montefortino	37	311	561	14.208159	426	0	0	0	0	46.5	11109	0	-2.21857
Monte Giberto	71	212	398	62.630147	254	41.3	0	0	0	48.58	10657	0	-3.186275
Montegiorgio	723	1740	3453	141.696138	2287	0	0	0	0	48.44	11867	523	-1.519495

Montegranaro	1325	3246	6472	409.818325	3602	16.1	289	29472	3646	52.42	12799	6000	4.643563
Monteleone di Fermo	31	124	177	46.381963	136	0	0	0	0	45.8	11260	0	0.229885
Montelparo	76	237	381	35.04943	326	0	0	0	0	45.35	10729	0	27.198124
Monte Rinaldo	32	119	179	45.317983	116	0	0	0	0	51.51	11057	0	-3.778338
Monterubbiano	153	599	1119	67.130542	803	1.4	0	0	0	46.98	10871	0	5.942275
Monte San Pietrangeli	225	606	1244	130.506417	705	1.2	65	0	0	50.87	12133	0	-0.314713
Monte Urano	923	1967	4143	491.627732	2149	74.2	55	0	1570	50.3	11209	4188	-0.205165
Monte Vidon Combatte	51	123	237	38.864163	159	2	0	0	0	39.85	10911	0	-4.793028
Monte Vidon Corrado	62	198	357	117.664857	244	0	0	0	0	47.51	11979	0	-2.316602
Montottone	97	287	506	58.000391	335	0	0	0	0	45.02	9959	0	-0.594059
Moresco	54	167	294	90.70152	205	0	0	0	0	46.88	11811	0	-2.475248
Ortezzano	65	205	383	108.127208	272	0	0	0	0	51.71	11146	0	-1.903553
Pedaso	440	628	1463	732.258903	1159	72.1	56	6720	0	50.5	10947	0	18.433345
Petritoli	214	645	1184	95.697567	857	25.9	22	0	404	47.62	10425	0	-2.303579
Ponzano di Fermo	128	366	826	115.784383	540	19.8	0	0	0	50.72	10871	0	-1.461988
Porto San Giorgio	983	4240	8526	1827.300331	7360	99.5	45	26580	29471	45.48	13763	13542	4.042941
Porto Sant'Elpidio	3673	5765	13542	1456.928798	8529	95.6	135	0	9437	50.28	10970	13627	3.576763
Rapagnano	234	458	1053	164.244255	617	3.9	0	0	0	50.23	10345	0	-2.191914
Santa Vittoria in Matenano	105	373	678	50.497527	513	0	0	0	0	48.9	10498	0	-1.346563
Sant'Elpidio a Mare	1741	3963	8683	339.364187	5193	10	180	103969	0	51.62	13845	7629	-1.497642
Servigliano	205	608	1146	122.592891	814	0	0	0	0	45.62	10691	0	-0.594985
Smerillo	33	103	174	31.436516	133	0	0	0	0	44.44	9650	0	-3.108808
Torre San Patrizio	288	553	998	166.511636	509	16.7	7	0	0	47.69	11320	0	0.77332

Table ix.6: Selected indicators for the health *and* infrastructural dimensions *of resilience, per each Municipality.*

MUNICIPALITY			*HEALTH*				*INFRASTRUCTRAL*		
	MENT_DISCH	ELDWELF_FAC	HOSP_BED	HOSP_STAFF	ARR_TIME	MITIG_EXP	MUN_ROAD	WAST_WAT	BUILD_AGE
Acqualagna	0.289706	2	965	1920	12.9	207683.56	199	51.79	1961-1970
Apecchio	0.289706	1	965	1920	12.9	67540.72	95	55.86	1946-1960
Auditore	0.289706	0	965	1920	12.9	41989.04	96	46.94	1961-1970
Belforte all'Isauro	0.289706	1	965	1920	12.9	550796.07	9	50	1946-1960
Borgo Pace	0.289706	0	965	1920	12.9	0	105	53.13	1946-1960
Cagli	0.289706	1	965	1920	12.9	272641.14	433	49.03	1946-1960
Cantiano	0.289706	1	965	1920	12.9	0	70	48.13	1946-1960
Carpegna	0.289706	1	965	1920	12.9	0	30	70.4	1961-1970
Cartoceto	0.289706	1	965	1920	12.9	0	108	39.63	1961-1970
Fano	0.289706	24	965	1920	12.9	2572403.98	386	30.46	1961-1970
Fermignano	0.289706	1	965	1920	12.9	115577.37	88	45.53	1961-1970
Fossombrone	0.289706	2	965	1920	12.9	105000	218	57.82	1946-1960
Fratte Rosa	0.289706	1	965	1920	12.9	0	60	42.86	1919-1945
Frontino	0.289706	0	965	1920	12.9	0	38	73.44	1946-1960
Frontone	0.289706	0	965	1920	12.9	0	47	54.19	1961-1970
Gabicce Mare	0.289706	0	965	1920	12.9	6503.01	72	36.15	1971-1980
Gradara	0.289706	1	965	1920	12.9	0	50	20.4	1971-1980
Isola del Piano	0.289706	0	965	1920	12.9	0	33	49.4	1961-1970
Lunano	0.289706	0	965	1920	12.9	48313.45	53	56.29	1971-1980
Macerata Feltria	0.289706	2	965	1920	12.9	0	44	31.76	1946-1960
Mercatello sul Metauro	0.289706	1	965	1920	12.9	0	124	66.86	1946-1960
Mercatino Conca	0.289706	0	965	1920	12.9	0	29	75.54	1961-1970
Mombaroccio	0.289706	2	965	1920	12.9	0	233	20.71	1961-1970
Mondavio	0.289706	3	965	1920	12.9	0	142	48.94	1961-1970

Mondolfo	0.289706	2	965	1920	12.9	0	70	25.16	1971-1980
Montecalvo in Foglia	0.289706	0	965	1920	12.9	0	26	42.58	1971-1980
Monte Cerignone	0.289706	0	965	1920	12.9	0	77	50.59	1946-1960
Monteciccardo	0.289706	0	965	1920	12.9	0	31	39.52	1971-1980
Montecopiolo	0.289706	1	965	1920	12.9	0	71	26.76	1961-1970
Montefelcino	0.289706	4	965	1920	12.9	0	40	49.58	1946-1960
Monte Grimano Terme	0.289706	1	965	1920	12.9	0	60	61.82	1946-1960
Montelabbate	0.289706	1	965	1920	12.9	0	58	34.69	1971-1980
Monte Porzio	0.289706	1	965	1920	12.9	0	32	28.76	1961-1970
Peglio	0.289706	0	965	1920	12.9	0	15	47.06	1946-1960
Pergola	0.289706	3	965	1920	12.9	305822.31	300	61.32	1961-1970
Pesaro	0.289706	17	965	1920	12.9	183194.43	691.4	33.57	1961-1970
Petriano	0.289706	0	965	1920	12.9	0	20	50.43	1961-1970
Piandimeleto	0.289706	1	965	1920	12.9	50427.21	138	45.98	1961-1970
Pietrarubbia	0.289706	0	965	1920	12.9	0	22	37.78	1946-1960
Piobbico	0.289706	1	965	1920	12.9	382059.88	35	37.74	1946-1960
San Costanzo	0.289706	0	965	1920	12.9	0	66	47.02	1971-1980
San Lorenzo in Campo	0.289706	1	965	1920	12.9	0	78	48.76	1946-1960
Sant'Angelo in Vado	0.289706	1	965	1920	12.9	75635.64	101	41.25	1946-1960
Sant'Ippolito	0.289706	0	965	1920	12.9	0	70	47.77	1946-1960
Sassocorvaro	0.289706	1	965	1920	12.9	223930.75	105	59	1961-1970
Sassofeltrio	0.289706	0	965	1920	12.9	0	116	75.17	1961-1970
Serra Sant'Abbondio	0.289706	0	965	1920	12.9	0	45	52.59	1946-1960
Tavoleto	0.289706	1	965	1920	12.9	0	40	55.34	1961-1970
Tavullia	0.289706	0	965	1920	12.9	0	62	27.05	1971-1980
Urbania	0.289706	3	965	1920	12.9	117056.34	173	38.66	1946-1960
Urbino	0.289706	5	965	1920	12.9	0	319	58.3	1961-1970
Vallefoglia	0.289706	3	965	1920	12.9	0	146	36.87	1971-1980
Colli al Metauro	0.289706	3	965	1920	12.9	0	133	48.29	1971-1980
Terre Roveresche	0.289706	1	965	1920	12.9	0	202	51.35	1946-1960
Agugliano	0.404746	2	2160	3457	13.1	0	26	37.19	1961-1970
Ancona	0.404746	7	2160	3457	13.1	0	350	27.87	1961-1970
Arcevia	0.404746	2	2160	3457	13.1	0	317	37.11	1946-1960
Barbara	0.404746	1	2160	3457	13.1	0	48	26.67	1961-1970
Belvedere Ostrense	0.404746	1	2160	3457	13.1	0	28	34.34	1961-1970
Camerano	0.404746	2	2160	3457	13.1	0	51	50.69	1961-1970
Camerata Picena	0.404746	2	2160	3457	13.1	0	25	14.41	1971-1980
Castelbellino	0.404746	4	2160	3457	13.1	0	14	40.18	1971-1980
Castelfidardo	0.404746	6	2160	3457	13.1	311757.05	158	21.61	1961-1970
Castelleone di Suasa	0.404746	1	2160	3457	13.1	0	36	43.27	1961-1970
Castelplanio	0.404746	2	2160	3457	13.1	0	15	46.77	1946-1960
Cerreto d'Esi	0.404746	3	2160	3457	13.1	2186.91	60	53.11	1946-1960
Chiaravalle	0.404746	2	2160	3457	13.1	0	113	25.33	1961-1970
Corinaldo	0.404746	1	2160	3457	13.1	0	142	22.06	1961-1970
Cupramontana	0.404746	1	2160	3457	13.1	0	93	42.94	1919-1945
Fabriano	0.404746	4	2160	3457	13.1	1090907.59	623	51.93	1946-1960
Falconara Marittima	0.404746	4	2160	3457	13.1	0	118	27.58	1961-1970
Filottrano	0.404746	4	2160	3457	13.1	0	136	21.13	1961-1970
Genga	0.404746	0	2160	3457	13.1	819984.64	272	27.73	1961-1970
Jesi	0.404746	10	2160	3457	13.1	0	344	31.66	1961-1970
Loreto	0.404746	4	2160	3457	13.1	0	740	32.3	1961-1970
Maiolati Spontini	0.404746	2	2160	3457	13.1	0	82	39.59	1961-1970
Mergo	0.404746	1	2160	3457	13.1	0	20	69.57	1961-1970
Monsano	0.404746	2	2160	3457	13.1	0	46	45.66	1961-1970

Montecarotto	0.404746	3	2160	3457	13.1	0	56	37.5	1946-1960
Montemarciano	0.404746	5	2160	3457	13.1	0	18	31.44	1961-1970
Monte Roberto	0.404746	0	2160	3457	13.1	0	33	38.24	1961-1970
Monte San Vito	0.404746	3	2160	3457	13.1	0	18	27.65	1961-1970
Morro d'Alba	0.404746	2	2160	3457	13.1	0	38	32.18	1961-1970
Numana	0.404746	2	2160	3457	13.1	0	64	38.56	1971-1980
Offagna	0.404746	1	2160	3457	13.1	0	45	39.7	1961-1970
Osimo	0.404746	5	2160	3457	13.1	0	264	28.66	1961-1970
Ostra	0.404746	2	2160	3457	13.1	0	120	21.16	1961-1970
Ostra Vetere	0.404746	3	2160	3457	13.1	0	136	22.53	1961-1970
Poggio San Marcello	0.404746	0	2160	3457	13.1	0	42	53.92	1946-1960
Polverigi	0.404746	2	2160	3457	13.1	0	28	14.62	1971-1980
Rosora	0.404746	3	2160	3457	13.1	0	29	32.37	1961-1970
San Marcello	0.404746	3	2160	3457	13.1	0	4	26.77	1919-1945
San Paolo di Jesi	0.404746	0	2160	3457	13.1	0	24	16.13	1946-1960
Santa Maria Nuova	0.404746	3	2160	3457	13.1	0	41	18.84	1961-1970
Sassoferrato	0.404746	2	2160	3457	13.1	0	487	63.92	1961-1970
Senigallia	0.404746	13	2160	3457	13.1	2292292.39	427	19.77	1961-1970
Serra de' Conti	0.404746	5	2160	3457	13.1	0	49	47.92	1961-1970
Serra San Quirico	0.404746	2	2160	3457	13.1	7500	110	59.25	1946-1960
Sirolo	0.404746	2	2160	3457	13.1	0	70	31.2	1961-1970
Staffolo	0.404746	2	2160	3457	13.1	0	40	41.23	1946-1960
Trecastelli	0.404746	5	2160	3457	13.1	0	106	36.26	1961-1970
Apiro	0.282829	1	2160	3457	15.2	0	135	12.99	1946-1960
Appignano	0.282829	3	946	2852	15.2	0	36	34.59	1961-1970
Belforte del Chienti	0.282829	3	946	2852	15.2	0	46	62.72	1961-1970
Bolognola	0.282829	0	946	2852	15.2	0	24	36.36	1961-1970
Caldarola	0.282829	0	946	2852	15.2	0	76	44.57	1946-1960
Camerino	0.282829	4	946	2852	15.2	0	275	22.85	1946-1960
Camporotondo di Fiastrone	0.282829	1	946	2852	15.2	0	17	36.17	1961-1970
Castelraimondo	0.282829	6	946	2852	15.2	0	95	31.06	1961-1970
Castelsantangelo sul Nera	0.282829	1	946	2852	15.2	437211.27	40	71.62	1919-1945
Cessapalombo	0.282829	0	946	2852	15.2	0	52	46.55	1946-1960
Cingoli	0.282829	3	2160	3457	15.2	0	477	30.47	1961-1970
Civitanova Marche	0.282829	4	946	2852	15.2	297703.08	102	45.17	1971-1980
Colmurano	0.282829	0	946	2852	15.2	0	27	45.07	1961-1970
Corridonia	0.282829	3	946	2852	15.2	112141.72	146	42.32	1961-1970
Esanatoglia	0.282829	2	946	2852	15.2	243731.61	92	53.47	1946-1960
Fiastra	0.282829	0	946	2852	15.2	0	100	19.17	1946-1960
Fiuminata	0.282829	4	946	2852	15.2	116571.45	71	40	1946-1960
Gagliole	0.282829	4	946	2852	15.2	0	50	27.5	1946-1960
Gualdo	0.282829	1	946	2852	15.2	0	59	42.98	1946-1960
Loro Piceno	0.282829	2	946	2852	15.2	0	85	32.73	1946-1960
Macerata	0.282829	21	946	2852	15.2	160664.79	225	8.66	1961-1970
Matelica	0.282829	5	946	2852	15.2	0	65	33.87	1961-1970
Mogliano	0.282829	2	946	2852	15.2	0	62	35.41	1961-1970
Montecassiano	0.282829	3	946	2852	15.2	34798.26	77	41.3	1961-1970
Monte Cavallo	0.282829	0	946	2852	15.2	0	84	19.23	1961-1970
Montecosaro	0.282829	4	946	2852	15.2	0	84	31.85	1961-1970
Montefano	0.282829	3	946	2852	15.2	0	39	33.52	1946-1960
Montelupone	0.282829	1	946	2852	15.2	133522.8	36	33.66	1961-1970
Monte San Giusto	0.282829	4	946	2852	15.2	0	53	13.5	1961-1970
Monte San Martino	0.282829	0	946	2852	15.2	153537.08	52	32.18	1946-1960
Morrovalle	0.282829	2	946	2852	15.2	0	89	51.33	1971-1980

Muccia	0.282829	1	946	2852	15.2	0	26	44.44	1971-1980
Penna San Giovanni	0.282829	2	946	2852	15.2	238324.43	35	39.16	1961-1970
Petriolo	0.282829	3	946	2852	15.2	0	40	18.49	1946-1960
Pieve Torina	0.282829	1	946	2852	15.2	0	39	49.82	1946-1960
Pioraco	0.282829	4	946	2852	15.2	0	85	49.01	1946-1960
Poggio San Vicino	0.282829	0	2160	3457	15.2	0	39	10.71	1961-1970
Pollenza	0.282829	11	946	2852	15.2	0	63	27.29	1961-1970
Porto Recanati	0.282829	3	946	2852	15.2	1716775.63	52	46.98	1961-1970
Potenza Picena	0.282829	5	946	2852	15.2	138545.81	194	37.69	1961-1970
Recanati	0.282829	5	946	2852	15.2	202683.78	303	22.93	1961-1970
Ripe San Ginesio	0.282829	1	946	2852	15.2	0	18	38.89	1971-1980
San Ginesio	0.282829	1	946	2852	15.2	0	110	51.21	1946-1960
San Severino Marche	0.282829	2	946	2852	15.2	74486	207	52.19	1946-1960
Sant'Angelo in Pontano	0.282829	1	946	2852	15.2	0	82	36.08	1961-1970
Sarnano	0.282829	2	946	2852	15.2	0	95	18.77	1946-1960
Sefro	0.282829	1	946	2852	15.2	0	69	21.48	1971-1980
Serrapetrona	0.282829	0	946	2852	15.2	0	33	55.64	1946-1960
Serravalle di Chienti	0.282829	0	946	2852	15.2	0	140	42.5	1961-1970
Tolentino	0.282829	3	946	2852	15.2	0	235	39.56	1961-1970
Treia	0.282829	4	946	2852	15.2	0	97	36.12	1961-1970
Urbisaglia	0.282829	4	946	2852	15.2	0	23	11.24	1946-1960
Ussita	0.282829	1	946	2852	15.2	102345.1	62	24.41	1946-1960
Visso	0.282829	2	946	2852	15.2	286421.86	141	44.08	1919-1945
Valfornace	0.282829	1	946	2852	15.2	0	128	36.88	1946-1960
Acquasanta Terme	0.312246	1	793	2124	15.2	0	172	30.34	1919-1945
Acquaviva Picena	0.312246	1	793	2124	15.2	0	64	29.1	1961-1970
Appignano del Tronto	0.312246	0	793	2124	15.2	0	65	29.02	1946-1960
Arquata del Tronto	0.312246	0	793	2124	15.2	2349.89	49.63	31.07	1919-1945
Ascoli Piceno	0.312246	7	793	2124	15.2	1098112.29	408	25.71	1946-1960
Carassai	0.312246	0	793	2124	15.2	27816.76	35	29.51	1946-1960
Castel di Lama	0.312246	2	793	2124	15.2	0	36	29.75	1971-1980
Castignano	0.312246	0	793	2124	15.2	152016.14	65	28.57	1961-1970
Castorano	0.312246	0	793	2124	15.2	0	70	28.91	1971-1980
Colli del Tronto	0.312246	2	793	2124	15.2	0	21	30.34	1961-1970
Comunanza	0.312246	1	793	2124	15.2	0	56	28.98	1946-1960
Cossignano	0.312246	0	793	2124	15.2	47983.86	45	28.57	1961-1970
Cupra Marittima	0.312246	2	793	2124	15.2	152531.89	80	33.42	1961-1970
Folignano	0.312246	2	793	2124	15.2	0	66	29.93	1971-1980
Force	0.312246	0	793	2124	15.2	0	60	29.33	1946-1960
Grottammare	0.312246	6	793	2124	15.2	201283.56	114	31.84	1971-1980
Maltignano	0.312246	4	793	2124	15.2	0	42.04	29.26	1961-1970
Massignano	0.312246	0	793	2124	15.2	36793.59	51	32.8	1946-1960
Monsampolo del Tronto	0.312246	2	793	2124	15.2	0	16	29.18	1961-1970
Montalto delle Marche	0.312246	1	793	2124	15.2	0	97	29.6	1961-1970
Montedinove	0.312246	0	793	2124	15.2	0	35	30.36	1946-1960
Montefiore dell'Aso	0.312246	4	793	2124	15.2	0	70	29.52	1946-1960
Montegallo	0.312246	0	793	2124	15.2	0	40	32	1919-1945
Montemonaco	0.312246	0	793	2124	15.2	3610	91	30.56	1961-1970
Monteprandone	0.312246	1	793	2124	15.2	0	120	29.44	1971-1980
Offida	0.312246	3	793	2124	15.2	0	125	28.6	1946-1960
Palmiano	0.312246	1	793	2124	15.2	0	19	28.57	1946-1960
Ripatransone	0.312246	4	793	2124	15.2	0	208	29.47	1946-1960
Roccafluvione	0.312246	1	793	2124	15.2	0	250	29.35	1971-1980
Rotella	0.312246	0	793	2124	15.2	126000	81	28.57	1971-1980

San Benedetto del Tronto	0.312246	10	793	2124	15.2	79997.36	230	30.71	1961-1970
Spinetoli	0.312246	6	793	2124	15.2	945636.9	38	29.21	1961-1970
Venarotta	0.312246	0	793	2124	15.2	0	111	29.41	1946-1960
Altidona	0.410068	1	480	1438	15.2	0	25	31.08	1971-1980
Amandola	0.410068	2	480	1438	15.2	0	657	28.6	1946-1960
Belmonte Piceno	0.410068	1	480	1438	15.2	18822.23	35	28.57	1946-1960
Campofilone	0.410068	0	480	1438	15.2	265935.47	32	30.18	1961-1970
Falerone	0.410068	3	480	1438	15.2	0	52	42.11	1946-1960
Fermo	0.410068	11	480	1438	15.2	1720658.9	241	28.24	1961-1970
Francavilla d'Ete	0.410068	4	480	1438	15.2	0	20	25.88	1961-1970
Grottazzolina	0.410068	1	480	1438	15.2	0	34	29.35	1961-1970
Lapedona	0.410068	2	480	1438	15.2	0	25	30.47	1961-1970
Magliano di Tenna	0.410068	0	480	1438	15.2	0	34	10.08	1971-1980
Massa Fermana	0.410068	1	480	1438	15.2	0	22	12.7	1946-1960
Monsampietro Morico	0.410068	1	480	1438	15.2	0	38	29.85	1946-1960
Montappone	0.410068	0	480	1438	15.2	0	30	19.84	1961-1970
Montefalcone Appennino	0.410068	1	480	1438	15.2	0	33	32.08	1946-1960
Montefortino	0.410068	0	480	1438	15.2	507643.75	108	29.73	1961-1970
Monte Giberto	0.410068	3	480	1438	15.2	0	44	28.26	1946-1960
Montegiorgio	0.410068	4	480	1438	15.2	98911	55	29.49	1961-1970
Montegranaro	0.410068	3	480	1438	15.2	0	100	24.39	1961-1970
Monteleone di Fermo	0.410068	1	480	1438	15.2	0	29	29.27	1946-1960
Montelparo	0.410068	1	480	1438	15.2	0	69	29	1961-1970
Monte Rinaldo	0.410068	0	480	1438	15.2	0	20	31.58	1961-1970
Monterubbiano	0.410068	2	480	1438	15.2	149999.77	82	29.29	1961-1970
Monte San Pietrangeli	0.410068	3	480	1438	15.2	0	52	38.87	1961-1970
Monte Urano	0.410068	1	480	1438	15.2	0	40	28.78	1961-1970
Monte Vidon Combatte	0.410068	1	480	1438	15.2	37631.24	24	29.55	1946-1960
Monte Vidon Corrado	0.410068	0	480	1438	15.2	0	17	12.07	1946-1960
Montottone	0.410068	1	480	1438	15.2	0	49	29.46	1946-1960
Moresco	0.410068	1	480	1438	15.2	0	16	29.31	1946-1960
Ortezzano	0.410068	1	480	1438	15.2	75923.62	24	30.11	1961-1970
Pedaso	0.410068	1	480	1438	15.2	84235.91	16	30.62	1961-1970
Petritoli	0.410068	1	480	1438	15.2	73829.88	40	28.2	1946-1960
Ponzano di Fermo	0.410068	1	480	1438	15.2	0	51	29.75	1961-1970
Porto San Giorgio	0.410068	4	480	1438	15.2	0	120	30.43	1961-1970
Porto Sant'Elpidio	0.410068	7	480	1438	15.2	0	107	23.02	1971-1980
Rapagnano	0.410068	2	480	1438	15.2	0	34	29.09	1961-1970
Santa Vittoria in Matenano	0.410068	1	480	1438	15.2	0	28	28.89	1971-1980
Sant'Elpidio a Mare	0.410068	6	480	1438	15.2	200000	105	12.83	1961-1970
Servigliano	0.410068	1	480	1438	15.2	324918.14	33	29.31	1961-1970
Smerillo	0.410068	1	480	1438	15.2	0	40	31.82	1961-1970
Torre San Patrizio	0.410068	1	480	1438	15.2	0	30	13.75	1961-1970

Sustainability

Table ix.7: Selected indicators for each dimension of sustainability, per each Municipality.

MUNICIPALITY	*ECOSYSTEM INTEGRITY*					*ECOSYSTEM BENEFITS*		*PHYSICAL PROCESSES STATE*		*EXTERNAL PRESSURES*		
	HABITAT_INADEG	GRASS_PAST	WOOD_FARM	GEOBOTVAL_HIGH	GEOBOTVAL_LOW	FOR_WOODS	QUAL_PROD	TREND_FLOOD	PM10_AVG	AGR_AREA	LIVESTOCK	FRAGM_PRESS
Acqualagna	4	282.66	1116.12	alta	bassa	1.69	6	-7.447891	21.349	1903.75	1990	high
Apecchio	4	1229.29	3416.92	alta	bassa	60	5	-7.665201	20.305	2289.68	1355	high
Auditore	3	40.67	177.5	alta	bassa	0.2	2	-7.035033	22.014	1123.14	351	high
Belforte all'Isauro	5	127.71	232.01	alta	bassa	4.4	5	-7.240671	20.66	889.92	767	high
Borgo Pace	5	373.43	2368.24	alta	bassa	29	1	-7.410893	14.323	1563.59	303	medium
Cagli	4	2004.51	7019.96	alta	bassa	13.69	9	-7.652798	21.349	7921.42	77329	high
Cantiano	4	1190.82	2109.95	alta	bassa	0.06	7	-7.840927	19.941	2099.9	2103	medium
Carpegna	5	180.53	181.68	alta	bassa		4	-7.123289	20.548	621.74	942	high
Cartoceto	4	2.65	50.18	alta	media	0.72	8	-7.257635	23.358	1500.34	498	very high
Fano	6	18.53	201.2	alta	bassa	10.75	3	-7.165801	24.681	7269.77	2657	very high
Fermignano	4	75.46	463.02	alta	bassa	8.3	0	-7.457409	21.413	1534.11	387	very high
Fossombrone	4	120.36	1466.11	alta	bassa	32.75	7	-7.418617	22.178	4453.54	1353	high
Fratte Rosa	3	2.25	52.86	media	bassa		2	-7.556213	19.003	1140.47	230	high
Frontino	5	57.25	130.02	alta	bassa	3.19	5	-7.130713	14.11	554.72	1053	high
Frontone	4	971.31	172.16	alta	bassa		2	-7.827619	20.367	1682.56	1103	very high
Gabicce Mare	5	0.6	38.49	alta	bassa	1.7	0		24.916	122.39	2	very high
Gradara	4	9.69	9.38	media	media	7.82	0	-6.837226	24.905	1014.34	19	very high
Isola del Piano	3	47.02	404.08	alta	bassa	8.33	5	-7.350013	20.02	1352.02	856	high
Lunano	5	35.1	171.22	alta	bassa		0	-7.2453	21.057	417.03	105568	high
Macerata Feltria	4	335.36	512.91	alta	bassa		7	-7.027264	21.078	2282.6	1765	high
Mercatello sul Metauro	5	247.25	2783.8	alta	bassa	17	10	-7.424324	19.466	1162.84	2710	medium
Mercatino Conca	3	21.05	75.47	alta	bassa		1	-6.923027	16.421	748.29	675	high
Mombaroccio	3	44.11	248.62	alta	bassa	10.17	2	-7.15703	22.322	1749.25	3237	high
Mondavio	3	2.8	25.84	media	media	2	1	-7.458672	22.358	2194.35	2325	very high
Mondolfo	4	2.47	4.6	media	media	0.01	0	-7.319042	23.537	1223.54	91	very high
Montecalvo in Foglia	3	104.44	79.93	alta	bassa	15.86	1		22.272	1156.1	1269	very high
Monte Cerignone	4	222.16	159.66	alta	bassa	4.93	4		19.473	1110.07	2284	high
Monteciccardo	3	21.59	319.39	media	bassa	1.5	0	-7.15278	22.778	928.04	1399	high
Montecopiolo	5	766.81	337.18	alta	bassa	0	5	-6.913786	20.39	1588.16	4839	medium
Montefelcino	3	46.06	450.57	alta	bassa	14.49	2	-7.253889	22.15	2220.64	1024	high
Monte Grimano Terme	4	204.79	204.92	alta	bassa		8	-6.918647	21.25	1179.17	2618	very high
Montelabbate	3	15.41	101.35	media	media		0		24.246	907.72	630	very high
Monte Porzio	4	36.72	7.87	media	media		1		22.741	1174.11	16094	high
Peglio	3	186.87	324.18	alta	bassa	8	6		21.034	997.88	34534	high
Pergola	4	301.31	1660.68	alta	bassa	19.73	14	-7.675176	20.965	6191.37	3960	high
Pesaro	5	188.92	340.44	alta	bassa	23.51	2	-7.015253	25.176	5561.88	2051	very high
Petriano	3	15.65	183.82	alta	bassa		1	-7.146234	22.01	605.37	548	high
Piandimeleto	5	136.75	501.02	alta	bassa		7		21.057	1535.14	26109	high
Pietrarubbia	4	60.43	108.7	alta	bassa	11.15	1	-7.021968	16.937	601.46	188	high
Piobbico	4	762.24	1564.91	alta	bassa		1	-7.577308	20.499	1038.36	1591	medium
San Costanzo	5	3.19	21.43	media	media	2	0	-7.316506	23.56	3526.3	92	high
San Lorenzo in Campo	3	15.27	61.06	media	bassa	67.67	3		22.022	1854.75	347	high
Sant'Angelo in Vado	5	140	1438.44	alta	bassa	22.58	8	-7.353897	20.797	1809.24	2521	high
Sant'Ippolito	3	19.68	79.68	alta	bassa		3	-7.407063	21.65	1363.25	808	high
Sassocorvaro	5	311.66	1152.26	alta	bassa	8.67	8	-7.10237	21.163	3186.61	236602	high
Sassofeltrio	5	123.72	108.58	alta	bassa	4	0		22.035	922.3	1387	high
Serra Sant'Abbondio	4	355.7	1389.13	alta	bassa		3	-7.868909	14.304	1048.91	496	high
Tavoleto	3	5.97	141.21	alta	bassa	2.54	3		21.033	475.98	1682	high
Tavullia	4	11.8	63.2	media	media	8	4	-6.976147	24.414	2595.34	1326	very high
Urbania	3	443.39	1247.49	alta	bassa	10.6	15	-7.437992	21.034	2960.44	3432	high
Urbino	5	858.01	3839.19	alta	bassa	22.44	20	-7.248936	22.039	10594.17	10458	very high
Vallefoglia	3	54.66	256.83	alta	bassa	1.86	2	-7.045665	23.273	1881.49	1288	very high
Colli al Metauro	4	23.76	165.09	alta	bassa	5.8	6	-7.261336	23.358	2880.96	10689	very high
Terre Roveresche	4	72.2	174.28	alta	media	3.86	3	-7.410606	23.468	5130.01	5266	very high
Agugliano	2	2.5		media	bassa	10.28	2	-7.726712	23.452	1715.69	60135	very high

Ancona	6	123.04	263.36	alta	bassa	40.59	3	-7.716137	24.178	6315.74	2334	very high
Arcevia	4	275.06	910.87	alta	bassa	15.88	5	-7.768278	22.359	7231.9	67986	high
Barbara	3	14.4	30.79	alta	media	1.29	0	-7.650419	22.476	883.09	158	high
Belvedere Ostrense	3	28.91	6.73	alta	bassa	2.48	2	-7.736378	23.037	2741.37	102620	high
Camerano	6	165.07	73.01	media	media	4.4	1	-7.798793	23.329	1568.74	25	very high
Camerata Picena	4	0.6	1.9	media	bassa	21.94	1		23.757	668.88	5613	very high
Castelbellino	3	0.6	9.78	media	bassa	5.35	0		22.884	245.47	489	very high
Castelfidardo	4	3.36	29.13	alta	media	1.26	1	-7.964961	22.846	2792.88	807	very high
Castelleone di Suasa	2	27.63	16.25	alta	media	0.7	0		22.022	1241.4	29681	high
Castelplanio	3	16.65	29.29	alta	bassa	6.54	1	-7.829612	22.875	1274.11	45240	very high
Cerreto d'Esi	4	43.93	64.56	media	bassa	2.61	0	-8.179973	20.277	875.31	32726	very high
Chiaravalle	4	1.16	5.6	media	bassa		1	-7.639451	24.938	1073.81	10	very high
Corinaldo	4	8.67	12.2	alta	bassa	13.58	6	-7.523674	22.669	4454.9	1017	high
Cupramontana	4	67.91	122.44	alta	bassa	32.34	1	-7.917094	21.471	1585.66	608617	very high
Fabriano	5	2177.47	4495.62	alta	bassa	25.09	24	-8.150186	20.634	8011.23	8800	very high
Falconara Marittima	4	6.08	7.17	alta	bassa		0	-7.636894	25.008	1292.06	170752	very high
Filottrano	4	77.08	38.62	alta	bassa	26.11	5	-7.98326	22.003	5361.09	307752	high
Genga	4	69.9	907.04	alta	bassa	29.54	1	-7.9955	16.666	1353.4	54	high
Jesi	4	135.31	22.02	alta	bassa	20.4	4	-7.846506	23.757	8721.98	832753	very high
Loreto	5	1.04	1.1	media	media	1.5	0	-7.957921	23.103	1712.43	39	very high
Maiolati Spontini	4	20.29	49.24	alta	bassa	15.7	6	-7.824973	22.884	1554.12	805	very high
Mergo	4	4.6	29.78	alta	bassa	7.83	0		21.414	422.28	331	high
Monsano	4	22.68	0.15	alta	media	0.2	1	-7.729949	23.784	1027.78	121	very high
Montecarotto	3	14.65	29.61	alta	bassa	5.48	2	-7.739849	22.344	1736.87	6145	high
Montemarciano	4	2.2	0.55	media	bassa	0.2	1	-7.551079	24.933	1234.88	65079	very high
Monte Roberto	5	9.53	15.3	media	bassa		0		22.113	793.1	55146	very high
Monte San Vito	2	0.78	2.6	media	media	8.66	0	-7.641745	24.688	1510.05	15	very high
Morro d'Alba	2	2.96	7.16	media	bassa	2.09	1	-7.643901	22.918	1482.22	818	high
Numana	6			alta	bassa		0		22.851	648.53	6	very high
Offagna	3	30.98	10.91	alta	bassa	13.32	1	-7.804013	23.82	889.52	293	high
Osimo	3	22.62	55.58	alta	bassa	4.12	10	-7.890124	23.664	7028.22	150124	very high
Ostra	3	10.98	2.69	alta	media	7.58	2	-7.600094	23.16	3553.34	2397	very high
Ostra Vetere	3	16.04	13.64	alta	bassa	1.1	0	-7.648183	22.452	2194.77	1237	very high
Poggio San Marcello	3	32.8	64.67	alta	bassa		1		19.74	677.94	270652	high
Polverigi	2	14.7	20.9	media	bassa	27.05	2	-7.810691	23.82	1807.75	814	high
Rosora	4	11.95	29.37	alta	bassa	3.8	0	-7.834836	21.414	532.09	320	very high
San Marcello	4	28.85	18.18	alta	bassa	16.8	4	-7.73312	23.649	1975.58	569722	medium
San Paolo di Jesi	4	10.03	19.88	media	media	11.51	0	-7.911516	21.777	898.36	604	high
Santa Maria Nuova	4	5.4	6.17	alta	media	3.02	0		22.384	1287.85	908	very high
Sassoferrato	5	547.3	1300.34	alta	bassa	34.16	14	-7.972321	20.817	5342.59	1930	very high
Senigallia	4	44.59	59.23	alta	bassa	14.2	4	-7.507	23.74	8171.58	11207	very high
Serra de' Conti	3	21.15	20.06	alta	bassa	6.2	0	-7.743637	22.483	1605.24	1217	high
Serra San Quirico	4	76.48	588.72	alta	bassa	17.19	7	-7.927305	21.319	2085.74	205616	high
Sirolo	6	0.3	7.37	alta	bassa		0	-7.87546	23.115	456.61	3	very high
Staffolo	4	120.12	71.15	alta	bassa	46.34	3	-7.906575	21.743	1880.54	47288	high
Trecastelli	6	4.73	28.7	media	bassa	12.7	0		23.537	2778.23	650	high
Apiro	4	238.34	506.82	alta	bassa	18.72	14	-8.04274	20.611	3218.33	420913	high
Appignano	2	3.7	1.1	media	bassa	1.8	4	-8.062893	20.425	1460.04	249	very high
Belforte del Chienti	3	40.46	71.23	media	bassa	8.24	1	-8.438838	18.467	954.7	7087	high
Bolognola	4	1598.85	453.36	alta	bassa		0	-8.625346	10.473	1626.2	736	high
Caldarola	4	212.86	206.7	alta	bassa		0	-8.493168	18.652	1118.47	3251	very high
Camerino	4	1071.57	1290.59	alta	bassa	40.88	19	-8.428986	19.107	6203.68	117676	very high
Camporotondo di Fiastrone	3	43.01	45.59	media	bassa	20.67	2		16.483	567.3	36062	high
Castelraimondo	4	315.33	517.52	alta	bassa	8.7	5		19.911	1732.04	2437	high
Castelsantangelo sul Nera	4	2375.81	2044.18	alta	bassa	1.8	8	-8.705606	12.09	2794.43	5207	low
Cessapalombo	4	47.22	299.77	alta	bassa		4	-8.503579	13.804	628.19	1110	very high
Cingoli	4	415.72	1533.27	alta	bassa	73.44	16	-8.059675	21.52	7868.27	55250	very high
Civitanova Marche	5	42.46	19.08	media	bassa	6.04	2	-8.19649	23.518	2577.9	869	very high
Colmurano	3	21.17	36.52	alta	bassa	4.1	0		18.539	665.7	5152	high
Corridonia	3	83.49	36.66	media	bassa	12.53	7	-8.316268	21.237	4309.38	7682	very high
Esanatoglia	5	648.09	1657.16	alta	bassa	4.95	4	-8.300497	19.347	1428.04	12664	medium
Fiastra	3	1968.31	1743.79	alta	bassa	27.8	3	-8.552964	12.833	2998.74	12241	high
Fiuminata	5	604.43	32.25	alta	bassa		1	-8.403775	18.543	892.81	1	medium

Gagliole	4	201.32	455.11	alta	bassa		1	-8.31137	18.311	695.44	13	medium
Gualdo	4	26.06	278.16	alta	bassa	14.66	2	-8.582456	14.253	1235.24	18875	high
Loro Piceno	3	25.79	111.28	alta	bassa	18.27	4	-8.452572	18.777	2454.58	1429	high
Macerata	3	109.05	115.7	media	bassa	36.47	4	-8.19014	21.616	6766.26	9245	very high
Matelica	4	564.84	2028.75	alta	bassa	35.89	12	-8.24669	19.792	4137.81	330017	high
Mogliano	3	6.33	41.11	media	bassa	61.45	2		19.736	1976.99	2046	very high
Montecassiano	3	5.86	19.05	media	media	5.7	4	-8.139451	21.528	2372.05	767	very high
Monte Cavallo	4	2156.93	48.89	alta	bassa		1	-8.526862	10.19	2464.92	309	medium
Montecosaro	3	4.56	7.73	media	media	4.49	2		22.562	1071.51	654	very high
Montefano	3	80.55	11.59	media	media	17.5	2	-8.00184	22.025	2852.37	10402	high
Montelupone	3	2.69	18.9	media	bassa	1.74	1	-8.129389	21.601	2469.51	1846	very high
Monte San Giusto	2	4.55	8	media	media	7.13	0	-8.374946	21.795	1110.91	380	high
Monte San Martino	4	27.78	201.88	alta	bassa	4.6	4	-8.680517	14.635	853.88	60661	medium
Morrovalle	3	1.08	20.96	media	bassa	8.49	5	-8.208008	22.216	3328.21	150800	very high
Muccia	4	324.33	326.15	alta	bassa		2	-8.477099	17.754	879.79	1466	high
Penna San Giovanni	4	124.08	335.82	alta	bassa	58.59	0	-8.604141	18.722	1278.29	8139	high
Petriolo	3	74.85	2.84	media	media	4.49	2	-8.37695	20.565	895.42	512	very high
Pieve Torina	4	1708.9	1455.46	alta	bassa	19.97	7	-8.51999	17.631	2970.05	7128	very high
Pioraco	4	40.81	57.5	alta	bassa	1	0	-8.380801	17.544	423.35	200	high
Poggio San Vicino	4	39.66	658.68	alta	bassa	0.09	3		15.278	294.93	60162	high
Pollenza	3	25.44	31.06	media	bassa	5.91	2	-8.273954	20.866	2881.88	4496	very high
Porto Recanati	5	1.8	12.8	alta	media	0.25	1	-8.031629	22.9	836.81	565	very high
Potenza Picena	5	44.94	33.95	alta	bassa	7.33	2	-8.118167	22.928	2873.5	3641	very high
Recanati	5	10.73	10.22	media	bassa	10.48	4	-8.046955	22.578	7328.14	18156	very high
Ripe San Ginesio	3	11.62	38.36	alta	bassa	9.69	4		16.556	654.24	13836	high
San Ginesio	4	82.09	590.39	alta	bassa	19.31	15	-8.540028	18.554	4330.52	19426	high
San Severino Marche	4	1152.08	3201.62	alta	bassa	231.72	11	-8.253895	19.747	9235.97	170139	high
Sant'Angelo in Pontano	4	71.84	296.18	alta	bassa	22.82	5	-8.524268	17.991	1575.7	13579	high
Sarnano	4	1558	819.01	alta	bassa	6.3	5	-8.625736	17.312	2793.56	20280	very high
Sefro	5	777.76	1358.47	alta	bassa		4	-8.442486	12.714	1465.29	1092	medium
Serrapetrona	4	336.77	388.68	alta	bassa	5.7	0	-8.401984	18.652	1251.99	917	very high
Serravalle di Chienti	5	3241.2	2623.35	alta	bassa	0.72	7	-8.503952	12.127	4989.72	7455	high
Tolentino	3	402.4	133.36	alta	bassa	46.88	13	-8.396483	20.866	6376.74	307745	very high
Treia	3	62.3	147.79	alta	bassa	53.19	4	-8.171629	20.688	6100.71	112446	very high
Urbisaglia	3	11	14.16	alta	bassa		3	-8.375573	19.402	1653.03	8603	high
Ussita	4	1373.71	1142.32	alta	bassa		2	-8.632609	12.84	1418.61	1836	high
Visso	4	4213.74	3587.35	alta	bassa	1	13	-8.560625	17.319	4720.49	4074	high
Valfornace	4	417.41	315.59	alta	bassa	4.81	3	-8.519991	17.631	1595.64	3578	high
Acquasanta Terme	5	983.29	1525.76	alta	bassa	25.2	3	-9.164992	16.433	1830.36	4109	medium
Acquaviva Picena	5	48.23	10.81	alta	bassa	1.1	1		21.692	1116.47	20719	very high
Appignano del Tronto	4	101.48	22.72	alta	bassa	9.7	2	-9.003712	19.71	1400.97	12771	high
Arquata del Tronto	5	2631.91	1223.02	alta	bassa	100.3	7	-8.923605	12.978	2942.32	8084	high
Ascoli Piceno	4	601.13	1224.91	alta	bassa	41.57	15	-9.085249	21.034	4776.35	67016	very high
Carassai	4	4.3	107.61	media	bassa	4.4	1	-8.714282	19.654	1716.48	4342	high
Castel di Lama	3	62.12	11.6	alta	media	4.2	2	-9.109922	21.093	907.35	101745	very high
Castignano	4	54.84	207.88	alta	bassa	106.02	6	-8.899439	19.144	1888.9	7717	high
Castorano	3	213.05	44.84	alta	bassa	11.25	1		21.093	955.27	1151	high
Colli del Tronto	3	11.61	2.6	media	bassa	2.3	0		21.043	267.51	97	very high
Comunanza	4	171.57	644.1	alta	bassa	79.55	2	-8.862684	17.946	776.71	788	very high
Cossignano	3	3	28.02	alta	bassa	34.74	0		18.023	1013.32	4138	very high
Cupra Marittima	5	7.55	98.89	media	bassa	0.5	2	-8.789632	21.595	647.14	247	high
Folignano	4	58.35	43.4	alta	bassa	1	5	-9.221016	20.773	785.12	317100	very high
Force	3	120.34	462.49	alta	bassa	4.75	3	-8.821972	16.427	1890.09	14086	high
Grottammare	5	22.94	92.54	media	bassa	2.4	2	-8.886121	22.095	811.05	209	very high
Maltignano	4	24.6	2.62	alta	bassa	5.03	1		20.927	422.16	1527	very high
Massignano	4	2.77	99.32	media	bassa	2.4	0	-8.695673	20.322	880.95	380	high
Monsampolo del Tronto	3	0.3	31.39	alta	bassa	10.4	3	-8.998411	21.871	841.85	720	very high
Montalto delle Marche	4	34.1	197.26	alta	bassa	102.48	3	-8.804973	18.902	2007.31	98626	very high
Montedinove	4	12.5	144.51	alta	bassa	0.4	1		15.479	809.06	244	high
Montefiore dell'Aso	3	17.36	120.98	media	bassa	19.36	4	-8.707426	20.365	1579.9	4034	very high
Montegallo	4	478.52	219.18	alta	bassa		0	-8.892545	11.368	579.5	128	high
Montemonaco	4	2853.56	1135.97	alta	bassa	2	4	-8.826834	12.331	3509.59	2193	very high
Monteprandone	5	19.86	14.18	alta	bassa	1.1	1	-8.985209	21.959	1457.15	2519	very high

Offida	3	73.45	117.08	alta	bassa	82.03	6	-8.954695	19.094	3234.97	24411	very high
Palmiano	3	37.36	174.71	alta	bassa	3.2	0		11.713	288.87	209	very high
Ripatransone	5	172.65	476.14	alta	bassa	33	5	-8.835797	20.313	4380.99	38709	high
Roccafluvione	4	68.59	1020.89	alta	bassa	1.6	2	-9.011491	17.334	829.06	3985	high
Rotella	4	112.86	373.03	alta	bassa	40	0	-8.878887	16.877	1246.27	1607	high
San Benedetto del Tronto	6	6.9	59.06	alta	bassa	3.93	0		21.987	1096.5	657	very high
Spinetoli	3	23.05	14.26	alta	bassa	0.99	1	-9.101848	21.871	870.8	1510	very high
Venarotta	3	61.01	278.44	alta	bassa	9.04	2		17.987	704.92	511	high
Altidona	5	4.89	34.32	alta	bassa	8.2	0	-8.604072	21.298	591.73	121	very high
Amandola	4	382.15	938.58	alta	bassa	69.19	2	-8.69918	18.467	2411.12	4242	very high
Belmonte Piceno	3	20.24	57.69	media	bassa	17.53	4		17.676	697.9	26736	high
Campofilone	4	50	34.13	media	bassa	7.1	5		20.874	683.97	190	very high
Falerone	3	15.37	159.76	alta	bassa	50.86	0	-8.532478	18.742	1467.29	9765	very high
Fermo	5	118.62	125.94	alta	bassa	56.72	5	-8.353873	23.015	8331.87	59025	very high
Francavilla d'Ete	3	25.85	18.42	media	media	2.7	0		19.736	790.01	82754	medium
Grottazzolina	3	18.5	19.75	media	bassa	1.89	0		20.617	444.66	420	very high
Lapedona	5	22.8	68.3	alta	bassa	19.45	0	-8.616034	20.11	934.37	592	very high
Magliano di Tenna	3	21.19	15.51	bassa	bassa	5.95	1		20.617	497.28	708	high
Massa Fermana	3	0.7	15.97	media	bassa	2.65	0		18.802	378.56	182	high
Monsampietro Morico	3	36.46	90.9	media	bassa	18.93	2		17.082	542.26	6554	high
Montappone	3	8.8	41.64	alta	bassa	6.75	0		18.802	617.97	12	medium
Montefalcone Appennino	3	3.98	131.23	alta	bassa	19.8	0	-8.770598	14.593	419.2	162	high
Montefortino	4	779.88	999.41	alta	bassa	4.58	2	-8.763183	17.629	1743.22	8594	very high
Monte Giberto	3	17.45	71.45	media	bassa	15.46	0	-8.626832	19.642	1050.57	162	very high
Montegiorgio	3	50.2	111.57	media	bassa	8	2	-8.539483	19.726	3697.5	141836	high
Montegranaro	2	1.83	22.75	media	bassa	11.6	1	-8.329044	22.117	2001.72	162	very high
Monteleone di Fermo	3	10.1	59.87	media	bassa	14.28	1		17.082	571.97	1237	high
Montelparo	4	19.39	262.04	media	bassa	60.4	2		15.555	1205.37	34421	high
Monte Rinaldo	4	10	23.1	media	bassa	9	0	-8.712364	17.07	439.63	627	medium
Monterubbiano	3	69.05	168.51	alta	bassa	19.7	3	-8.623656	20.546	2142.28	29587	very high
Monte San Pietrangeli	3	18.13	26.32	media	media	20.95	3	-8.457416	19.724	1579.09	4141	high
Monte Urano	5	7	2	media	bassa	21.77	0	-8.448777	21.941	990.69	704	very high
Monte Vidon Combatte	3	6	77.47	media	bassa	24.8	1	-8.715978	18.33	656.16	301	high
Monte Vidon Corrado	3	0.46	23.06	media	bassa	8.01	0		17.176	231.43	1411	medium
Montottone	3	14.8	68.61	media	bassa	44.72	1	-8.625563	18.662	1130.46	2925	high
Moresco	3	1.95	9.79	alta	bassa	7.04	0		17.864	369.63	410	very high
Ortezzano	4		20.81	media	media	2.7	0		17.92	501.44	202	very high
Pedaso	4	2.7	27.28	media	bassa		0		21.298	122.34	66	very high
Petritoli	3	18.98	154.18	media	bassa	42.9	3		20.915	1615.23	1148292	very high
Ponzano di Fermo	3	18.3	105.28	media	bassa	25.92	0	-8.539909	18.745	699.32	6422	very high
Porto San Giorgio	5		0.9	media	media		0		21.858	311.55	16	very high
Porto Sant'Elpidio	5	5.58	1.72	media	bassa		0	-8.26943	23.248	521.07	8	very high
Rapagnano	3	31.73	25.6	media	media	0.5	1		19.683	701.05	873	high
Santa Vittoria in Matenano	3	35.76	232.43	alta	bassa	46.78	4	-8.703482	18.439	1608.41	2248	high
Sant'Elpidio a Mare	5	68.01	131.92	media	bassa	1.4	1	-8.321681	23.248	2894.98	617967	very high
Servigliano	3	63.7	84.74	media	bassa	36.42	0	-8.620011	18.722	1156.21	41561	high
Smerillo	3	16.49	138.87	media	bassa	2.5	1		14.483	527.37	127	high
Torre San Patrizio	3	55.85	20.07	media	media	2.8	2	-8.454662	20.695	942.57	29378	high

x. Appendix II: Indicators for the quantitative assessment of the Resilience and Sustainability Level of Hokkaidō

List of tables

Outline of the indicators

First phase – classification

Table x.1 — Tested indicators for each core *and each* attribute*, their source and year of reference for the Hokkaidō case study.*

CORE	***ATTRIBUTE***	**INDICATOR**	**SOURCE**	**REFERENCE YEAR**
resilience	*learn*	total affected area	Japanese Government Statistics	2016
		distance from the nearest water body	Geospatial Information Authority of Japan	2016
		population exposed to flood hazard	Japanese Government Statistics, Ministry of Land, Infrastructure, Transport and Tourism	(depending on Municipality)
	absorb	flood damages	Japanese Government Statistics	2016
	recover	percentual difference in income after 2 years and on the year of the last flood event	Japanese Government Statistics	2015-2017
sustainability	*functions*	land transaction	Ministry of Land, Infrastructure, Transport and Tourism	2015

		altered vegetation	Biodiversity Center of Japan	1994-1998
	services	number of establishments employees in power supply	Japanese Government Statistics Japanese Government Statistics	2014-2016 2014-2016
	integrity	distribution of raccoon (浣熊 rōmaji: *araiguma*)	Biodiversity Centre of Japan	2017

Second phase – characterisation

Table x.2 — Tested indicators for each core *and each* dimension*, their source and year of reference for the Hokkaidō case study.*

CORE	***DIMENSION***	**INDICATOR**	**SOURCE**	**REFERENCE YEAR**
resilience	*demographic*	immigrants	Japanese Government Statistics	2015
		population over 65 y.o. population over 75 y.o. population over 80 y.o.	Japanese Government Statistics Japanese Government Statistics Japanese Government Statistics	2015 2015 2015
		female population	Japanese Government Statistics	2015
		population density	Japanese Government Statistics	2015
	social	population with compelled education population with university education	Japanese Government Statistics Japanese Government Statistics	2010 2010
		tv subscriptions satellite subscriptions	Japanese Government Statistics Japanese Government Statistics	2015 2015
		public halls public halls and similar infrastructures personnel of public halls and similar infrastructures	Japanese Government Statistics Japanese Government Statistics Japanese Government Statistics	2015 2015 2015
		sport facilities personnel of sport facilities	Japanese Government Statistics Japanese Government Statistics	2015 2015
	economic	employment	Japanese Government Statistics	2015
		taxable income	Japanese Government Statistics	2015
		social welfare expenses	Japanese Government Statistics	2015
		in-migrants from other Municipalities	Japanese Government Statistics	2015
		inflow of population from the same Prefecture	Japanese Government Statistics	2015
		inflow of population from a different Prefecture	Japanese Government Statistics	2015
		total inflow of population	Japanese Government Statistics	2015
	health	welfare facilities for the elderly	Japanese Government Statistics	2015
		nursing care facilities for the elderly	Japanese Government Statistics	2015
		medical facility doctors	Japanese Government Statistics	2016
		hospital with medical beds hospital beds beds in general clinics	Japanese Government Statistics Japanese Government Statistics Japanese Government Statistics	2015 2015 2015
		firefighting expenses	Japanese Government Statistics	2015
	infrastructural	disaster recovery expenses	Japanese Government Statistics	2015
		extension of roadways	Geospatial Information Authority of Japan	2014
		population served by septic tank	Japanese Government Statistics	2015
		average building construction year	Japanese Government Statistics	2018
sustainability	*ecosystems integrity*	forest and grassland forests grasslands	Japanese Government Statistics Japanese Government Statistics Japanese Government Statistics	2014 2014 2014

		wildlife sanctuary	Ministry of Land, Infrastructure, Transport and Tourism	2015
	ecosystem benefits	private forests	Japanese Government Statistics	2017
		fisheries and aquaculture entities	Japanese Government Statistics	2003
	physical processes state	water intake of water supply businesses	Environmental Bureau of Hokkaidō	2015
		difference from optimal pH value in river water	Environmental Bureau of Hokkaidō	2015
	external pressures	cultivated land area	Japanese Government Statistics	2015
		revenue from livestock revenue from beef cattle	Japanese Government Statistics Japanese Government Statistics	2016 2016

Quantification of the indicators

First phase – classification

Resilience

Table x.3: Selected indicators for each attribute *of resilience, per each Municipality.*

MUNICIPALITY	ID	LEARN EXP_POP	ABSORB FLOOD_DAMAGE	RECOVER TAXINCOME_1715
Sapporo-shi	1100	561144	183657	1.951557
Hakodate-shi	1202	0	289186	1.708617
Otaru-shi	1203	0	44218	1.422601
Asahikawa-shi	1204	150484	2507341	1.254553
Muroran-shi	1205	0	2328	1.088109
Kushiro-shi	1206	55262	256121	2.101733
Obihiro-shi	1207	60688	6848986	2.487406
Kitami-shi	1208	25801	5743403	2.53614
Yubari-shi	1209	0	19744	3.130952
Iwamizawa-shi	1210	23696	310552	2.928168
Abashiri-shi	1211	3190	542145	3.653402
Rumoi-shi	1212	9447	32000	1.578772
Tomakomai-shi	1213	0	83719	1.774257
Wakkanai-shi	1214	0	453248	3.376641
Bibai-shi	1215	1941	24950	3.908477
Ashibetsu-shi	1216	673	723826	3.210705
Ebetsu-shi	1217	33516	1695	1.172462
Akabira-shi	1218	5172	350532	3.609314
Monbetsu-shi	1219	1786	96657	0.038248
Shibetsu-shi	1220	1744	179505	4.977063
Nayoro-shi	1221	24027	418170	1.376376
Mikasa-shi	1222	6422	17138	2.986142
Nemuro-shi	1223	0	12275	0.825209
Chitose-shi	1224	9572	7559	2.211834
Takikawa-shi	1225	17935	60948	1.930473
Sunagawa-shi	1226	2874	803739	2.415513
Utashinai-shi	1227	0	294490	1.742735
Fukagawa-shi	1228	11925	1080670	3.577853
Furano-shi	1229	12292	1301591	2.147874
Noboribetsu-shi	1230	0	11767	1.347518
Eniwa-shi	1231	30140	16776	0.300376
Date-shi	1233	0	68389	1.777287
Kitahiroshima-shi	1234	11204	10010	2.769805
Ishikari-shi	1235	52	13271	2.925333
Hokuto-shi	1236	0	4691	2.82297
Tobetsu-cho	1303	6279	4101	1.908729
Shinshinotsu-mura	1304	1118	1444	14.288663
Matsumae-cho	1331	0	104	7.213939
Fukushima-cho	1332	0	1386	6.59965
Shiriuchi-cho	1333	0	75876	3.1546
Kikonai-cho	1334	0	1111	5.085164
Nanae-cho	1337	0	42291	3.60018
Shikabe-cho	1343	0	109919	-3.976822
Mori-machi	1345	0	55708	3.295795
Yakumo-cho	1346	0	67702	7.745164
Oshamambe-cho	1347	0	1134	-1.51233
Esashi-cho	1361	0	0	1.350292
Kaminokuni-cho	1362	0	0	3.998126
Assabu-cho	1363	0	2360	8.854455
Otobe-cho	1364	0	0	3.60324
Okushiri-cho	1367	0	0	0.854179
Imakane-cho	1370	3617	1455	2.446957
Setana-cho	1371	3591	13192	4.137548
Shimamaki-mura	1391	0	7088	3.05288
Suttsu-cho	1392	0	0	-0.910913
Kuromatsunai-cho	1393	0	984	3.59519
Rankoshi-cho	1394	2660	15127	5.285812
Niseko-cho	1395	0	10560	16.093122
Makkari-mura	1396	0	1110	22.111348
Rusutsu-mura	1397	0	1140	18.781056
Kimobetsu-cho	1398	0	27750	7.030597
Kyogoku-cho	1399	0	60494	6.955785
Kutchan-cho	1400	0	30050	11.015543
Kyowa-cho	1401	0	10650	8.939622
Iwanai-cho	1402	0	0	0.704146
Tomari-mura	1403	0	69900	7.275157
Kamoenai-mura	1404	0	0	12.807618
Shakotan-cho	1405	0	0	11.611413
Furubira-cho	1406	0	0	0.578877
Niki-cho	1407	0	84000	4.064759
Yoichi-cho	1408	0	18800	1.317757
Akaigawa-mura	1409	0	12000	6.217034
Nanporo-cho	1423	4746	511	7.014827
Naie-cho	1424	2031	75658	3.481154
Kamisunagawa-cho	1425	0	2480	0.731525
Yuni-cho	1427	1086	3000	8.134441
Naganuma-cho	1428	4256	14788	3.146956
Kuriyama-cho	1429	10072	63981	3.938958
Tsukigata-cho	1430	2020	61741	6.884072
Urausu-cho	1431	93	0	13.202549
Shintotsukawa-cho	1432	4261	25692	9.662496
Moseushi-cho	1433	332	0	18.167985
Chippubetsu-cho	1434	2227	1326	14.734932
Uryu-cho	1436	434	40345	16.527714
Hokuryu-cho	1437	88	2400	13.565338
Numata-cho	1438	617	4723	11.417649
Takasu-cho	1452	3306	17563	5.252418
Higashikagura-cho	1453	111	81020	2.879268
Tohma-cho	1454	851	91976	6.175409
Pippu-cho	1455	121	9000	4.418043
Aibetsu-cho	1456	400	290359	4.841616
Kamikawa-cho	1457	875	3810248	4.216686
Higashikawa-cho	1458	4866	644657	2.048792
Biei-cho	1459	4557	6061308	8.263459
Kamifurano-cho	1460	0	837354	3.700229
Nakafurano-cho	1461	0	320766	2.028881
Minamifurano-cho	1462	1205	10240016	9.876943
Shimukappu-mura	1463	0	270025	1.027622
Wassamu-cho	1464	0	65906	4.593543
Kenbuchi-cho	1465	0	327607	5.401694
Shimokawa-cho	1468	3122	61401	2.943365
Bifuka-cho	1469	2863	37700	5.380206
Otoineppu-mura	1470	803	20000	12.792702
Nakagawa-cho	1471	1676	60000	5.195647
Horokanai-cho	1472	1141	47860	6.869066
Mashike-cho	1481	0	0	5.673035
Obira-cho	1482	0	37630	6.681702
Tomamae-cho	1483	0	428576	8.746907
Haboro-cho	1484	0	231622	4.799159
Shosambetsu-mura	1485	0	66000	3.052999
Enbetsu-cho	1486	0	106000	9.903312
Teshio-cho	1487	748	61000	6.582628
Sarufutsu-mura	1511	0	243	3.731229
Hamatombetsu-cho	1512	0	12176	-3.55168
Nakatombetsu-cho	1513	0	0	-1.312375
Esashi-cho	1514	0	2408178	4.608976
Toyotomi-cho	1516	1	85	12.233135
Rebun-cho	1517	0	590	16.428618
Rishiri-cho	1518	0	21859	2.153762
Rishirifuji-cho	1519	0	184664	0.697732
Horonobe-cho	1520	495	0	4.424281
Bihoro-cho	1543	5207	147016	1.678524
Tsubetsu-cho	1544	748	263039	3.846008
Shari-cho	1545	0	586963	3.415026
Kiyosato-cho	1546	0	15548	3.369945
Koshimizu-cho	1547	0	127120	2.47019
Kunneppu-cho	1549	1738	375607	7.707925
Oketo-cho	1550	1671	162455	15.671104
Saroma-cho	1552	0	210552	3.784331
Engaru-cho	1555	7546	2137599	72.006318
Yubetsu-cho	1559	5507	1001879	-3.723708
Takinoue-cho	1560	0	6770	8.613261
Okoppe-cho	1561	0	60841	-2.239049
Nishiokoppe-mura	1562	0	1794	8.595978

Omu-cho	1563	0	11775	-7.86786
Ozora-cho	1564	1998	526273	4.356339
Toyoura-cho	1571	0	16100	9.475401
Sobetsu-cho	1575	0	238829	2.313261
Shiraoi-cho	1578	0	1744864	-0.298631
Atsuma-cho	1581	0	415874	3.370345
Toyako-cho	1584	0	60797	5.063189
Abira-cho	1585	0	19562	1.97432
Mukawa-cho	1586	5951	1035071	2.577951
Hidaka-cho	1601	4051	23934395	2.750342
Biratori-cho	1602	1810	599519	3.357465
Niikappu-cho	1604	0	562221	8.347322
Urakawa-cho	1607	0	550907	4.22376
Samani-cho	1608	0	725987	4.930698
Erimo-cho	1609	0	28091	-2.414396
Shinhidaka-cho	1610	0	1491337	5.521052
Otofuke-cho	1631	25097	4733198	4.339871
Shihoro-cho	1632	187	3112648	10.6814
Kamishihoro-cho	1633	0	4235231	11.273939
Shikaoi-cho	1634	0	624740	7.57025
Shintoku-cho	1635	16	10850639	6.769885
Shimizu-cho	1636	342	25487033	7.814028
Memuro-cho	1637	913	15614171	6.312361
Nakasatsunai-mura	1638	40	1750453	5.19742
Sarabetsu-mura	1639	0	719103	1.471452
Taiki-cho	1641	0	1630762	4.800933
Hiroo-cho	1642	0	248333	3.591644
Makubetsu-cho	1643	7485	1674669	4.443617
Ikeda-cho	1644	5932	798136	4.228705
Toyokoro-cho	1645	2228	96362	5.174234
Honbetsu-cho	1646	2741	498892	4.59373
Ashoro-cho	1647	0	1092922	6.524322
Rikubetsu-cho	1648	0	99384	2.259159
Urahoro-cho	1649	284	507666	8.854427
Kushiro-cho	1661	19377	84055	2.383263
Akkeshi-cho	1662	0	6560	3.078475
Hamanaka-cho	1663	0	2185	8.344752
Shibecha-cho	1664	4115	102429	9.833415
Teshikaga-cho	1665	954	1721799	6.474271
Tsurui-mura	1667	0	29058	11.248035
Shiranuka-cho	1668	0	445842	3.214925
Betsukai-cho	1691	0	776	16.349693
Nakashibetsu-cho	1692	0	145725	5.385238
Shibetsu-cho	1693	0	75063	4.261409
Rausu-cho	1694	0	1033201	7.257197

Sustainability

Table x.4: Selected indicators for each attribute *of sustainability, per each Municipality.*

		FUNCTIONS	*SERVICES*	*INTEGRITY*
MUNICIPALITY	ID	ALT_VEG	POW_NUM	ARAIG_AREA
Sapporo-shi	1100	13904276	0	460.100808
Hakodate-shi	1202	5511170	0	0
Otaru-shi	1203	2149637	1	69.733527
Asahikawa-shi	1204	13798205	-2	465.132304
Muroran-shi	1205	4976507	-2	46.868768
Kushiro-shi	1206	9852032	2	11.940985
Obihiro-shi	1207	4426849	2	29.38471
Kitami-shi	1208	23509668	2	53.570719
Yubari-shi	1209	23176725	1	238.865471
Iwamizawa-shi	1210	8085545	1	450.728303
Abashiri-shi	1211	4151571	-1	0
Rumoi-shi	1212	8484650	1	64.794198
Tomakomai-shi	1213	28888147	0	429.143362
Wakkanai-shi	1214	19791276	0	247.180802
Bibai-shi	1215	3147253	0	195.650566
Ashibetsu-shi	1216	42923139	-2	130.510813
Ebetsu-shi	1217	1924136	0	172.165813
Akabira-shi	1218	1432766	0	103.457679
Monbetsu-shi	1219	11362571	0	0
Shibetsu-shi	1220	10503730	2	327.670909
Nayoro-shi	1221	4718815	-2	338.838885
Mikasa-shi	1222	12340816	1	158.105655
Nemuro-shi	1223	161448	-1	0
Chitose-shi	1224	21722180	-1	136.925175
Takikawa-shi	1225	881505	-1	115.120667
Sunagawa-shi	1226	1024131	1	78.211111
Utashinai-shi	1227	1633071	0	46.727062
Fukagawa-shi	1228	9088835	2	159.486126
Furano-shi	1229	11212686	0	267.946181
Noboribetsu-shi	1230	4729492	0	163.119609
Eniwa-shi	1231	12396927	-1	205.930135
Date-shi	1233	10547955	0	327.96132
Kitahiroshima-shi	1234	3443739	0	118.302932
Ishikari-shi	1235	11960517	-1	432.433842
Hokuto-shi	1236	2569386	0	0
Tobetsu-cho	1303	4921397	0	258.640012
Shinshinotsu-mura	1304	0	0	78.188922
Matsumae-cho	1331	1651561	0	0
Fukushima-cho	1332	1089563	0	0
Shiriuchi-cho	1333	2177045	0	0
Kikonai-cho	1334	2076764	0	0
Nanae-cho	1337	2916628	-4	41.526962
Shikabe-cho	1343	2594982	0	4.654436
Mori-machi	1345	6824448	2	1.763571
Yakumo-cho	1346	17111462	0	0
Oshamambe-cho	1347	9962514	0	0
Esashi-cho	1361	1431183	0	0
Kaminokuni-cho	1362	2660263	0	0
Assabu-cho	1363	3370868	0	0
Otobe-cho	1364	1385032	0	0
Okushiri-cho	1367	1897144	0	0
Imakane-cho	1370	4652369	0	0
Setana-cho	1371	7554434	0	0
Shimamaki-mura	1391	6168597	0	38.311332
Suttsu-cho	1392	1741640	0	12.488775
Kuromatsunai-cho	1393	12396917	0	47.431527
Rankoshi-cho	1394	13780987	0	132.769374
Niseko-cho	1395	3162417	0	120.417363
Makkari-mura	1396	729922	0	111.614935
Rusutsu-mura	1397	2787150	0	104.852843
Kimobetsu-cho	1398	3879413	1	132.847869
Kyogoku-cho	1399	1978844	-1	133.875911
Kutchan-cho	1400	8295629	0	160.255475
Kyowa-cho	1401	1421044	0	142.336185
Iwanai-cho	1402	37901	0	26.339827
Tomari-mura	1403	318391	1	18.114407
Kamoenai-mura	1404	0	0	50.794153
Shakotan-cho	1405	2193748	0	238.24441
Furubira-cho	1406	3145311	0	71.265299
Niki-cho	1407	4600623	0	120.608651
Yoichi-cho	1408	1789195	0	45.657575
Akaigawa-mura	1409	3863273	0	55.881387
Nanporo-cho	1423	984869	0	81.388792
Naie-cho	1424	288759	1	64.553176
Kamisunagawa-cho	1425	1005092	0	23.273391
Yuni-cho	1427	279392	0	96.009314
Naganuma-cho	1428	2034574	0	168.421613
Kuriyama-cho	1429	3582769	0	177.07721

Tsukigata-cho	1430	3456059	0	108.804923
Urausu-cho	1431	1064430	0	73.182955
Shintotsukawa-cho	1432	10869316	0	184.400876
Moseushi-cho	1433	249518	1	19.088303
Chippubetsu-cho	1434	172895	0	21.928458
Uryu-cho	1436	3510390	0	77.278548
Hokuryu-cho	1437	3666877	0	49.646738
Numata-cho	1438	9963885	0	121.211999
Takasu-cho	1452	4738826	0	69.443952
Higashikagura-cho	1453	1028721	0	49.966057
Tohma-cho	1454	2581428	0	173.177677
Pippu-cho	1455	1900370	0	64.642661
Aibetsu-cho	1456	1684176	0	119.135355
Kamikawa-cho	1457	27331462	0	65.776802
Higashikawa-cho	1458	7495653	0	86.943869
Biei-cho	1459	17567205	0	262.045
Kamifurano-cho	1460	4389998	0	150.25274
Nakafurano-cho	1461	435780	0	77.058577
Minamifurano-cho	1462	24922911	0	1.431809
Shimukappu-mura	1463	16573285	0	196.760003
Wassamu-cho	1464	2432807	0	6.127957
Kenbuchi-cho	1465	510463	0	47.215177
Shimokawa-cho	1468	6888630	0	55.044456
Bifuka-cho	1469	9549090	0	54.280534
Otoineppu-mura	1470	2401269	0	99.7437
Nakagawa-cho	1471	9343328	0	240.961113
Horokanai-cho	1472	11588701	1	32.827235
Mashike-cho	1481	1329984	2	6.682157
Obira-cho	1482	6020936	0	184.6615
Tomamae-cho	1483	6760433	0	120.026811
Haboro-cho	1484	2597925	0	83.735574
Shosambetsu-mura	1485	9622320	0	68.469275
Enbetsu-cho	1486	14110700	1	274.546462
Teshio-cho	1487	7312402	1	223.392634
Sarufutsu-mura	1511	11479013	0	68.801072
Hamatombetsu-cho	1512	2633032	0	160.006403
Nakatombetsu-cho	1513	6758335	0	182.217472
Esashi-cho	1514	21116006	0	239.681673
Toyotomi-cho	1516	10506226	0	406.943573
Rebun-cho	1517	433860	0	0
Rishiri-cho	1518	0	0	0
Rishirifuji-cho	1519	252427	0	0
Horonobe-cho	1520	13629847	0	292.622662
Bihoro-cho	1543	3867544	0	21.251477
Tsubetsu-cho	1544	5566330	0	20.373273
Shari-cho	1545	2478918	1	106.826257
Kiyosato-cho	1546	975896	0	0
Koshimizu-cho	1547	1677939	0	0
Kunneppu-cho	1549	1122295	0	19.193575
Oketo-cho	1550	14162716	0	0
Saroma-cho	1552	3654034	0	23.183554
Engaru-cho	1555	23674687	0	0
Yubetsu-cho	1559	7392688	0	0
Takinoue-cho	1560	5902992	0	0
Okoppe-cho	1561	4859693	0	0
Nishiokoppe-mura	1562	1534715	0	0
Omu-cho	1563	5085392	0	0
Ozora-cho	1564	2222971	0	2.044959
Toyoura-cho	1571	5265850	-1	115.334132
Sobetsu-cho	1575	5902576	0	97.621701
Shiraoi-cho	1578	9253033	-1	184.702802
Atsuma-cho	1581	6574014	0	46.917309
Toyako-cho	1584	2862242	0	123.568008
Abira-cho	1585	12560127	0	229.932666
Mukawa-cho	1586	14470579	0	179.313408
Hidaka-cho	1601	20235355	-1	630.80975
Biratori-cho	1602	22582837	0	339.632301
Niikappu-cho	1604	6080783	0	269.446627
Urakawa-cho	1607	8611085	0	261.856553
Samani-cho	1608	3486098	0	59.002634
Erimo-cho	1609	17374	0	97.372351
Shinhidaka-cho	1610	29433562	0	592.430736
Otofuke-cho	1631	1786412	1	76.121956
Shihoro-cho	1632	5181535	0	85.847042
Kamishihoro-cho	1633	25728315	1	35.492448
Shikaoi-cho	1634	5109805	0	155.930315
Shintoku-cho	1635	25724762	1	56.484496
Shimizu-cho	1636	6738716	0	131.494501
Memuro-cho	1637	4022886	0	238.143428
Nakasatsunai-mura	1638	5988998	1	0.141991
Sarabetsu-mura	1639	2227537	0	63.996616
Taiki-cho	1641	2103252	0	0
Hiroo-cho	1642	29720	0	23.864292
Makubetsu-cho	1643	918103	1	30.254638
Ikeda-cho	1644	2467489	0	0
Toyokoro-cho	1645	3026610	0	8.249203
Honbetsu-cho	1646	2741558	0	39.870201
Ashoro-cho	1647	38884557	1	0
Rikubetsu-cho	1648	7095360	0	0
Urahoro-cho	1649	6670425	0	15.881648
Kushiro-cho	1661	2064879	0	9.787399
Akkeshi-cho	1662	18554358	0	2.348097
Hamanaka-cho	1663	3099780	0	0
Shibecha-cho	1664	12551237	-1	16.344382
Teshikaga-cho	1665	1194478	-1	0
Tsurui-mura	1667	12658523	0	1.837701
Shiranuka-cho	1668	7763845	-1	23.582431
Betsukai-cho	1691	6749106	2	4.763351
Nakashibetsu-cho	1692	1939950	-1	0
Shibetsu-cho	1693	2040756	0	9.225913
Rausu-cho	1694	828619	0	26.379099

Second phase – characterisation

Resilience

Table x.5: Selected indicators for the demographic*,* social *and* economic dimensions *of resilience, per each Municipality.*

		DEMOGRAPHIC				*SOCIAL*					*ECONOMIC*			
MUNICIPALITY	ID	IMMIGR_PERC	POP_OVER65_PERC	POP_FEM_PERC	POP_DENS	COMPEL_EDU_PERC	TV_SUBSCRIPT_POP	SAT_SUBSCRIPT_POP	PUBL_HALL_POP	SPORT_FAC	EMPLOYED_POP_PERC	TAX_INCOME	SOC_EXPENSE	INFLOW_TOT_PERC
Sapporo-shi	1100	0.451762	24.766692	53.358199	1741.2	8.958608	314.011891	144.315893	0.5	708	43.245853	3038.6	103318520	23.608092
Hakodate-shi	1202	0.289873	32.307438	54.742292	392.4	16.945691	396.35084	153.37677	11.3	60	44.035431	2721.5	16819789	6.488858
Otaru-shi	1203	0.337095	37.105082	54.902234	500	18.997483	404.620911	158.861258	0	79	42.089334	2488.4	5895655	10.278534
Asahikawa-shi	1204	0.180504	31.343473	53.945908	454.2	18.757977	318.870452	116.95352	82.4	116	44.871247	2718.1	18478278	3.627155
Muroran-shi	1205	0.335351	34.007046	51.286076	1095	22.251018	410.573145	178.661759	0	83	42.100628	2830.6	4242036	14.6922
Kushiro-shi	1206	0.2518	30.254318	52.967804	128.2	21.749858	387.519886	161.403669	5.7	74	42.828856	2683.5	8789085	4.159275
Obihiro-shi	1207	0.30946	26.360828	52.167109	273.4	12.602867	310.800995	137.125207	0	86	47.15137	2858.4	7982940	10.891352
Kitami-shi	1208	0.233448	30.057083	52.13898	84.9	18.725585	321.127481	150.644251	66	126	46.170788	2760.1	6692160	2.6199
Yubari-shi	1209	0.995137	48.580798	53.726111	11.6	37.78612	518.376117	205.020921	113.1	17	42.07848	2152.7	822278	7.033812
Iwamizawa-shi	1210	0.113611	32.548314	53.468088	175.7	19.158023	331.222855	133.646552	0	59	44.787512	2622.8	4367776	7.979976
Abashiri-shi	1211	0.481101	27.358804	49.282186	83	19.84487	353.839855	162.576452	0	55	45.947744	2945.2	1843599	4.895463
Rumoi-shi	1212	0.445525	33.81036	52.675397	74.6	24.291614	390.261464	142.162819	45	30	48.661176	2698.3	1005173	4.774763
Tomakomai-shi	1213	0.23446	25.743761	51.020916	307.6	17.004385	314.784904	123.505676	5.8	42	44.456602	2789.9	8622369	4.750575
Wakkanai-shi	1214	0.819131	28.875756	51.047279	47.8	23.975249	428.916987	218.361737	0	42	46.531061	2955.6	1948210	1.077515
Bibai-shi	1215	0.14326	38.43282	53.318863	83	29.907045	377.469069	139.830692	173.6	15	43.616236	2456.2	1492069	9.316258
Ashibetsu-shi	1216	0.286182	43.642682	54.57209	17	36.865528	364.677024	140.02453	0	16	41.918779	2264.3	986332	5.512401
Ebetsu-shi	1217	0.324116	27.011008	52.426307	643.8	11.98655	306.442521	138.358367	24.9	102	44.005106	2729.3	5267571	12.860174
Akabira-shi	1218	0.486267	44.700585	54.750113	85.5	40.33394	372.714993	149.572265	180.1	18	40.288158	2271.9	995096	16.001801
Monbetsu-shi	1219	1.341469	33.021766	52.598555	27.8	27.309091	384.26587	171.448353	129.8	24	48.768878	2876	1494882	2.6137
Shibetsu-shi	1220	0.286231	37.415888	52.887416	17.8	29.857254	352.817114	159.636437	853.7	46	47.740283	2746.6	1200592	4.921161
Nayoro-shi	1221	0.406224	30.274029	51.556045	54.3	24.304534	351.005233	148.960342	654.1	41	49.493941	2797.2	1487333	4.127651
Mikasa-shi	1222	0.187307	46.066549	55.101366	30	35.290089	412.736888	136.734244	110.2	18	37.461437	2237	644629	15.777876
Nemuro-shi	1223	0.939926	30.779805	52.216072	65.4	29.814047	395.586432	194.598209	148.6	21	51.551064	2872	1269085	1.344875
Chitose-shi	1224	0.454793	20.888048	49.201238	160.9	14.087005	366.960104	160.536551	125.5	101	48.10869	2866.4	4004892	14.505269
Takikawa-shi	1225	0.194212	32.416489	52.721402	355.4	17.243456	345.139833	127.500486	24.3	30	45.761313	2626.3	1967814	10.854049
Sunagawa-shi	1226	0.129988	36.113937	53.566181	224.9	24.695634	374.703289	141.403866	56.5	27	43.743642	2666.1	1168733	20.012434
Utashinai-shi	1227	0.111576	46.638773	53.919107	64.1	39.32072	452.719665	167.642957	0	5	36.429568	2123.1	356284	10.655509
Fukagawa-shi	1228	0.223652	39.326304	53.818066	41.4	25.450251	312.383039	115.295084	319.5	23	45.670729	2557.4	1177785	9.01456
Furano-shi	1229	0.610394	30.938263	52.986571	38.2	25.776001	373.735612	180.938263	130.8	51	51.634984	2705	1241547	8.266481
Noboribetsu-shi	1230	0.18539	33.454912	52.578338	233.8	23.07961	398.811083	164.292191	60.5	14	42.414106	2538	2051929	7.254408
Eniwa-shi	1231	0.272589	25.05667	51.535107	236.6	14.64891	326.303406	140.670282	14.3	59	45.401854	2763.2	2705684	15.02109
Date-shi	1233	0.277182	34.596371	53.481926	78.8	21.489608	411.058723	171.367338	0	24	46.075154	2627.6	2208693	7.498214
Kitahiroshima-shi	1234	0.235338	28.956725	52.131586	496.1	10.509834	300.572261	140.288501	33.9	123	44.470405	2787.2	2829124	25.782202
Ishikari-shi	1235	0.353437	29.996866	52.03705	79.5	18.526804	288.094575	113.535065	52.2	71	45.504562	2543.3	3210614	28.772895
Hokuto-shi	1236	0.194007	26.507868	53.34986	116.7	20.309377	318.042682	112.58892	21.6	27	46.809657	2483.2	2615101	14.843716
Tobetsu-cho	1303	0.20257	30.153953	51.881005	40.9	19.556645	289.616854	110.371571	57.9	28	47.059845	2640.5	1119755	22.94247
Shinshinotsu-mura	1304	0.030039	33.042956	51.817363	42.7	27.169275	310.003004	138.780415	0	10	47.131271	2422.2	312153	15.770502
Matsumae-cho	1331	0.422516	45.958839	55.254191	25	50.377229	488.483031	289.355322	136.3	9	44.309663	2783.5	544339	1.335696
Fukushima-cho	1332	0.678426	41.904116	53.708729	23.6	45.737192	439.167797	176.164631	0	4	42.650384	2745.6	301971	3.9801
Shiriuchi-cho	1333	0.085966	34.214485	50.440576	23.6	31.789515	374.167204	131.957877	429.8	10	52.460778	2396.5	186515	10.466366
Kikonai-cho	1334	0.43985	44.073015	52.716077	20.5	35.180678	425.995162	165.38377	219.9	8	45.238619	2430.6	373443	13.129536

Nanae-cho	1337	0.113798	32.211949	54.409673	129.7	17.910972	347.866287	153.627312	106.7	13	44.224751	2447.1	1344574	12.176387
Shikabe-cho	1343	1.538097	35.920492	51.419782	38.2	35.305223	407.950781	159.488878	236.6	6	47.681022	2519.6	348198	8.826313
Mori-machi	1345	1.18525	34.654459	54.069986	43.2	34.414021	372.569923	142.418161	125.4	18	49.172206	2539.6	1134415	6.960993
Yakumo-cho	1346	0.504289	31.121029	51.304197	18	30.588484	390.447484	150.591236	58	20	49.681196	2837.9	1457287	4.179226
Oshamambe-cho	1347	1.147486	36.955788	51.58623	19.1	31.835265	401.788728	157.61053	0	4	43.958826	3114.4	396911	5.804927
Esashi-cho	1361	0.084869	34.420466	52.594568	75.3	28.665038	417.677013	171.556741	0	8	46.702231	2806.8	745723	15.276431
Kaminokuni-cho	1362	0.205086	39.848236	55.02461	8.9	42.299189	421.862182	194.626743	0	12	44.175554	2561.2	393504	5.352748
Assabu-cho	1363	0.395159	38.429242	52.630279	8.8	36.85643	418.621882	166.954804	0	12	50.753272	2710.5	353805	12.81798
Otobe-cho	1364	0.051203	40.399386	54.147465	24	34.30127	434.459805	171.530978	256	10	45.084485	2481.1	266781	5.401946
Okushiri-cho	1367	0.223048	36.988848	48.996283	18.8	46.818332	573.605948	235.687732	0	4	50.074349	2950.2	147312	1.115242
Imakane-cho	1370	0.035537	37.260128	52.380952	9.9	29.890074	388.592751	156.538735	0	13	50.195451	2582.8	457382	5.170576
Setana-cho	1371	0.354066	42.358079	53.357725	13.3	35.380605	464.180338	164.640623	0	25	46.93733	2518.4	692596	4.295999
Shimamaki-mura	1391	0.066711	40.560374	51.034023	3.4	48.961258	483.655771	256.170781	0	5	46.497665	2751.5	199709	3.268846
Suttsu-cho	1392	1.147593	36.978004	51.291042	32.9	37.554458	435.766656	106.471151	0	6	44.405483	2744.5	348671	6.598661
Kuromatsunai-cho	1393	0.129786	37.345879	54.088254	8.9	33.261538	419.208306	137.897469	0	12	43.186243	2495	301891	5.743024
Rankoshi-cho	1394	0.330374	37.187694	52.054512	10.8	32.161754	401.817056	105.719595	0	15	49.30828	2485.9	383379	6.049969
Niseko-cho	1395	2.884228	26.663977	49.334409	25.2	17.33361	545.582896	312.020976	0	17	50.887455	2461.3	219062	12.343687
Makkari-mura	1396	0.570613	33.19068	50.689491	18.4	25.673824	358.059914	97.479791	475.5	8	54.398478	2715.8	144309	13.694722
Rusutsu-mura	1397	2.779234	24.226534	50.131096	15.9	20.20649	601.992659	265.862611	524.4	12	63.607761	2576	105025	26.586261
Kimobetsu-cho	1398	0.523104	37.750654	48.953793	12.1	25.702811	376.198779	90.671316	0	8	52.397559	2271.5	179990	12.249346
Kyogoku-cho	1399	0.345152	35.895827	51.270788	13.8	30.595644	382.805146	197.678067	313.8	13	48.50957	2596.4	227579	14.339504
Kutchan-cho	1400	1.072047	24.690372	49.806898	57.5	17.452467	409.50859	157.011586	66.6	30	52.070848	2953.1	785703	11.159941
Kyowa-cho	1401	0.064267	29.305913	47.895244	20.4	23.024269	339.652956	114.877892	0	31	56.169666	2860.3	342883	15.809769
Iwanai-cho	1402	0.199356	33.798497	52.660635	184.7	32.343782	394.64806	120.38031	0	18	48.159791	2655.7	791702	7.62153
Tomari-mura	1403	0.112931	35.290796	49.858837	21.5	34.25385	495.765104	241.106719	564.7	9	50.084698	2694.1	310264	84.58498
Kamoenai-mura	1404	0	45.61753	53.984064	6.8	47.326203	445.219124	188.247012	0	5	47.011952	2803.8	119132	4.880478
Shakotan-cho	1405	0	43.782506	52.529551	8.9	42.09062	547.990544	253.427896	0	7	49.314421	2425.2	323730	5.295508
Furubira-cho	1406	0.846926	40.589711	52.38394	16.9	41.01357	432.873275	131.116688	0	7	49.372647	2332.1	526519	8.312422
Niki-cho	1407	4.08805	37.164094	53.544883	20.8	27.868421	392.510006	139.794168	0	14	53.544883	2600.4	581244	17.867353
Yoichi-cho	1408	0.586525	36.364564	53.776712	139.5	23.308872	382.159433	131.738665	51	15	45.58576	2473.9	1115448	8.573469
Akaigawa-mura	1409	1.873327	32.471008	49.509367	4	30.031696	780.553078	527.20785	0	15	57.270294	2578.4	94238	20.874219
Nanporo-cho	1423	0.441529	29.796897	52.832093	97.4	18.603326	297.338211	108.36382	0	16	50.245995	2583.1	461916	14.885833
Naie-cho	1424	0.140994	38.984843	53.137117	64.3	32.063287	367.641875	135.53049	176.2	14	45.541065	2464.7	381013	24.427212
Kamisunagawa-cho	1425	0.258695	47.542397	54.72837	87	41.776799	419.085944	140.84507	0	11	33.256683	2009.5	426687	10.319057
Yuni-cho	1427	0.188182	37.692887	52.277004	39.7	24.881275	367.143395	160.895747	0	14	51.938276	2442.7	414714	16.748212
Naganuma-cho	1428	0.108342	34.669556	52.21199	65.7	22.299205	314.463705	115.023474	0	39	52.82593	2732.8	617441	16.675695
Kuriyama-cho	1429	0.494167	37.216461	53.499676	60.5	25.577211	363.739469	146.386909	81	27	47.367142	2503.2	999196	13.609851
Tsukigata-cho	1430	0.415119	32.073411	37.928774	30.4	41.798724	511.688879	97.006773	0	11	37.360717	2542.1	297313	13.305659
Urausu-cho	1431	0.201511	38.740554	51.838791	19.5	26.473255	371.284635	116.876574	0	11	51.536524	2416.2	167640	12.040302
Shintotsukawa-cho	1432	0.087835	38.515591	54.677207	13.8	28.431508	337.578685	134.094569	0	11	47.123408	2485.9	490106	14.156053
Moseushi-cho	1433	0.258816	43.642834	53.057263	63.5	27.325246	339.695891	125.84924	323.5	5	47.557425	2300.2	202667	15.334843
Chippubetsu-cho	1434	0.079586	41.822523	53.16355	53.3	26.117216	390.768006	153.601273	0	11	46.756864	2369.2	174392	10.823717
Uryu-cho	1436	0.363769	37.904693	51.873409	14.4	29.747458	336.122226	114.950891	363.8	12	46.307748	2386.9	299209	16.296835
Hokuryu-cho	1437	0.100959	43.412418	52.650177	12.5	31.600547	400.302877	132.761232	504.8	13	50.227158	2451.1	162377	11.206461
Numata-cho	1438	0.031437	40.741905	52.813581	11.2	29.208195	378.497328	124.489154	0	15	51.367494	2537.3	201275	11.442942
Takasu-cho	1452	0.056996	30.293531	52.849815	50.3	22.586794	275.149615	109.860359	0	17	47.69165	2646.4	453457	16.229695
Higashikagura-cho	1453	0.136812	25.574123	53.366559	149.4	16.358158	253.786768	98.016222	781.8	19	48.851754	2841	672146	14.853904

Tohma-cho	1454	0.104649	39.751831	54.014053	32.6	26.471003	329.795186	128.718792	1046.5	18	49.319779	2354.5	459308	12.76723
Pippu-cho	1455	0.026476	40.323008	52.687318	43.5	30.999505	371.45883	163.886683	1059	12	51.284088	2483	286917	10.722796
Aibetsu-cho	1456	1.176075	42.271505	53.192204	11.9	32.331731	410.61828	191.532258	2352.2	16	47.983871	2497.1	270461	12.298387
Kamikawa-cho	1457	1.038576	39.688427	52.126607	3.9	32.193292	722.057369	480.959446	247.3	9	51.36004	2324.1	317114	10.707221
Higashikawa-cho	1458	2.601405	32.09222	54.148687	32.8	24.150655	328.689434	141.289607	123.3	33	48.366416	2533.2	712856	23.141413
Biei-cho	1459	0.388651	36.290323	53.109211	15.2	26.433005	373.29965	172.755538	1457.4	15	50.582977	2552.2	762467	9.696852
Kamifurano-cho	1460	0.203214	29.872529	49.732126	45.7	27.579039	356.087197	137.723998	1200.8	10	52.290781	2664.7	634093	9.624977
Nakafurano-cho	1461	0.236733	32.98481	52.554745	46.7	30.125981	356.677846	165.515881	1578.2	15	49.713948	2770	320623	12.684948
Minamifurano-cho	1462	0.430528	31.937378	50.176125	3.8	33.084577	428.571429	177.299413	2739.7	15	49.745597	2779.2	314198	10.097847
Shimukappu-mura	1463	5.037159	25.681255	50.123865	2.1	23.38594	1051.197358	824.938068	3303.1	11	61.354253	2588.5	183308	16.928159
Wassamu-cho	1464	0.222469	42.463849	53.948832	16	34.290188	355.67297	142.658509	278.1	10	49.749722	2571	260323	6.145717
Kenbuchi-cho	1465	0.092937	36.802974	51.45601	24.6	31.472651	383.209418	148.079306	309.8	7	56.009913	2621.4	308218	8.705081
Shimokawa-cho	1468	0.902171	38.624189	51.564703	5.5	39.311258	396.391317	155.9064	281.9	11	49.309275	2687.4	519143	9.33183
Bifuka-cho	1469	0.27903	37.089504	50.912213	6.9	30.436462	392.144237	157.759176	214.6	8	49.259498	2617	467965	7.405023
Otoineppu-mura	1470	0.841346	27.524038	47.716346	3	21.909548	411.057692	161.057692	2403.8	6	50.961538	2784.4	73683	15.144231
Nakagawa-cho	1471	0.679117	35.427278	46.915676	3	35.448348	406.904358	290.322581	1131.9	8	55.970572	2931.3	159065	4.923599
Horokanai-cho	1472	0.131148	39.147541	50.557377	2	35.672515	474.098361	142.95082	3934.4	6	52.065574	2822.8	149053	7.540984
Mashike-cho	1481	1.35646	42.050256	54.992217	12.2	39.838519	428.730265	171.892373	0	12	48.276629	2548.9	261462	6.62664
Obira-cho	1482	0.44964	36.690647	52.48801	5.3	39.548023	429.856115	171.76259	599.5	16	50.059952	2616.1	234392	8.123501
Tomamae-cho	1483	0.336907	39.050536	52.557427	7.2	37.089716	425.114855	171.822358	612.6	13	50.321593	2748.4	195809	6.676876
Haboro-cho	1484	0.081889	39.620581	52.367954	15.5	33.211954	430.053228	170.738365	136.5	15	48.846731	2569.2	462180	3.507575
Shosambetsu-mura	1485	0.082169	35.90797	52.506163	4.4	37.107378	577.649959	303.204601	0	12	52.095316	2977.4	202484	5.012325
Enbetsu-cho	1486	0.605845	37.883108	51.247327	4.7	35.40856	403.42124	188.880969	0	10	51.88881	2771.8	308104	3.528154
Teshio-cho	1487	0.70922	32.346593	49.337034	9.2	30.132275	432.315757	188.097441	0	17	55.010792	2895.5	239100	7.061363
Sarufutsu-mura	1511	3.912072	22.801788	52.235469	4.5	30.123894	399.403875	200.074516	0	6	58.420268	7844.6	231004	6.184799
Hamatombetsu-cho	1512	3.040453	32.105128	51.790776	9.7	29.390595	425.405823	211.028086	0	15	53.465602	3291.4	236133	6.003607
Nakatombetsu-cho	1513	0.056915	38.702334	50.540694	4.4	30.597771	502.561184	310.18782	0	10	50.654525	2697.4	141849	3.756403
Esashi-cho	1514	1.742325	32.20339	52.791277	7.6	32.734247	422.069456	244.518194	0	28	54.10691	3721	561107	1.054877
Toyotomi-cho	1516	0.444006	30.192403	49.75333	7.8	32.434902	427.232363	204.489393	0	16	53.971386	2637.1	275302	4.316724
Rebun-cho	1517	0.865489	34.006491	49.585287	34	44.152047	548.142806	260.367833	0	9	64.839524	3080.6	180585	2.48828
Rishiri-cho	1518	0.043422	37.993921	51.280938	30.1	41.312741	544.507165	282.674772	434.2	10	61.094225	2934.4	150012	5.036908
Rishirifuji-cho	1519	0.466451	35.880875	52.601363	26.4	41.02733	560.818084	306.063868	358.8	17	58.091137	2809.1	173084	3.301041
Horonobe-cho	1520	0.817327	26.522272	47.731917	4.3	27.493463	487.127094	220.678382	0	10	56.845116	3019.7	131413	8.050674
Bihoro-cho	1543	0.266062	32.188609	51.896926	46.3	24.584009	316.712653	147.812377	0	20	48.985022	2698.8	1146048	6.316516
Tsubetsu-cho	1544	0.219649	41.793131	51.53754	7	36.716259	391.174121	174.520767	199.7	14	46.425719	2636.5	433471	13.338658
Shari-cho	1545	0.727659	29.973019	50.02044	16.6	26.063626	411.004824	194.505764	1144.6	14	53.789551	3484.6	607587	6.042024
Kiyosato-cho	1546	0.071073	35.868278	51.457001	10.5	31.619424	380.004738	222.696044	0	10	50.035537	2804.2	257086	5.425255
Koshimizu-cho	1547	0.452311	34.867257	52.52704	17.7	29.712579	356.932153	164.995084	590	14	53.569322	2809.5	289792	5.152409
Kunneppu-cho	1549	0.352941	35.882353	52.705882	26.7	29.181233	335.882353	155.882353	196.1	16	52.568627	2758.2	381984	11.72549
Oketo-cho	1550	0.129366	42.205692	53.945666	5.9	34.218203	449.547219	219.27555	1293.7	11	48.09185	2636.7	221325	8.538163
Saroma-cho	1552	2.666915	37.411414	53.412906	13.2	34.114053	364.975755	180.902648	0	18	51.603879	3459	426338	6.93771
Engaru-cho	1555	0.22038	35.1363	51.703157	15.7	28.865933	376.036027	174.723327	191.6	51	46.356537	2722.4	1242007	3.866239
Yubetsu-cho	1559	1.419131	35.803272	52.572852	18.3	30.783786	378.940526	182.103781	0	25	51.727873	3147.4	501455	9.002275
Takinoue-cho	1560	0.404263	41.161338	52.517457	3.5	37.450462	459.022418	190.371187	735	12	46.78427	2622.7	376262	4.29989
Okoppe-cho	1561	1.688411	31.389102	51.522128	10.8	28.830505	386.543873	167.562036	511.6	15	53.415196	3684.6	230342	10.207214
Nishiokoppe-mura	1562	0.985663	32.885305	51.433692	3.6	35.154185	490.143369	288.530466	896.1	12	49.37276	2769.9	160739	3.136201

Omu-cho	1563	3.668508	31.779006	52.79558	7.1	30.350273	400	187.18232	0	9	55.779006	3632.5	319802	2.78453
Ozora-cho	1564	0.108696	33.478261	51.73913	21.4	20.005042	354.483696	170.652174	271.7	22	51.956522	2860.2	621808	12.173913
Toyoura-cho	1571	0.489396	35.749243	53.390818	18.4	30.521201	376.136099	142.158005	1398.3	10	48.007457	2636.3	366084	10.067583
Sobetsu-cho	1575	0.581793	42.368241	53.114305	14.3	28.217822	524.982888	145.448323	0	7	47.570157	2472.7	293477	29.431896
Shiraoi-cho	1578	0.479143	40.608794	52.147689	41.7	28.813997	385.794814	154.678692	169.1	19	39.667418	2411	1256191	12.085682
Atsuma-cho	1581	0.475403	35.427863	48.697809	12	27.586912	352.418355	135.386523	206.7	13	57.606449	2800.9	397449	23.398098
Toyako-cho	1584	0.774277	40.197871	53.973546	51.4	31.030399	518.765459	222.497043	0	14	46.639424	2468.8	667999	16.646951
Abira-cho	1585	0.441826	34.536082	50.306824	34.4	22.026129	381.688758	160.284732	490.9	22	49.165439	4447.1	625000	22.864507
Mukawa-cho	1586	1.070265	36.540251	51.012099	12.1	30.976811	374.941833	133.201489	0	19	52.17543	2610.6	646485	10.09772
Hidaka-cho	1601	0.888673	32.000323	50.121183	12.5	27.932427	347.956051	128.615285	80.8	28	53.247698	2774.2	949578	6.511553
Biratori-cho	1602	2.351834	32.060207	50.517404	7.2	33.595425	355.785513	169.143932	564.4	20	53.471308	2859.3	424481	9.049859
Niikappu-cho	1604	1.090844	30.543634	51.412732	9.5	29.974026	344.957082	126.609442	0	7	52.467811	2621.2	536093	10.693848
Urakawa-cho	1607	0.565966	29.789675	51.296367	18.8	24.400584	386.768642	149.98088	0	26	51.541109	2831.6	1001407	6.256214
Samani-cho	1608	0.309872	36.188579	52.656042	12.4	31.658193	424.524126	162.461266	221.3	14	51.460823	2575.7	296119	5.799026
Erimo-cho	1609	0.468814	27.86384	50.081533	17.3	27.267689	412.352222	162.861802	0	11	57.867917	2862	375418	2.09947
Shinhidaka-cho	1610	0.271189	31.970212	51.840214	20.2	27.440104	351.98657	121.776936	43	43	48.461108	2624.5	1695606	5.204253
Otofuke-cho	1631	0.169616	26.482469	52.95378	96.1	17.986026	285.892829	124.690339	89.3	48	47.831812	2732.8	2365312	9.875689
Shihoro-cho	1632	0.636008	29.25636	52.071102	23.7	18.983791	325.179387	156.555773	2283.1	14	54.484671	3203.7	460062	21.379648
Kamishihoro-cho	1633	0.797482	35.173137	51.731375	6.9	26.299213	358.237146	142.07765	0	14	52.004197	3091.2	292585	12.717733
Shikaoi-cho	1634	0.811981	28.274991	50.956333	13.8	19.028411	376.759293	179.177192	2165.3	20	54.366655	3163.7	328248	9.689643
Shintoku-cho	1635	1.160941	34.716921	50.333969	5.9	26.860063	482.347328	204.516539	159	19	52.449109	2635.2	631644	8.794529
Shimizu-cho	1636	0.552141	34.691114	51.213668	23.9	24.917177	369.309303	150.953224	208.4	15	49.505157	2761.7	703860	13.334722
Memuro-cho	1637	0.124432	27.277646	52.53733	36	15.323988	298.149751	127.515689	54.1	61	51.26055	2886.4	1049583	24.458992
Nakasatsunai-mura	1638	0.504286	27.407968	51.28593	13.6	17.024463	356.782653	148.008069	0	23	53.177005	2930.3	287701	20.776601
Sarabetsu-mura	1639	0.21978	28.979592	50.800628	18	20.996756	333.124019	173.940345	0	13	57.864992	3234.9	294558	14.788069
Taiki-cho	1641	0.836528	33.861973	51.028233	7	23.155429	369.466713	170.268386	0	18	54.130359	2916.1	365441	10.038341
Hiroo-cho	1642	0.469417	34.864865	52.247511	11.8	31.303134	438.691323	196.301565	284.5	11	50.697013	2915.1	598745	3.044097
Makubetsu-cho	1643	0.171898	29.988789	52.813901	56	19.682073	291.03139	128.961136	149.5	80	49.241405	2687	1282366	11.132287
Ikeda-cho	1644	0.159837	39.973845	52.731764	18.5	25.800452	373.292647	176.838128	0	22	47.224644	2646.2	450961	10.069747
Toyokoro-cho	1645	0.785669	37.900691	52.137021	5.9	34.266352	429.91829	226.90132	0	13	54.934004	3030.4	536737	11.439346
Honbetsu-cho	1646	0.244632	38.081	50.869802	18.8	28.942598	408.942647	186.599619	543.6	28	51.8891	2721.1	502434	7.665126
Ashoro-cho	1647	0.128755	37.88269	51.645207	5	29.187418	411.444921	177.825465	715.3	26	50.300429	2861.6	510486	5.579399
Rikubetsu-cho	1648	0.846092	37.187752	49.516519	4.1	36.226415	479.854956	209.911362	402.9	8	50.523771	2948	299082	4.955681
Urahoro-cho	1649	0.142305	37.832893	52.00244	6.7	33.992674	403.740598	156.332588	813.2	22	53.52714	2798.6	324257	6.200447
Kushiro-cho	1661	0.141179	24.973529	52.740382	78.5	23.643184	314.022084	127.262643	201.7	19	51.15212	2576.3	864315	17.571724
Akkeshi-cho	1662	0.940888	31.75496	52.669258	13.2	32.220132	400.797709	224.585805	511.4	16	56.606668	2874.8	694537	4.182859
Hamanaka-cho	1663	0.725953	28.724633	51.262168	14.3	29.596068	383.105098	180.168289	0	13	61.788484	2919.2	362850	3.877248
Shibecha-cho	1664	0.477913	31.464738	51.98915	7	27.435124	383.234306	182.76931	904.2	37	51.059158	2845.4	636998	5.773702
Teshikaga-cho	1665	0.309358	36.581593	52.577984	10	29.753564	458.752256	215.906161	1417.9	20	51.018304	2619.6	563388	4.137664
Tsurui-mura	1667	0.670876	31.925809	51.302289	4.4	27.636087	389.108129	189.029203	0	18	48.539858	2799.6	187305	14.759274
Shiranuka-cho	1668	0.260288	36.948438	53.49529	10.4	31.848504	411.87407	181.45761	123.9	18	48.26475	2401.3	562535	18.554784
Betsukai-cho	1691	1.329143	24.526943	49.669351	11.6	23.399558	371.505271	193.806063	523.8	33	55.699601	3260	809492	7.935573
Nakashibetsu-cho	1692	0.227139	23.09666	51.089425	34.7	20.365274	339.740893	170.143855	0	23	53.062169	2841.1	932814	4.012787
Shibetsu-cho	1693	0.534147	28.576879	51.068295	8.4	27.523911	384.013735	197.252957	0	26	55.303319	3109.3	332593	11.846623
Rausu-cho	1694	1.089566	26.463527	50.193906	13.6	34.15463	384.302862	259.833795	184.7	12	59.482918	3067.3	363784	2.160665

Table x.6: Selected indicators for the health *and* infrastructural dimensions *of resilience, per each Municipality.*

MUNICIPALITY	ID	*HEALTH*				*INFRASTRUCTURE*			
		NURS_FAC	HOSP_BEDS_POP	MEDFAC_DOCT	FIREFIGHT_EXPENSE	DISREC_EXP_PROCAP	ROAD_LENGHT_POP	SEPTTANK_PERC	AVG_BUILD_AGE
Sapporo-shi	1100	59	18.9069	6322	17534080	0.95372	0.185826	0.1	4
Hakodate-shi	1202	16	23.57329	773	4180775	0	0.681027	2.4	3
Otaru-shi	1203	4	26.131032	307	2223379	0	0.640691	1	3
Asahikawa-shi	1204	17	21.171655	1290	3907367	0.391631	0.656117	4.2	3
Muroran-shi	1205	4	24.36656	268	1828081	26.782891	0.534368	3.4	3
Kushiro-shi	1206	9	20.309943	352	3177771	403.915487	1.688497	0.3	3
Obihiro-shi	1207	7	19.636561	484	3994683	0	0.872522	1.5	3
Kitami-shi	1208	7	14.988534	218	2040550	1216.85942	2.278655	2.8	3
Yubari-shi	1209	1	0	7	316716	0	12.655079	31	3
Iwamizawa-shi	1210	4	20.615629	177	1341633	0	1.837457	5.2	4
Abashiri-shi	1211	1	20.267677	62	684767	8026.025539	3.46883	5.7	3
Rumoi-shi	1212	1	25.651411	45	1106561	0	2.245091	10.7	3
Tomakomai-shi	1213	5	15.341241	323	3575356	306.923242	1.005439	0.6	4
Wakkanai-shi	1214	3	14.211105	38	675428	7991.698736	5.382622	11.6	3
Bibai-shi	1215	2	18.840894	40	570561	0	3.724088	7.1	3
Ashibetsu-shi	1216	0	28.686291	17	1453401	0	7.598217	3.6	3
Ebetsu-shi	1217	3	9.731755	172	1215751	0	0.691514	2	4
Akabira-shi	1218	3	43.76407	27	1007633	0	1.691555	5	3
Monbetsu-shi	1219	1	18.564196	34	365885	3541.780259	6.8458	2.6	3
Shibetsu-shi	1220	2	9.99297	20	799928	6766.495933	6.246101	13.7	3
Nayoro-shi	1221	2	23.340677	88	664860	2598.870834	3.60555	9.1	3
Mikasa-shi	1222	1	32.172763	15	237875	0	7.440731	2	3
Nemuro-shi	1223	2	13.040086	31	700236	1307.537987	4.692101	6.1	3
Chitose-shi	1224	2	10.549097	118	1355918	1280.28814	1.52368	1.1	4
Takikawa-shi	1225	1	28.403574	86	629346	257.841328	0.984248	1.9	3
Sunagawa-shi	1226	1	35.153159	100	357221	0	1.581711	3.4	3
Utashinai-shi	1227	1	16.736402	4	319739	778.800558	3.708858	0.5	3
Fukagawa-shi	1228	2	51.074901	51	511989	470.811082	7.371625	18.8	3
Furano-shi	1229	0	24.720963	41	0	147.540984	4.238094	11.4	4
Noboribetsu-shi	1230	2	27.405542	53	763244	99.143577	1.207333	5.5	3
Eniwa-shi	1231	1	15.767123	110	867423	232.575823	1.226436	1.4	4
Date-shi	1233	4	23.774825	67	907088	370.33862	2.57538	5.7	3
Kitahiroshima-shi	1234	3	11.546797	59	955179	302.129893	0.72542	0.8	4
Ishikari-shi	1235	3	11.543283	61	1269650	48.889198	2.360566	2.7	3
Hokuto-shi	1236	3	0	22	820149	176.870015	2.131143	3.7	4
Tobetsu-cho	1303	2	3.35687	9	418001	0	6.490611	4.9	3
Shinshinotsu-mura	1304	1	0	2	235922	0	8.214897	49.2	
Matsumae-cho	1331	1	13.629549	7	485915	0	5.266113	17.3	
Fukushima-cho	1332	1	0	2	217572	0	5.578161	21.4	
Shiriuchi-cho	1333	1	0	2	308902	9958.306469	3.852141	14.9	
Kikonai-cho	1334	1	21.772597	9	229364	0	6.027464	6.1	
Nanae-cho	1337	1	21.159317	37	500191	0	1.733016	2.1	4
Shikabe-cho	1343	1	0	3	222624	0	5.078829	13.7	
Mori-machi	1345	2	15.238931	17	448338	0	4.393966	4.4	3
Yakumo-cho	1346	2	40.401113	28	794517	5764.896824	9.49006	8.6	4
Oshamambe-cho	1347	1	9.112386	4	192253	2352.683091	14.596006	3.7	
Esashi-cho	1361	1	31.28031	17	326923	0	2.838837	18.7	
Kaminokuni-cho	1362	1	0	2	220879	0	10.646637	11.4	
Assabu-cho	1363	1	17.041245	3	242093	1040.009879	17.146637	68.9	
Otobe-cho	1364	0	15.873016	2	151307	0	5.217676	14.7	

Okushiri-cho	1367	0	20.074349	4	187210	0	22.297517	18.1	
Imakane-cho	1370	1	9.239517	4	227744	0	8.905558	20.8	
Setana-cho	1371	2	31.983949	12	908705	2325.740588	13.155882	6.7	
Shimamaki-mura	1391	0	0	1	150280	0	27.226644	30.3	
Suttsu-cho	1392	1	0	5	156032	3045.266178	9.084286	24.2	
Kuromatsunai-cho	1393	1	12.978585	3	151653	309.863725	22.625094	12.9	
Rankoshi-cho	1394	1	24.77803	4	587670	1.032418	21.046091	74.7	
Niseko-cho	1395	1	0	2	165277	2022.791448	7.05294	29.2	
Makkari-mura	1396	0	0	2	109782	2544.460295	13.588744	19.2	
Rusutsu-mura	1397	0	0	2	123032	0	8.752474	20.7	
Kimobetsu-cho	1398	1	0	2	163083	0	19.298562	11.5	
Kyogoku-cho	1399	0	37.652965	6	155933	0	8.414602	14.1	
Kutchan-cho	1400	1	15.581302	39	328286	771.807165	3.190262	8.7	4
Kyowa-cho	1401	1	0	3	687604	0	8.28322	8.8	
Iwanai-cho	1402	1	18.402086	18	272323	0	1.421388	9.3	
Tomari-mura	1403	1	0	2	144826	0	7.359287	0	
Kamoenai-mura	1404	0	0	1	73732	0	34.354393	25.4	
Shakotan-cho	1405	0	0	1	185170	0	21.3203	20.6	
Furubira-cho	1406	0	0	1	184339	0	8.090389	7.4	
Niki-cho	1407	1	0	2	189379	0	8.163941	44.6	
Yoichi-cho	1408	2	18.207783	30	482106	0	1.351871	1.5	3
Akaigawa-mura	1409	0	0	1	145682	0	35.008533	15.3	
Nanporo-cho	1423	1	10.09209	3	234662	0	2.771807	17.5	
Naie-cho	1424	1	16.919281	8	198559	0	5.182503	7.8	
Kamisunagawa-cho	1425	1	0	2	694704	0	3.175621	24.3	
Yuni-cho	1427	1	10.726383	3	257903	0.940911	5.978799	67.6	
Naganuma-cho	1428	1	11.556519	12	251095	3771.668472	4.919819	22.6	
Kuriyama-cho	1429	1	11.017498	13	366339	3089.679196	4.075395	17.5	
Tsukigata-cho	1430	3	8.739349	3	159550	0	6.768067	85.3	
Urausu-cho	1431	1	0	1	144862	2584.88665	7.067924	25.8	
Shintotsukawa-cho	1432	1	29.27829	4	185070	2316.205534	6.249559	25.9	
Moseushi-cho	1433	0	0	1	105173	0	6.763354	86.6	
Chippubetsu-cho	1434	1	0	1	71158	0	8.842126	95.1	
Uryu-cho	1436	1	39.287013	2	101992	0	5.109865	85.4	
Hokuryu-cho	1437	1	0	1	220897	5.047956	21.727366	83.9	
Numata-cho	1438	1	0	2	218373	1.571833	8.636725	17.6	
Takasu-cho	1452	1	0	2	184100	3365.488743	7.613512	18.5	
Higashikagura-cho	1453	1	11.726766	4	166031	0	1.883246	16.4	
Tohma-cho	1454	1	0	2	220922	0	3.851965	28.8	
Pippu-cho	1455	1	0	2	152453	1014.561822	10.807533	27.4	
Aibetsu-cho	1456	1	0	1	158407	11646.16936	16.72133	24.8	
Kamikawa-cho	1457	1	0	4	329611	10336.54797	31.905386	4.4	
Higashikawa-cho	1458	1	0	2	175202	915.423499	3.86069	32.7	
Biei-cho	1459	1	9.521959	7	319811	0.485814	8.45668	22.5	
Kamifurano-cho	1460	1	4.06429	6	249893	1645.113615	5.561875	10.5	
Nakafurano-cho	1461	1	6.904715	2	174822	305.780233	4.27459	33	
Minamifurano-cho	1462	2	0	2	1030	0	28.142104	18	
Shimukappu-mura	1463	0	0	0	0	0	96.19243	26.9	
Wassamu-cho	1464	1	8.342603	3	195956	4296.996663	19.608664	21.1	
Kenbuchi-cho	1465	1	0	1	110100	612.143742	12.932979	23.5	
Shimokawa-cho	1468	1	11.840992	3	163786	8988.440936	18.36835	13.6	
Bifuka-cho	1469	1	13.736853	2	263870	26185.23288	18.823452	14.4	
Otoineppu-mura	1470	0	0	1	109265	0	46.551491	90.8	
Nakagawa-cho	1471	1	0	1	123357	75877.75891	36.7962	9.4	

Horokanai-cho	1472	0	27.540984	2	141915	1180.327869	71.455321	88.7	
Mashike-cho	1481	1	0	1	175401	2357.794085	11.932801	16.6	
Obira-cho	1482	1	0	1	231752	27546.16307	18.938363	6.3	
Tomamae-cho	1483	1	0	2	193361	72397.24349	20.477271	11.6	
Haboro-cho	1484	2	21.154634	11	345854	1343.250989	6.37997	8	
Shosambetsu-mura	1485	0	0	2	112887	0	19.904448	76.2	
Enbetsu-cho	1486	1	12.829651	2	151728	13299.7149	24.034559	10.4	
Teshio-cho	1487	1	14.80111	2	204542	0	22.053245	11.6	
Sarufutsu-mura	1511	1	10.432191	2	264813	949.701937	42.722689	93.8	
Hamatombetsu-cho	1512	2	15.459933	2	239856	0	16.077999	7.8	
Nakatombetsu-cho	1513	1	28.457598	1	154815	17685.25896	33.716924	9.7	
Esashi-cho	1514	2	9.83762	4	1577791	1678.440204	17.628413	8	
Toyotomi-cho	1516	1	10.360138	3	292753	0	37.17673	18	
Rebun-cho	1517	1	0	2	140641	49473.49441	7.400001	18.3	
Rishiri-cho	1518	1	18.237082	2	157764	0	7.231731	22.4	
Rishirifuji-cho	1519	1	0	2	242337	5477.933262	10.582852	6.6	
Horonobe-cho	1520	1	0	1	158622	8498.161013	34.490192	17	
Bihoro-cho	1543	1	12.268427	23	467367	1885.839574	4.646625	7	4
Tsubetsu-cho	1544	1	17.971246	5	268972	0	21.549807	13.5	
Shari-cho	1545	1	9.0753	6	404706	1817.512877	10.741045	9.1	
Kiyosato-cho	1546	1	0	2	182761	5472.162995	13.833184	96.4	
Koshimizu-cho	1547	1	19.469027	3	163425	0	15.133631	25.9	
Kunneppu-cho	1549	1	0	1	190335	0	8.186363	79.4	
Oketo-cho	1550	1	30.72445	4	172352	0	32.008755	25.4	
Saroma-cho	1552	1	0	2	216401	15685.19209	14.037296	29	
Engaru-cho	1555	2	29.751353	53	756954	1568.773056	10.181206	5	3
Yubetsu-cho	1559	2	5.091539	2	439161	15299.42585	7.278781	15.6	
Takinoue-cho	1560	1	19.845645	2	161206	0	30.854443	7.3	
Okoppe-cho	1561	0	12.790995	2	155979	3580.711179	8.100671	3.9	
Nishiokoppe-mura	1562	2	0	1	87636	795.698925	31.954216	12.7	
Omu-cho	1563	1	5.524862	4	130453	0	19.303992	7.3	
Ozora-cho	1564	3	11.141304	3	365244	20423.50544	10.172831	25.2	
Toyoura-cho	1571	3	13.982755	3	203560	1057.096248	15.090376	17.9	
Sobetsu-cho	1575	1	130.047912	7	207732	1632.1013	15.041344	72.5	
Shiraoi-cho	1578	2	3.269448	9	558776	13112.23224	4.992698	2.6	3
Atsuma-cho	1581	1	0	2	292316	384.869781	17.473512	34.5	
Toyako-cho	1584	1	54.62953	18	746665	0	7.756534	7.8	
Abira-cho	1585	1	4.90918	4	370768	0	5.721944	15.3	
Mukawa-cho	1586	2	4.653327	4	541564	0	19.320006	38.4	
Hidaka-cho	1601	2	6.382291	10	1746178	738.730005	11.762973	20.8	
Biratori-cho	1602	1	9.031044	4	259918	45.907808	13.688276	54.7	
Niikappu-cho	1604	1	0	2	236993	0	9.382746	24.8	
Urakawa-cho	1607	1	19.57935	16	365660	1475.793499	4.094779	22.8	
Samani-cho	1608	1	0	1	220714	114.209827	4.526379	10.8	
Erimo-cho	1609	1	0	2	230606	0	12.971925	12.8	
Shinhidaka-cho	1610	2	22.254746	32	785777	367.353967	5.020679	8.3	4
Otofuke-cho	1631	2	13.993349	39	794718	0	3.318341	8	4
Shihoro-cho	1632	0	9.784736	4	261314	2880.789302	9.131568	28.3	
Kamishihoro-cho	1633	1	0	3	286320	1093.809024	21.558524	13.5	
Shikaoi-cho	1634	1	9.022014	4	267674	0	12.803804	94.1	
Shintoku-cho	1635	1	0	3	301716	0	15.304032	10.8	
Shimizu-cho	1636	1	14.584853	11	876145	374.518179	12.456578	33.7	
Memuro-cho	1637	2	8.115127	18	586694	181.40013	6.839805	20	4
Nakasatsunai-mura	1638	1	0	1	249362	0	14.583847	26.2	

Sarabetsu-mura	1639	0	0	4	216065	0	17.506432	29.4	
Taiki-cho	1641	1	9.062391	6	304557	0	12.704337	10.6	
Hiroo-cho	1642	1	8.534851	6	351501	2256.330014	9.835011	5.2	
Makubetsu-cho	1643	1	4.110613	12	771024	217.526158	3.715345	12.9	4
Ikeda-cho	1644	1	8.718396	7	344524	0	9.298694	12.8	
Toyokoro-cho	1645	1	0	0	352619	1374.921433	36.111721	24	
Honbetsu-cho	1646	1	8.15439	5	335702	3933.67763	13.453678	15.1	
Ashoro-cho	1647	1	8.583691	5	416007	1841.917024	21.075547	12.1	
Rikubetsu-cho	1648	1	0	2	233469	70.104754	19.77147	8.2	
Urahoro-cho	1649	1	0	2	341806	2536.69445	31.88929	15.2	
Kushiro-cho	1661	2	0	8	594399	1603.690818	3.885856	2.3	3
Akkeshi-cho	1662	1	5.624872	6	358202	0	11.545398	5.4	
Hamanaka-cho	1663	1	0	2	354031	0	18.074401	16.8	
Shibecha-cho	1664	1	7.749935	2	288581	8080.986825	26.943208	9	
Teshikaga-cho	1665	1	25.650941	9	377663	2573.085847	20.416715	9.6	
Tsurui-mura	1667	0	57.616417	5	244654	0	31.522487	96	
Shiranuka-cho	1668	1	0	4	442316	222.235994	15.973137	3.6	
Betsukai-cho	1691	1	5.499902	11	877978	3357.428141	18.535657	22.8	4
Nakashibetsu-cho	1692	2	13.41802	30	448938	340.161521	6.999311	8.2	4
Shibetsu-cho	1693	1	6.676841	4	283061	0	19.695917	10.3	
Rausu-cho	1694	0	0	1	298196	0	11.054765	75.2	

Sustainability

Table x.7: Selected indicators for each dimension *of sustainability, per each Municipality.*

MUNICIPALITY	ID	*ECOSYSTEM INTEGRITY*			*ECOSYSTEM BENEFITS*		*PHYSICAL PROCESSES STATE*		*EXTERNAL PRESSURES*	
		FOREST_AREA	GRASS_AREA	WLDLF_SANCT	PRIV_FOREST	FISH_ACQCUL	WAT_INT_POP	WAT_QUAL	AGRIC_AREA	BEEFCATTLE_REV
Sapporo-shi	1100	67690	538	71.484775	2652.64	3	98.663871		2830	2
Hakodate-shi	1202	52925	2528	26.621694	4564.51	2183	136.226262	4.1	1980	5
Otaru-shi	1203	15824	550	9.402745	2216.37	213	137.788122	0.4	200	
Asahikawa-shi	1204	39419	153	32.404306	5308.76	1	116.159058	1.4	13900	37
Muroran-shi	1205	2508	1253	2.963438	118.41	88	135.404905		227	2
Kushiro-shi	1206	97770	5999	154.391273	9982.03	210	133.719203	1.1	10600	84
Obihiro-shi	1207	23173	480	6.612379	1071.27	2	103.357941	0.7	23000	467
Kitami-shi	1208	93198	1777	18.280301	15568.26	150	129.629906	0.5	23900	41
Yubari-shi	1209	65127	15	14.382806	688.68	1	267.895511	0.4	723	
Iwamizawa-shi	1210	16206	65	3.692579	3314.01	0	113.622646	0.6	19800	1
Abashiri-shi	1211	15979	1239	84.271134	4663.49	165	176.961307	1	14000	71
Rumoi-shi	1212	24187	395	7.902232	2108.95	64	173.214527	0.4	1070	8
Tomakomai-shi	1213	32347	3418	48.546205	3521.77	108	117.16656	1	1270	7
Wakkanai-shi	1214	42295	1453	23.725765	4289.09	508	203.54552	0.6	14700	231
Bibai-shi	1215	11975	18	1.205938	2164.19	0	135.402648	1.3	9420	2
Ashibetsu-shi	1216	72178	622	15.668704	2161.52	1	123.126192	0.3	3550	1
Ebetsu-shi	1217	1950	25	18.178965	126.06	0	90.047747	1	7080	27
Akabira-shi	1218	9316	3	5.948746	934.83	0	164.790635		835	1
Monbetsu-shi	1219	65047	85	20.319473	15236.24	124	186.26877	0.8	8550	190
Shibetsu-shi	1220	81310	2634	7.95143	5065.54	0	132.318972	0.4	16700	133
Nayoro-shi	1221	33470	198	24.640307	7303.08	0	108.434178	0.6	10400	11
Mikasa-shi	1222	24573	1	4.2076	421.01	0	145.107977	0.9	1340	2
Nemuro-shi	1223	17204	2580	61.087862	1768.23	835	151.990155	0.1	9640	15

Chitose-shi	1224	30435	1544	226.065982	860.66	2	135.509044	0.8	5850	8
Takikawa-shi	1225	1270	114	0.042874	188.67	0	113.977548	0.7	5120	7
Sunagawa-shi	1226	2885	99	0	851.43	0	113.977548	0.7	1520	
Utashinai-shi	1227	4194	3	0	760.03	0	113.977548		12	
Fukagawa-shi	1228	31325	165	10.23942	7046.08	2	98.224474	0.5	11500	107
Furano-shi	1229	40301	30	132.40221	2760.92	0	98.585237	0.4	10500	10
Noboribetsu-shi	1230	15097	2380	10.574615	456.54	64	99.143577	1	1050	42
Eniwa-shi	1231	17909	1820	0.007223	110.19	1	95.219649		4360	4
Date-shi	1233	29682	1647	1.545441	2517.54	164	133.104558	0.3	4970	40
Kitahiroshima-shi	1234	4324	181	2.140196	561.37	2	94.321414		2020	12
Ishikari-shi	1235	49430	1279	8.871174	2093.18	173	110.888641	1.8	5610	11
Hokuto-shi	1236	29252	657	15.814457	2490.72	138	123.884458	0.5	4270	28
Tobetsu-cho	1303	26285	69	7.982972	1046.89	0	126.114134	0.4	8600	16
Shinshinotsu-mura	1304	200	15	0	0	0	150.139135		5150	
Matsumae-cho	1331	23884	3078	20.807996	437.46	460	202.147472		434	20
Fukushima-cho	1332	16901	186	9.114312	1013.26	231	140.886477		106	
Shiriuchi-cho	1333	15681	881	5.591056	2360.8	144	267.773694		1530	3
Kikonai-cho	1334	19469	497	1.979991	4119.35	60	323.729932		984	23
Nanae-cho	1337	12230	322	133.259524	1601.13	1	123.838478	4.3	3000	136
Shikabe-cho	1343	7429	1501	0.186643	1314.64	366	230.477993	0.6	230	47
Mori-machi	1345	27340	536	56.76311	3885.1	445	111.59783	4.2	2620	76
Yakumo-cho	1346	76798	999	10.90212	7830.1	446	126.219395	0.5	6660	92
Oshamambe-cho	1347	22732	122	5.666433	2472.34	133	150.860614	0.1	2470	22
Esashi-cho	1361	7788	475	10.415955	1284.39	88	122.211445		1070	2
Kaminokuni-cho	1362	49561	926	3.655811	2228.37	90	143.09598	0.8	1040	2
Assabu-cho	1363	37010	124	4.374791	3257.6	1	265.801432		3950	35
Otobe-cho	1364	13274	464	0.192104	1273.3	100	190.361751		840	1
Okushiri-cho	1367	10930	1402	65.275112	597.92	206	183.298885		598	9
Imakane-cho	1370	44636	34	9.812512	5787.58	0	162.127754	0.4	5660	65
Setana-cho	1371	49035	974	8.75974	4000.12	380	172.549628	0.7	5950	35
Shimamaki-mura	1391	35939	819	0	260.09	153	254.940627		317	5
Suttsu-cho	1392	7241	812	0	190	152	258.979598	2.7	282	0
Kuromatsunai-cho	1393	25792	1488	1.254991	4332.83	0	116.379948		3480	37
Rankoshi-cho	1394	35473	2380	7.638989	6677.79	13	130.916168	0.7	4040	2
Niseko-cho	1395	13370	1189	0	1494.68	0	176.981041	0.6	2770	0
Makkari-mura	1396	6652	1164	0	1161.94	0	171.225868	0.2	3020	11
Rusutsu-mura	1397	7099	344	0	1563.02	0	296.665443	0.2	2400	5
Kimobetsu-cho	1398	14588	1029	0	2572.9	0	184.802092	0.4	1250	
Kyogoku-cho	1399	17253	2158	5.450786	2610.37	0	159.404769	0.2	2540	1
Kutchan-cho	1400	16112	3133	1.444164	1739.59	0	165.068584		4590	3
Kyowa-cho	1401	20280	1541	10.84855	1861.68	0	111.433644	0.2	5170	
Iwanai-cho	1402	4938	765	0	73.48	72	112.022696	0.8	360	1
Tomari-mura	1403	7160	521	0	143.56	80	357.464145		0	
Kamoenai-mura	1404	13138	668	0	41.56	106	219.951195		4	
Shakotan-cho	1405	16325	2414	0	745.44	293	82.269504		857	4
Furubira-cho	1406	15667	487	0.129522	419.94	76	0		92	4
Niki-cho	1407	12377	352	0.127082	1047.92	0	118.622927		1490	
Yoichi-cho	1408	9075	596	3.765579	1071.33	109	139.133983	0.4	1460	
Akaigawa-mura	1409	23675	2607	0	767.89	0	301.150758	0.4	805	2
Nanporo-cho	1423	141	1	0	0	0	122.980582		5590	0
Naie-cho	1424	4860	26	0	279.33	0	113.977548	0.4	2030	0
Kamisunagawa-cho	1425	3454	0	0	659.79	0	154.21213		1	
Yuni-cho	1427	4834	65	0	175.27	0	150.545728	0.4	5860	5
Naganuma-cho	1428	1834	16	0	188.45	0	122.980582	0.4	11200	45

Kuriyama-cho	1429	10468	543	0.516505	2614.08	0	160.80687	0.4	5930	15
Tsukigata-cho	1430	8910	37	4.166443	819.03	0	150.139135		3110	18
Urausu-cho	1431	4884	36	0	313.47	0	99.351492	0.4	3470	103
Shintotsukawa-cho	1432	38340	36	0.000063	3792.53	0	99.351492	1	5390	14
Moseushi-cho	1433	1	2	0	1.71	0	79.122938	0.3	3440	1
Chippubetsu-cho	1434	272	18	0	82.13	0	112.423796		3090	
Uryu-cho	1436	12063	1	13.790087	457.18	0	99.351492	0.5	3530	1
Hokuryu-cho	1437	10219	7	4.296984	1248.64	0	126.015144		3200	2
Numata-cho	1438	20508	12	0.006404	1173.15	0	110.028293	0.5	4130	0
Takasu-cho	1452	6419	0	4.32494	1662.44	0	107.010544	0.5	4370	2
Higashikagura-cho	1453	1447	0	0	1091.46	0	53.845402		3230	9
Tohma-cho	1454	13405	0	4.36406	1586.09	1	197.189415		4380	
Pippu-cho	1455	4437	0	0.089355	1025.72	1	72.522902		2570	3
Aibetsu-cho	1456	20383	102	5.792498	1829.74	0	159.218414	0.5	1830	59
Kamikawa-cho	1457	89142	8	87.478059	1134.15	3	228.70549	0.7	2310	23
Higashikawa-cho	1458	16806	3	52.791647	1702.59	0	0		3560	1
Biei-cho	1459	36104	47	117.991038	7209.38	0	145.744267	1.3	12700	111
Kamifurano-cho	1460	11421	347	9.113842	3745.99	0	118.441622		6410	98
Nakafurano-cho	1461	4183	8	0	2021.75	0	175.839416		4850	12
Minamifurano-cho	1462	56108	605	27.170452	1610.07	1	182.636008		2890	1
Shimukappu-mura	1463	52063	71	13.365518	797.31	1	738.440958		713	17
Wassamu-cho	1464	14208	164	4.273748	2546.23	0	170.522525		4610	5
Kenbuchi-cho	1465	3804	1	4.597219	1364.94	0	135.390335	0.5	6490	1
Shimokawa-cho	1468	55379	91	10.359197	2316.91	0	164.237384	0.1	3620	32
Bifuka-cho	1469	57767	41	18.639209	2937.34	1	152.844387	0.5	5010	118
Otoineppu-mura	1470	23687	5	85.790673	338.4	0	161.502404		1730	0
Nakagawa-cho	1471	51014	132	113.014367	1506.09	0	216.500283	1	3550	11
Horokanai-cho	1472	63515	11	7.857616	615.53	0	113.546885		4610	11
Mashike-cho	1481	31960	224	0	2634.25	187	182.168779		767	2
Obira-cho	1482	54792	265	6.563755	4600.56	43	342.741607	0.5	2250	16
Tomamae-cho	1483	36306	100	7.85675	1950.07	63	120.878714		3260	0
Haboro-cho	1484	38154	177	14.405444	1896.13	175	141.703699		2820	2
Shosambetsu-mura	1485	22814	126	5.527616	2715.59	52	251.099425		1760	7
Enbetsu-cho	1486	48754	612	7.016576	5219.58	21	196.289736		3890	30
Teshio-cho	1487	19694	634	2.102987	3511.82	26	244.833796	0.4	10200	34
Sarufutsu-mura	1511	43909	2147	7.906397	3397.73		321.55924		5670	0
Hamatombetsu-cho	1512	25704	4749	30.31605	1905.08	61	468.684875	0.8	5920	4
Nakatombetsu-cho	1513	32933	399	18.266212	2902.37	0	341.627775	0.5	3680	1
Esashi-cho	1514	88269	1959	24.812066	13501.31	245	507.295603	1	10800	7
Toyotomi-cho	1516	24545	3548	54.774477	4553.15	14	292.02072		13300	21
Rebun-cho	1517	4160	2372	59.840744	6.85	455	260.665344		7	
Rishiri-cho	1518	4538	363	73.329438	99.92	380	129.816327		18	
Rishirifuji-cho	1519	6347	369	98.561456	284.03	443	179.792967		14	
Horonobe-cho	1520	38099	5309	25.501794	2628.6	0	96.202289		8210	20
Bihoro-cho	1543	26799	9	1.322835	8218.18	0	126.281041	0.5	10700	109
Tsubetsu-cho	1544	60990	26	12.172154	4339.26	0	252.42472		5710	244
Shari-cho	1545	42555	282	236.697163	2200.4	48	335.661434	0.5	10700	22
Kiyosato-cho	1546	27052	4	7.20675	424.01	0	163.001658	0.2	9100	25
Koshimizu-cho	1547	13455	387	14.483527	1199.24	7	123.904818	0.3	10400	57
Kunneppu-cho	1549	9269	1319	0.433777	1235.09	0	171.372549		7060	20
Oketo-cho	1550	44388	171	6.433847	3607.73	1	161.864812		4820	21
Saroma-cho	1552	22318	29	4.703609	2860.97	111	200.464379	0.4	7510	134
Engaru-cho	1555	113052	90	23.912019	8771.18	1	153.127916	0.3	7710	37
Yubetsu-cho	1559	27319	2144	8.552578	10483.04	185	141.001408	0.3	11000	128

Takinoue-cho	1560	67077	43	14.482514	3716.9	0	201.380375	0.2	3630	24
Okoppe-cho	1561	26105	2510	4.253865	6681.94	71	386.295216	0.4	6330	18
Nishiokoppe-mura	1562	27496	2	0.29553	1576.75	1	395.743728	0.3	1640	1
Omu-cho	1563	47365	617	7.934019	6027.22	117	148.864309		10000	66
Ozora-cho	1564	13740	39	8.81453	5792.78	1	172.540082	0.6	13700	90
Toyoura-cho	1571	17886	1376	0	3349.64	110	176.629923	0.3	1940	63
Sobetsu-cho	1575	12924	1019	34.988799	1670.63	0	214.727926	0.9	1490	17
Shiraoi-cho	1578	32642	2013	18.763698	2358.79	172	181.116122	3.1	1260	476
Atsuma-cho	1581	28352	2201	7.790868	5367.67	31	136.098388	0.3	5710	45
Toyako-cho	1584	7579	467	40.711781	829.85	72	181.364448	0.4	2560	40
Abira-cho	1585	10054	1919	3.754888	2247.68	0	92.883284		7480	89
Mukawa-cho	1586	55911	1329	9.085398	7384.13	35	122.577013	0.8	6690	101
Hidaka-cho	1601	75794	560	14.532051	4322.62	84	143.789304	0.9	9460	120
Biratori-cho	1602	60918	371	0.659911	6380.19	1	182.815428	0.7	4670	84
Niikappu-cho	1604	43117	832	1.409167	751.06	28	134.818312		7190	120
Urakawa-cho	1607	56469	208	34.921972	4063.83	245	117.692084		5480	64
Samani-cho	1608	32815	8	9.562806	1701.99	259	150.325587		1030	3
Erimo-cho	1609	23797	988	2.977364	907.73	654	221.494089		1840	50
Shinhidaka-cho	1610	90145	1399	20.271099	5773.78	254	115.217726		9180	165
Otofuke-cho	1631	10999	2094	4.56795	3663.49	0	102.777468	1.5	24300	206
Shihoro-cho	1632	5664	443	0.000113	1768.76	3	324.654436		16000	1005
Kamishihoro-cho	1633	50438	453	26.682536	1979.41	0	299.685414	0.6	11200	326
Shikaoi-cho	1634	21305	2611	14.159102	1028.4	3	131.099062	0.3	12100	230
Shintoku-cho	1635	84456	42	114.529006	3377.07	2	264.349714	0.6	6520	313
Shimizu-cho	1636	16982	861	0.06773	1977.55	2	199.916658	0.3	14900	225
Memuro-cho	1637	20773	1741	7.453623	2326.42	3	105.714023	0.3	21400	187
Nakasatsunai-mura	1638	16223	321	0	479.56	0	256.051689		7140	8
Sarabetsu-mura	1639	2703	408	0	666.2	2	218.404082		11500	57
Taiki-cho	1641	55622	1463	12.865209	3130.15	32	343.499477	0.5	14200	133
Hiroo-cho	1642	46681	536	4.794394	3697.37	173	206.273826	0.4	6210	51
Makubetsu-cho	1643	14777	1316	0.281048	4501.49	1	117.551868	0.7	22500	231
Ikeda-cho	1644	22558	886	1.480701	7373.18	1	108.834641	0.4	9520	141
Toyokoro-cho	1645	32695	1929	9.906725	4978.9	36	266.174733	1.7	11500	125
Honbetsu-cho	1646	21503	499	6.871496	4193.19	0	117.387605		12000	147
Ashoro-cho	1647	115253	3151	41.623051	6759.32	0	138.693419		13400	276
Rikubetsu-cho	1648	49028	2412	7.666564	4883.67	0	184.980661		6080	41
Urahoro-cho	1649	54188	1175	13.224604	13365.38	77	215.05001	0.5	11300	172
Kushiro-cho	1661	18630	2039	25.239093	3100.59	219	13.829678		974	39
Akkeshi-cho	1662	38514	13033	95.389183	3951.79	499	188.495602		9030	24
Hamanaka-cho	1663	15970	6552	30.836194	1658.51	580	112.522686		14900	29
Shibecha-cho	1664	57951	14961	80.251342	8227.14	0	80.340997	0.4	29000	233
Teshikaga-cho	1665	47824	3589	90.161178	2919.17	1	136.512117	0.2	10200	51
Tsurui-mura	1667	36137	9296	46.745314	5870.7	1	359.449092	0.6	9640	28
Shiranuka-cho	1668	63110	3939	17.710147	3851.44	181	185.519336		4790	253
Betsukai-cho	1691	35480	15959	110.171699	3200.22	291	422.772212	0.4	63500	166
Nakashibetsu-cho	1692	32061	915	5.046248	1532.32	3	189.579667	0.2	24600	101
Shibetsu-cho	1693	40746	806	6.745127	2414.17	67	377.956505	0.2	12100	58
Rausu-cho	1694	27862	111	210.496502	15.96	369	238.875346		745	0

xi. Appendix III: Questionnaire for the assessment of the perceived level of resilience and sustainability

Introduction

Dear citizen,

Thank you for your cooperation.

I am Alessandra Colocci, Doctoral student in Civil and Environmental Protection at the Università Politecnica delle Marche, Ancona.

My research is about flood risk management to inform local municipal authorities about effective and sustainable strategies, including the preferences of the population.

For this purpose, I am collecting information from citizens through this brief questionnaire. It will take you around 10-15 minutes. The participation is completely voluntary

All data collected is anonymous and it will not be handed to third-parties. The data will be analysed by me through statistical methods. It will be published only for scientific purposes and only in an aggregated form (percentages).

If you have any question or doubt, feel free to contact me:
e-mail: a.colocci@pm.univpm.it
phone: 071 220 4332

From here on the questionnaire will follow.

Each section has a specific introduction: please, read it carefully and pick the most appropriate answer. Only one choice is allowed (unless stated differently).

Please, keep in mind that:

- "Municipality" means the Municipality you are currently living in;
- "flood" means any kind of flood, possibly due to e.g. rivers, lakes, see, heavy rain, failure of the drainage system.

Godspeed!

See you in the last section for the farewells!

Outline of the questionnaire

RESILIENCE

Considering your Municipality in the last 10 years,

what is your opinion about the influence of <u>flood risk</u> on the following aspects:

1.	social cohesion	worse ☐	same ☐	better ☐
2.	household income	worse ☐	same ☐	better ☐
3.	infrastructural development	less projects ☐	some projects ☐	more projects ☐
4.	flood management activities	less activities ☐	some activities ☐	more activities ☐

most common activities (<u>up to 3</u>)

- embankments ☐
- river management ☐
- drainage system management ☐
- coastal defence ☐
- coastal maintenance ☐
- urban development planning ☐
- flood-related maps ☐
- early warning systems ☐

5.	number of flood-proof building and infrastructures	lower ☐	same ☐	higher ☐

how much do you agree with the following statements:

6.	my fellow citizens have become more aware of flood risk	disagree ☐	uncertain/neutral ☐	agree ☐
7.	I have become more aware of flood risk	disagree ☐	uncertain/neutral ☐	agree ☐
8.	the citizens of my Municipality have enough means and sources to manage a flood emergency	disagree ☐	uncertain/neutral ☐	agree ☐

Considering your Municipality,

what is your opinion about the influence of the <u>last flood</u> on the following aspects:

9.	population growth in flooding areas	less people ☐	same ☐	more people ☐
10.	economic welfare	worse ☐	same ☐	better ☐
11.	amount of damage	low ☐	medium ☐	high ☐

which of the following would suffer more damages (<u>up to 3</u>)

- public buildings ☐
- private buildings ☐
- productive system ☐
- energy system ☐
- banking/financial services ☐

		communication system		☐
		transportation system		☐
		health system		☐
		water system		☐
		sewage system		☐
		waste disposal system		☐
		none		☐

		absent	partial	complete
12.	recovery of social life and public services	☐	☐	☐
		long	medium	short
13.	duration of the recovery of social life and public services	☐	☐	☐
		absent	partial	complete
14.	return to everyday life	☐	☐	☐

15. **do you know: (select all relevant options)**

Municipal Civil Protection Plan	☐
Flood Risk Management Plan	☐
River Contract	☐
none of the above	☐
other	☐

if yes, how do you know it/them?

I have read it/them	I have attended discussions about it/them	I have heard about it/them
☐	☐	☐

how did you come to know it/them the first time?

by word of mouth among acquaintances	☐
television and/or radio	☐
books and/or magazines and/or newspapers	☐
websites and/or social media	☐
websites and/or social media of public authorities	☐
mails and/or e-mails from public authorities	☐
activities and/or flyers of public authorities	☐

how much do you agree with the following statements:

		disagree	uncertain/neutral	agree
16.	local authorities have become able to effectively manage a flood emergency	☐	☐	☐
17.	my fellow citizens have become able to effectively manage a flood emergency	☐	☐	☐
18.	I have become able to effectively manage a flood emergency	☐	☐	☐

why?

I learnt the emergency procedures	☐
I survived the last flood	☐
I am sure that I will get help	☐

SUSTAINABILITY

Considering your Municipality in the last 10 years,

what is your opinion about the influence of <u>flood risk management</u> on the following aspects:

		smaller	same	wider
19.	transformation of green land (parks, fields, woods)			

			☐	☐	☐
20.	land use change (natural and cultivated areas in urban and industrial areas)		low ☐	average ☐	high ☐

which is the most frequent land use change?

- urbanisation ☐
- industrialisation ☐
- naturalisation ☐

21.	urban and industrial use of water	lower ☐	same ☐	higher ☐
22.	characteristics of the river area (water flow, water course, ecology)	worse ☐	same ☐	better ☐
23.	soil fertility	lower ☐	same ☐	higher ☐
24.	wildlife catches (fishing, hunting activities)	lower ☐	same ☐	higher ☐
25.	landscape scenery	worse ☐	same ☐	better ☐
26.	number of species in dangerous conditions	low ☐	average ☐	high ☐
27.	effects of human activities on river and streams	negative ☐	neutral ☐	positive ☐

28.	protection of natural areas	significantly implemented ☐	not sufficiently implemented ☐	not implemented, but changes are happening ☐	not implemented and no possibility of changes ☐
29.	initiatives to reduce (water, air, soil) pollution	significantly implemented ☐	not sufficiently implemented ☐	not implemented, but changes are happening ☐	not implemented and no possibility of changes ☐

RESILIENCE

30. **In your opinion, which are the most important of the following? (<u>up to 3</u>)**

- productive system ☐
- banking/financial services ☐
- energy system ☐
- transportation system ☐
- water system ☐
- sewage system ☐
- waste disposal system ☐
- health system ☐
- police service ☐
- education system ☐
- communication system ☐
- social life ☐

Keeping in mind your choices, what is your opinion about the following aspects:

31.	what should be the maximum time of recovery?	few hours ☐	up to 1 day ☐	up to 1 week ☐	up to 1 month ☐

32.	what do you expect for their quality after recovery?	worse ☐	same ☐	better ☐

		few hours	up to 1 day	up to 1 week	up to 1 month
33.	if they stopped working, how long you could carry on your daily activities e.g. by using different supplies?	☐	☐	☐	☐

SUSTAINABILITY

34. **In your opinion, which are the most important of the following? (<u>up to 3</u>)**

food production	☐
raw materials production	☐
soil formation	☐
clean air supply	☐
clean water supply	☐
precipitation regulation	☐
scenery	☐

Keeping in mind your choices, what is your opinion about the following aspects:

		5 years	10 years	20 years	no need	impossible
35.	what should be the maximum time for coming back to normal conditions after being severely compromised?	☐	☐	☐	☐	☐

		worse	same	better
36.	what do you expect for their quality after coming back to normal conditions?	☐	☐	☐

		none	until you can make use of them	until you can compensate for them	all
37.	how much is acceptable to lose?	☐	☐	☐	☐

GENERAL INFORMATION

38. where were you born?

Italy	☐
Europe (other than Italy)	☐
Africa	☐
America	☐
Asia	☐
Oceania	☐

39. which gender do you identify with?

female	☐
male	☐
other (e.g. non-binary)	☐

40. what is your age?

less than 18 years old	☐
18-24 years old	☐
25-34 years old	☐
35-44 years old	☐
45-54 years old	☐
55-64 years old	☐
65-79 years old	☐
over 80 years old	☐

41. what is the highest degree or level of school that you have completed?

primary school	☐
middle school	☐

high school --------- ☐
Bachelor's degree or equivalent --------- ☐
Master's degree or equivalent --------- ☐
post-graduate degree, Doctoral degree or equivalent --------- ☐

42. which is your Municipality?

Fabriano ☐
Falconara Marittima ☐
Genga ☐
Jesi ☐
San Marcello ☐
Serra San Quirico ☐

43. how long have you been living in this municipality?

1 year or less ☐
2-5 years ☐
5-10 years ☐
more than 10 years ☐

44. how many people live in your same house, including yourself?

1 ☐
2 ☐
3-4 ☐
more than 4 ☐

45. are there minors (less than 18 years old) among them?

yes ☐
no ☐

46. do you take part in local civic organisations?

yes ☐
no ☐

47. did you vote in the last national elections?

yes ☐
no ☐

48. are you currently employed?

yes ☐
no ☐

49. what is your average income per year?

0-15 000€ ☐
15 001-30 000€ ☐
30 001-50 000€ ☐
more than 50 000€ ☐

50. do you have at least one phone?

yes ☐
no ☐

51. do you have at least one personal means of transportation (e.g. car, motorcycle, bicycle)?

yes ☐
no ☐

52. do you have internet access at your home?

yes ☐

	no	☐
53. if yes, which is the average data speed?		
	more than 100 Mb/s	☐
	more than 50 Mb/s	☐
	more than 20 Mb/s	☐
	more than 2 Mb/s	☐
	less than 2 Mb/s	☐
54. do you own the house that you live in?		
	yes	☐
	no	☐
55. when was the house you live in built?		
	1918 or before	☐
	1919-1945	☐
	1946-1960	☐
	1961-1970	☐
	1971-1980	☐
	1981-1990	☐
	1991-2000	☐
	2001-2005	☐
	2006 or after	☐