Trends and approaches in the analysis of ecosystem services provided by grazing system: A review

Trends and approaches in the analysis of ecosystem services provided by grazing systems: a review

D'Ottavio P.[1]*, Francioni M.[1], Trozzo L.[1], Sedić E.[1], Budimir K.[1], Avanzolini P.[1], Trombetta M.F.[1], Porqueddu C.[2], Santilocchi R.[1], Toderi M.[1]*

[1] Dipartimento di Scienze Agrarie, Alimentari ed Ambientali, Università Politecnica delle Marche, Ancona, Italy

[2] (CNR) National Research Council, (ISPAAM) Institute for Animal Production System in Mediterranean Environment, Sassari, Italy

***Correspondence to:** P. D'Ottavio and M. Toderi
Dipartimento di Scienze Agrarie, Alimentari ed Ambientali
Università Politecnica delle Marche
Ancona, Italy
E-mails: p.dottavio@univpm.it; m.toderi@univpm.it

Abstract

The ecosystem services (ES) approach is a framework for describing the benefits of nature to human well-being, and this has become a popular instrument for assessment and evaluation of ecosystems and their functions. Grazing lands can provide a wide array of ES that depend on their management practices and intensity. This article reviews the trends and approaches used in the analysis of some relevant ES provided by grazing systems, in line with the framework principles of the Millennium Ecosystem Assessment (MA). The scientific literature provides reports of many studies on ES in general, but the search here focussed on grazing systems, which returned only 62 papers. This review of published papers highlights that: (i) in some papers, the concept of ES as defined by the MA is misunderstood (e.g., lack of anthropocentric vision); (ii) 34% of the papers dealt only with one ES, which neglects the need for the multisectoral approach suggested by the MA; (iii) only a few papers included stakeholder involvement to improve local decision-making processes; (iv) cultural ES have been poorly studied despite being considered the most relevant for local and general stakeholders; and (v) stakeholder awareness of well-being as provided by ES in grazing systems can foster both agri-environmental schemes and the willingness to pay for these services.

Keywords. Primary production, habitat services, food, land degradation prevention, water quality regulation, regulation of water flows, climate regulation, moderation of extreme events, natural (landscape) heritage

1. Introduction

Although the first references to the concept of "ecosystem functions, services and values" date back to around the 1960s, the number of scientific papers concerning ecosystem services (ES) has grown exponentially in the last few decades (de Groot et al., 2002). This is particularly the case since the publication of the Millennium Ecosystem Assessment (MA) (Fisher et al., 2009). The MA (Alcamo et al., 2003; Millennium Ecosystem Assessment, 2005) represents one of the most extensive and widely accepted studies on the links between human well-being and the world ecosystems. It defines the ecosystem as "a dynamic complex of plant, animal (including humans), and microorganism communities and the non-living environment interacting as a functional unit", and ecosystem services as "the benefits people obtain from ecosystems". According to Alcamo et al. (2003), the goal of MA is to establish the scientific basis for actions that are needed to enhance the contributions of ecosystems to human well-being without undermining their long-term productivity. The MA conceptual framework assumes that there is a dynamic interaction between people and ecosystems that requires a multiscale approach, as this better reflects the multiscale nature of decision making. Effective incorporation of different types of knowledge into ES assessment can both improve the findings and help to increase their adoption by stakeholders. The MA conceptual framework places human well-being as the central focus for assessment.

The MA identified four groups of ES: (i) Supporting: services necessary for the production of all other ES (e.g., soil formation, nutrient cycling), where the impact on people is either indirect or occurs over a very long time; (ii) Provisioning: products obtained from ecosystems, such as food and fresh water; (iii) Regulating: benefits obtained from the regulation of ecosystem processes, such as climate and disease control; and (iv) Cultural: non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. A second key study concerning ES, The Economics of Ecosystems and Biodiversity (TEEB, 2010), defines ES as "the direct and indirect contributions of ecosystems to human well-being", and separates the concepts of services and benefits (welfare gains generated by ES), while considering supporting services merely as ecological processes, and not strictly as ES.

Although it is recognized that each ecosystem can produce a large number of ES (Alcamo et al., 2003; Millennium Ecosystem Assessment, 2005), ecosystems can also produce ecosystem disservices that are harmful or detrimental to human well-being (von Döhren and Haase, 2015). Thus, the term "ecosystem service" is anthropocentric and is intended to have a positive sense. This vision is one of the recurring critiques of the concept of ES, and according to Schröter et al. (2014), the ES concept is not meant to replace biocentric arguments, but to group together a wide variety of anthropocentric arguments for the protection and sustainable use of ecosystems by humans. Schröter et al. (2014) also counter-argued six other main critiques to the ES concept that were derived from the scientific literature.

Ecosystem services are spatial-scale and time-scale dependent, and there is a risk that spatial scale mismatches between ecological processes and decision making will occur. For this reason, the need for an integrated approach that also takes into account the local knowledge of stakeholders is a key requirement in assessing ES (Alcamo et al., 2003; Millennium Ecosystem Assessment, 2005; Reed, 2008).

According to Alcamo et al. (2003) and TEEB (2010), ecosystems and biodiversity are closely related concepts, although biodiversity is not strictly considered as an ES, but rather as a source or a regulator of the ecosystem (Harrison et al., 2014). The knowledge gap regarding both the links and the difficulties in understanding the relationships between ES and biodiversity has been highlighted by many authors (e.g., Jax and Heink, 2015; Sircely and Naeem, 2012; Harrison et al., 2014).

Livestock systems occupy about a third of the ice-free land surface of the planet, and they represent an important source of income; indeed, they can even be essential for the survival of vulnerable human communities. In these systems, grazing land can provide a large and differentiated number of ES (Porqueddu et al., 2016; Tarrasón et al., 2016). These ES are, in turn, dependent on the different management practices (Fischer et al., 2010; Steiner et al., 2014), such as different grazing regimes (Ford et al., 2012).

This article reviews the trends and approaches used in the analysis of some relevant ES provided by grazing systems, in line with the framework principles of the MA. In the context of this review, grazing systems include production systems in which grazing is one of the main management practices adopted across the grazing lands (Allen et al., 2011). This review will analyse: (i) if the papers follow the principles of the MA, and the main reasons behind their missed adoption; (ii) which are the most analysed ES, and which require further investigation within grazing systems; (iii) how different types of knowledge have been incorporated into ES assessment, as requested by the MA; and (iv) how ES concepts have fed the decision-making process. It is intended that the results of this review can be used to derive recommendations for research activities in the analysis of ES.

2. Links between biodiversity and ecosystem services

Biodiversity is the variability between living organisms, and it includes diversity within and among species and ecosystems. Biodiversity is the source of many goods and services, such as food and genetic resources, and changes in biodiversity can influence the supply of ES (Alcamo et al., 2003). Subsequently the MA (2005) defined biodiversity as a necessary condition for the delivery of all ES, and in most cases, a greater level of biodiversity is associated with a larger or more dependable supply of ES.

According to the MA (2005), biodiversity is both a response variable that is affected by the drivers of global change (e.g., climate, change in land use) and a factor that modifies ecosystem processes and ES, and indirectly, human well-being (e.g., health, freedom of choice and action). Changes in human well-being can lead to modifications to management practices, with direct effects on ecosystem processes and biodiversity (Figure 1). Although the MA describes a unilateral relationship between biodiversity and ES, some authors consider biodiversity as a service in its own right; e.g., as the basis of nature-based tourism (van Wilgen et al., 2008). However, others consider that biodiversity can have different roles as a regulator of ecosystem processes, as a service in itself, or as a good (Mace et al., 2012).

Insert Fig. 1 about here

Habitat provisioning is one of the main ecosystem services that links the effects of livestock grazing to the biodiversity of the host ecosystem (Hoffman et al., 2014). Habitat services arise from the direct interactions of animals with their environments, and are hence related to land-management practices, especially in relation to grazing systems. Unlike the MA (Alcamo et al., 2003; Millennium Ecosystem Assessment, 2005), the TEEB (2010) considers habitat services as a separate category. In agreement with these documents, this review considers habitat services within supporting services, because of their interconnected nature and their shared roles in underpinning the delivery of other services.

3. Bibliographic search and analysis criteria

This review is based on the ES provided by grazing systems as categorised and defined as prominent by Hoffman et al. (2014) (Table 1). Among these, the ES relevant to the expertise and background of the authors were analysed in detail: primary production (PP), habitat services (HS), food and other livestock-related products (FP), land degradation and soil erosion (LD), water quality regulation/ purification (WQ), regulation of water flows (WF), climate regulation (CR), moderation of extreme events (EE), and natural (landscape) heritage (NH) (Box 1).

Insert Box 1

Published papers dealing with ES were sampled in January 2016 using the Web of Science^{TM} (WoS). Within the search option of "topic" the basic string *"ecosystem service*" and ("grassland*" or "rangeland*" or "shrubland*" or "scrubland*") and "grazing"* was used as input in the "field search" ("basic search"), starting from 2004 as the "timespan". To have a preliminary selection for each analysed ES, specific search terms were added to the basic string according to the keywords (Table 1) included in the Food and Agriculture Organisation report (Hoffman et al., 2014). The additional strings used for the preliminary selection are reported in detail in Table 2.

All of the papers extracted with the basic string (155 papers) were analysed to verify the adoption of the MA framework and the attribution of the papers to each ES, which was corrected as necessary. The analysis of the extracted papers allowed the identification which ES were analysed for each paper in the light of the MA, and which did not take the MA into account (i.e., "ecosystem services" and/or "millennium ecosystem assessment" were merely cited in the Introduction or Conclusions).

After the analysis of the extracted papers the following manuscripts were excluded from this review: (i) papers dealing with ES that was not analysed (ii) reviews, editorials and meta-analyses; and (iii) papers that did not adopt the MA framework.

Insert Table 1

Insert Table 2

4. Trends and approaches in ecosystem services analysis

4.1. The extracted papers: numbers, exclusion, and reasons for exclusion

The basic string search returned a total of 155 papers (Table 1) with an increasing trend from 2010 (Figure 2). The multiple occurrence of different ES within single papers results in a total of 529 findings within the 155 papers. Most papers dealt in particular with supporting (mostly for PP and HS), regulating (in particular, CR and WF) and cultural (NH) ES. Only a few papers dealt with FP, and surprisingly, very few with food itself. The addition of some other terms to the basic string would have resulted in additional papers. For example, by adding *or "good*"* to the basic string, the total number of papers for FP would increase from 12 to 38. This highlights that many authors did not analyse food as an ES according to the MA framework. Similar considerations can be stated for the other ES analysed.

The total number of extracted papers is surprisingly low compared to the far more numerous papers that have analysed grazing systems from the economic and/or biophysical perspective, but that did not adopt the MA framework. Indeed, by removing the keyword "*ecosystem service**" from the basic string and maintaining the same time span, the number of papers reached 5,983.

Insert Fig. 2

According to the review criteria, 29 papers were excluded from this review, as reviews, editorials or meta-analyses, and 64 papers were excluded for only dealing with ES that were not analysed in this review (e.g., fuel, power, pollination; 9 papers) or did not adopt the MA framework (55 papers). With these papers, the term "ecosystem service" was present in the text (e.g., in the Introduction), and for this reason they were extracted.

Sixty-two papers (149 findings) were eligible for the present analysis. NH was apparently assessed in 25% of the papers, although it proved to be analysed as a cultural ES in only 6% of the papers (out of 39 publications, 4 were eligible; Table 1). In the papers excluded from the NH ES, the landscape was considered: (i) for the effects that it can have on biodiversity (e.g., Cole et al., 2015; Kearns and Oliveras, 2009; Lindborg et al., 2009; Littlewood et al., 2012; Sanderson et al., 2007); (ii) as support for improving or maintaining other ES, but not as an ES *per se* (e.g., Lavorel et al., 2011, 2015; Schaldach et al., 2013); (iii) as an assessment scale for other ES (e.g., Hussain and Tschirhart, 2013; Medina-Roldán et al., 2012; Peringer et al., 2013; Kimoto et al., 2012); and (iv) for the effects that different drivers had on it without directly analysing the consequences on its cultural value (e.g., Cousins et al., 2015; Lamarque et al., 2014; Schaich et al., 2015). The limited number of papers dealing with the landscape as a cultural ES might be explained by the difficulty for the measurement of this aspect, and to the few currently available indicators (Feld et al., 2009; TEEB, 2010). Rather than being considered as an EE, fire was analysed in some papers as a management tool for the enhancement of other ES (e.g., habitat provisioning, prevention of wildfires), and for this reason these papers were excluded from the EE analysis. For example, Joubert et al. (2014) investigated the effects of annual burning on plant species richness, composition and turnover in three firebreak types, and under different cattle grazing levels. Boughton et al. (2013) conducted an 8-year split-plot experiment to study the effects of the season of burn on the plant composition of a semi-natural grassland in Florida (USA), where in addition to prescribed winter burns, natural historical wildfires occurred on abandoned ranchlands. The response of vegetation disturbance was studied by Hancock and Legg (2012), for prescribed fire management in pine forests and ericaceous heathlands in the UK. These papers were excluded from the NH and EE analyses, but were included in the other ES analysed in this review; e.g., Lavorel et al. (2011) was excluded from NH but was included in the HS, PP and CR analyses. “Landscape” and “fire” were considered as particular cases, as these can have different meanings (e.g., scale of investigation or management tools). The main reasons for the exclusion for the rest of the papers (e.g., Bai et al., 2012; Loucougaray et al., 2015; Zeng et al., 2015) was the lack of adoption of the MA approach or for only mentioning the term “ecosystem service” in the text (e.g., in the Introduction or Abstract). Table 1 summarises these review categories according to the numbers of papers for each ES extracted by the strings, the numbers of papers eligible for the analysis, and the attribution of these papers to each ES.

4.2. The eligible papers: most and least analysed ecosystem services in combinations with each other

The predominance of papers dealing with PP (63% of the papers), HS (55%) and CR (50%) that emerged in the extracted papers was confirmed for the eligible papers. Although livestock production is clearly related to the forage characteristics of pastures (e.g., yield, quality, species diversity, plant active compounds) (Lieber et al., 2014), only five papers included PP and FP ES in the analyses (Figure 3). From the deep review of the papers, it clearly emerged that PP, CR and HS were often analysed together; i.e., PP was assessed in 80% of the papers dealing with CR (e.g., Medina-Roldán et al., 2012; Oñatibia et al., 2015) and in 60% of the papers dealing with HS (e.g., Duru et al., 2015; Marriot et al., 2010), while HS was analysed in 40% of the papers dealing with PP or CR. At the same time, these three ES were assessed with at least one other ES (e.g., Lamarque et al., 2014; Miller et al., 2011); i.e., PP was analysed in more than 70% of the papers dealing with FP (e.g., Koniak et al., 2011) or LD (e.g., Giese et al., 2013), HS was analysed in 100% of the papers dealing with NH (e.g., Fontana et al., 2014), CR was analysed in about 70% of the papers dealing with FP (e.g., Ford et al., 2012) and in 60% of the papers dealing with WQ (e.g., Roche et al., 2014) or with WF (e.g., Fisher et al., 2011) (Figure 3). In the grazing systems, PP and HS were classified as supporting ES, and were thus placed at the base of all of the other ES. This explains the high number of papers that dealt with PP and HS. As a regulating ES, CR is a well-investigated topic, because it is strongly linked to the urgent climate-change issues. Indeed, even if CR was one of the most analysed ES, its analysis was mostly at a global scale, in terms of its role in net sequestration or net emissions of greenhouse gases, while none of the papers analysed how changes in land cover can affect both temperature and precipitation at local levels. The relationships between the supporting ES, PP and HS and the other regulation ES was less analysed; i.e., WQ was assessed only in 3% and 4% of the papers dealing with PP and HS, respectively, while WF was analysed in about 20% of the papers dealing with PP or HS. Also, while 80% of the FP papers analysed the relation with PP and about 67% analysed the relation with HS, only 13% and 11% of the papers that assessed PP or HS included FP. A similar consideration can be derived for the cultural ES NH, where 100% of the papers analysed the NH relationship with HS, and 80% with PP. On the contrary, only 12% and 8% of the papers dealing with HS or PP included the effects of different management options on NH within their study (Figure 3).

This analysis highlights that the authors tended to concentrate their research on ES very close to each other in terms of their characteristics and relationships, and that they mostly focussed on the supporting and regulating ES. Indeed, papers that dealt with ES that are distant from each other represented the minority; e.g., between HS and FP or NH. In the next section, the literature was analysed in terms of the advantages that derive from a multisectoral analysis that also includes the provisioning and cultural ES, and how this analysis allows inclusion of different stakeholders in the definition of shared management options or support policies (e.g., "Payments for ES" or "agri-environmental schemes").

Insert Fig. 3

4.3. Millennium Ecosystem Assessment principles in the eligible papers

Despite the MA (2005) recommending the implementation of a multisectoral approach to fully evaluate changes in ES, their interactions, and the trade-offs and impact on people, 34% of the 62 papers analysed just one ES (i.e., 10 out of 35 papers for HS; 5 out of 31 for CR, and 3 out of 39 for PP), and 23% analysed only two ES (Figure 4). Only 11% of the papers dealt simultaneously with more than five ES.

Insert Fig. 4

The paper that dealt with one or a few ES turned out to be a very detailed analysis of the single ES, and at the same time, they lost the overview of the system and the potential other effects and trade-offs on the other ES. For example, Kimoto et al. (2012) analysed the effects of different intensities of livestock grazing on native bees, and they concluded that maintaining a heterogeneous landscape with some areas grazed and other not grazed, or with rotation of grazing, might be necessary to support native bee diversity. However, the consequences on FP and NH were not investigated by these authors.

In two interesting papers, Cole et al. (2012, 2015) analysed the effects of the main physical and botanical attributes and of the different management options of riparian field margins on ground beetle and pollinator diversity, and they concluded that wide riparian margins strategically placed within the landscape can enhance taxonomic and functional diversity. Nevertheless, this study did not analyse the effects on the landscape as cultural ES (i.e., the aesthetic value) generated by the different management options, and so they missed the opportunity to highlight further positive effects or trade-offs.

Another example is provided by Peringer et al. (2013), who analysed silvopastoral systems as traditional components of the landscape in the Swiss Jura Mountains, for the prevention of the loss of species-rich open grasslands and forest-grassland ecotones. In this paper, the landscape was an assessment scale for the other ES (i.e., HS), and so it was not an ES.

Other authors enlarged their analyses to other ES, to highlight potential trade-offs or existing relationships; e.g., between different management options on FP or on the aesthetic value of the landscape to produce income from tourism. In this vision, Fontana et al. (2014) analysed the effects of management changes of larch grasslands in the Italian Alps (abandonment and intensification *vs*. traditional management) on PP, HS and pollination, and also on valuable cultural ES (i.e., scenic beauty, traditional healing plants). They conducted a phyto-sociological study on plots that were randomly selected using geographic information systems. For each plant species recorded, three out of eight plant traits were chosen explicitly for their relevance for ES provision: flower colour, high diversity of pollination agents, and the occurrence of edible or healing value for traditional meals and medicines. The provision of scenic beauty and other ES was associated with specific management systems to be addressed when planning future subsidies, and with specific financial support for a traditional agroforestry system.

Other authors analysed the effects of several scenarios (e.g., climate change, policies, management) on FP and on other ES for a more holistic analysis; e.g., Koniak et al. (2011)

addressed issues related to honey production, and developed a mathematical model that predicted the dynamics of multiple services in response to management scenarios (grazing, fire, and their combination) mediated by vegetation changes. These authors combined the potential contribution to honey production with other ES from different groups into one “ES basket” (e.g., carbon retention for CR, forage production for PP, density of geophytes for HS), despite their different natures, which can help land managers to evaluate the effects and trade-offs of alternative management scenarios. Another example of a holistic approach is provided by Dong et al. (2012a, 2012b; 2014), who used the emergy[1] approach to calculate the performance of several ES (i.e., CR, EE, FP, WR, PP) under different systems and scenarios, to support local resource management and larger-scale environmental resource decision making. Ford et al. (2012) used a wide range of ES for each of the MA category of ES to test the hypothesis that changes in grazing intensity of semi-natural grassland differentially affect individual services and alter the balance of supporting, provisioning, regulating and cultural ES provision. This holistic approach underlined that in addition to biodiversity measures of “success” in conservation, ES measures and trade-offs need to be taken into account when choosing an appropriate grassland management scheme. Reed et al. (2015) analysed a combination of many ES to produce tools and frameworks to support the stakeholder decision-making processes for land management. These authors identified new economic instruments (e.g., payments for ES) to enhance the flow of ES provided by grazing systems.

4.4. Ecosystem services, and different types of knowledge and decision making in the eligible papers

A further approach to the analysis of ES provided by grazing systems emerged from some papers that included the involvement of stakeholders in different phases of the evaluation process and with different aims. Some other authors applied a holistic approach that combined the ES analysis with stakeholder involvement to explore the relationships between land management and ES. This approach was intended to influence the decision-making processes, to increase the stakeholder ES knowledge and awareness of the consequences of their activity. Lamarque et al. (2014) applied a role game, in which farmers were faced with changes in ES (i.e., PP, HS, WQ, CR) under climatic and socio-economic scenarios, and prompted to plan for the future and to take land-management decisions as deemed necessary. The results

[1] Emergy was defined as the amount of available energy of one type (usually solar) that is directly or indirectly required to provide a given flow or storage of energy or matter (Odum, 1996).

demonstrated that the farmers were not aware, e.g., of the potential effects of their activities on nitrate leaching, and that feedback loops between ES and land-management decisions can favour more sustainable ES management. A global-scale study was performed by Petz et al. (2014a) in South African rangelands that were affected by historical issues of land conservation and degradation due to overgrazing (e.g., vegetation cover, species diversity, soil erosion, carbon stock, water quality). These authors used the combined approach of a literature review, collected data, and models (i.e., “IMAGE-USLE”) to study the interactions between input data, livestock density, and ES, to strengthen and optimise the choices of local stakeholders for the future management of the area in three different land-management scenarios. A further example of the effectiveness of the use of this approach to identify the best land-management options was provided by Fisher et al. (2011). These authors explored the variations in ES delivery that resulted from different management practices in UK wetlands. In particular, the role of species-led (both animals and plants) management on biodiversity was investigated. In a following step, consultation with stakeholders and experts was carried out through workshops and meetings, to elaborate specific details of the management impact on CR, WQ and WR, linked to the range of management practices. These results are particularly relevant for the drafting of management plans that need to carefully balance the effects of management practices. One example in this sense was provided by Van Horn et al. (2012), who suggested taking into account grazing-related effects on some ES, such as water-quality parameters like turbidity and temperature.

Other authors used different approaches for the analysis of ES, with the integration of scientific knowledge with local knowledge, to create “hybrid knowledge”. In this vision, for a pastoral system of a semi-arid region of northern Nicaragua, Tarrasón et al. (2016) highlighted the importance of engaging relevant and interested stakeholders in dialogue with each other and with the researchers, and encouraging the participation of local stakeholders in the decision-making processes. They applied a participatory methodological framework to identify features of LD and links with other ES provisions. The study designed a four-step methodological framework to integrate local and scientific knowledge within a participatory assessment of land degradation. Field visits and in-depth interviews with key informants and farmers produced information that was integrated with the scientific knowledge that was validated by focus groups, and then used in a state-and-transition conceptual model. Field data on the cover vegetation and the plot life forms were used in thematic working groups with different stakeholders to discuss the results of the previous phases and to develop adaptive management options to maintain or improve ES.

The increase in awareness of local and general stakeholders (e.g., citizens, inhabitants, tourists) of the flow of ES provided by grazing systems was considered by some authors as a key element. The increased awareness of these stakeholders favours the acceptance of new economic instruments (e.g., Payments for ES), which increased their "willingness to pay" for ES. An example emerges from the analysis of Bernués et al. (2014), who attempted to determine the socio-cultural and economic value of some ES delivered by mountain agroecosystems in northeast Spain (e.g., forest fires, habitats for species, aesthetic and recreational values of the landscape, product quality linked to the territory), by identifying stakeholder willingness to pay for their provision. Focus groups and survey-based stated preference methods were combined to identify the effects on ES of three different scenarios that were derived from contrasting policies, and to test the willingness to pay for ES. Cultural ES were demonstrated to be a useful tool to engage with stakeholders to support grazing system policies. From this analysis, it emerged that the farmers were more interested in supporting ES, the local and general stakeholders were more interested in cultural ES, and the local stakeholders were more interested in the landscape than the general stakeholders. In any case, the willingness to pay for ES was higher compared to the current level of EU agri-environmental support.

5. Concluding remarks

The extraction criteria used for this bibliographic review resulted in a relatively small number of papers. The keyword "ecosystem service" was the dividing term between a vast literature that deals with biophysical and socio-economic features of the grazing systems and the minimal results of papers in this analysis that used the ES concept.

Although the MA has been the most widely accepted ES assessment framework since 2003, the analysis of these extracted papers has highlighted misunderstandings concerning the concept of ES. One clear example is the confusion concerning biodiversity, which contrary to the MA, was considered in several papers as an ES *per se* (e.g., Lindborg et al., 2009; Mace et al., 2012). Also, not all of the analysed papers understood or accepted the anthropocentric vision of the ES framework; e.g., some authors proposed biocentric solutions to reverse the inner dynamics of systems without taking into account stakeholder opinions or needs (e.g., Cole et al., 2015).

The need to examine the supply and condition of each ES, as well as the trade-offs (e.g., Marriot et al., 2010; Oñatibia et al., 2015) and interactions between them (as requested by the MA), was applied in a number of these analysed papers (e.g., Koniak et al., 2011; Petz et al., 2014a). Management and development options should take into account the internal dynamics of systems and the biophysical components, and also the socio-economic, socio-cultural and institutional features (Caballero and Fernández-Santos, 2009). Despite this, only a few authors integrated a multi-stakeholder approach into their analysis of ES and the interactions between these (e.g., Bernués et al., 2014; Petz et al., 2014b; Tarrasón et al., 2016). The need for stakeholder involvement emerged in some papers that underlined how the ES concept was not familiar to stakeholders, and was often confused, e.g., with the responsibility of humans to preserve nature (e.g., Bernués et al., 2014; Tarrasón et al., 2016). The use of ES as a basis for discussion might favour more sustainable practices, to increase the awareness of the effects of different management options on stakeholder well-being (e.g., Lamarque et al., 2014).

Other authors emphasised how the stakeholders and their knowledge inclusion is needed to improve the effectiveness of local decision-making processes (e.g., Lindborg et al., 2009; Tarrasón et al., 2016). The integration of local and scientific knowledge generates hybrid knowledge, thereby encouraging the participation of local stakeholders in the decision-making processes. This allowed the identification of adaptive strategies for key services to be maintained into the future (Lamarque et al., 2014; Francioni et al., 2014); e.g., through the implementation of *in-situ* experiments on native pasture management (Tarrasón et al., 2016). Many tools that are commonly used in scientific activities, such as mathematical models, future scenarios, indicators and biophysical data, were adopted by these authors to engage the stakeholders or to facilitate discussion with and between them.

In the analysed literature, cultural ES were poorly studied, despite these being considered the most relevant for local and general stakeholders (Bernués et al., 2014). This thus limited the ES framework to agriculture-related aspects. Better stakeholder awareness of the well-being provided by ES in grazing systems might foster agri-environmental schemes and the willingness to pay for these services. Many papers analysed and proposed different management options to improve the provision of ES (e.g., Cole et al., 2015), but did not analyse the effects on the natural heritage (e.g., the landscape aesthetic value), which can be relevant in policy-making processes (Bulte et al., 2008) and, for instance, in the definition of Payments for ES. Compensation and market-related policies have gained prominence to encourage farmers, policy makers and land managers to change their behaviour, and these might represent a mechanism to align potentially opposing interests; e.g., in the areas of wildlife management and biodiversity conservation.

Acknowledgements

The study was carried out with the support of the project MACSUR (D.M. 2660/7303/2012 - www.MACSUR.eu), funded for the Italian partnership by the Italian Ministry of Agricultural, Food and Forestry Policies. An earlier version of this study was presented at the 15th Meeting of the Mediterranean Sub-Network of the Food and Agriculture Organisation–International Centre for Advanced Mediterranean Agronomic Studies (FAO-CHIEAM), International Network for the Research and Development of Pastures and Fodder Crops, "Ecosystem services and socio-economic benefits of Mediterranean grasslands", Orestiada (Greece), 12-14 April 2016.

References

Alcamo, J., Ash, N. J., Butler, C. D., Callicot, J. B., Capistrano, D., & Carpenter, S. R. (2003). Ecosystems and human well-being: a framework for assessment. Washington, DC: Island Press.

Allen, V. G., Batello, C., Berretta, E. J., Hodgson, J., Kothmann, M., Li, X., Mcivor, J., Milne, J., Morris, C., Peeters, A., & Sanderson, M. (2011). An international terminology for grazing lands and grazing animals. Grass and Forage Science, 66, 2–28.

Bai, Y., Wu, J., Clark, C. M., Pan, Q., Zhang, L., Chen, S., Wang, Q., & Han, X. (2012). Grazing alters ecosystem functioning and C: N: P stoichiometry of grasslands along a regional precipitation gradient. Journal of Applied Ecology, 49, 1204–1215.

Bernués, A., Rodríguez-Ortega, T., Ripoll-Bosch, R., & Alfnes, F. (2014). Socio-cultural and economic valuation of ecosystem services provided by Mediterranean mountain agroecosystems. PloS one, 9, e102479.

Boughton, E. H., Bohlen, P. J., & Steele C. (2013). Season of fire and nutrient enrichment affect plant community dynamics in subtropical semi-natural grasslands released from agriculture. Biological Conservation, 158, 239–247.

Bulte, E., Boone, R. B., Stringer, R., & Thornton, P. K. (2008). Elephants or onions? Paying for nature in Amboseli, Kenya. Environment and Development Economics, 13, 395–414.

Caballero, R., & Fernández-Santos, X. (2009). Grazing institutions in Castilla-La Mancha, dynamic or downward trend in the Spanish cereal-sheep system. Agricultural Systems, 101, 69–79.

Cole, L. J., Brocklehurst, S., Elston, D. A., & McCracken, D. I. (2012). Riparian field margins: can they enhance the functional structure of ground beetle (Coleoptera: Carabidae) assemblages in intensively managed grassland landscapes? Journal of Applied Ecology, 49, 1384–1395.

Cole, L. J., Brocklehurst, S., Robertson, D., Harrison, W., & McCracken, D. I. (2015). Riparian buffer strips: Their role in the conservation of insect pollinators in intensive grassland systems. Agriculture, Ecosystems and Environment, 211, 207–220.

Cousins, S. A., Auffret, A. G., Lindgren, J., & Tränk, L. (2015). Regional-scale land-cover change during the 20th century and its consequences for biodiversity. Ambio, 44, 17–27.

de Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics, 41, 393–408.

Dong, X., Brown, M. T., Pfahler, D., Ingwersen, W. W., Kang, M., Jin, Y., Yu, B., Zhang, X., & Ulgiati, S. (2012a). Carbon modeling and emergy evaluation of grassland management schemes in Inner Mongolia. Agriculture, Ecosystems and Environment, 158, 49–57.

Dong, X., Yang, W., Ulgiati, S., Yan, M., & Zhang, X. (2012b). The impact of human activities on natural capital and ecosystem services of natural pastures in North Xinjiang, China. Ecological Modelling, 225, 28–39.

Dong, X. B., Yu, B.H., Brown, M. T., Zhang, Y. S., Kang, M. Y., Jin, Y., Zhang, X. S., & Ulgiati, S. (2014). Environmental and economic consequences of the overexploitation of natural capital and ecosystem services in Xilinguole League, China. Energy Policy, 67, 767–780.

Duru, M., Jouany, C., Theau, J. P., Granger, S., & Cruz, P. (2015). A plant-functional-type approach tailored for stakeholders involved in field studies to predict forage services and plant biodiversity provided by grasslands. Grass and Forage Science, 70, 2–18.

Hoffman, I., From, T., & Boerma, D. (2014). Ecosystem services provided by livestock species and breeds, with special consideration to the contributions of small-scale livestock keepers and pastoralists. FAO Commission on genetic resources for food and agriculture. Background study paper 66.

Feld, C. K., Martins da Silva, P., Paulo Sousa, J., De Bello, F., Bugter, R., Grandin, U., Hering, D., Lavorel, S., Mountford, O., Pardo, I., & Pärtel, M. I. (2009). Indicators of biodiversity and ecosystem services: a synthesis across ecosystems and spatial scales. Oikos, 118, 1862–1871.

Fischer, M., Bossdorf, O., Gockel, S., Hänsel, F., Hemp, A., Hessenmöller, D., Korte, G., Nieschulze, J., Pfeiffer, S., Prati, D., Renner, S., Schöning, I., Schumacher, U., Wells, K., Buscot, F., Kalko, E. K. V., Linsenmair, K. E., Shulze, E.-D., & Weisser, W. W. (2010). Implementing large-scale and long-term functional biodiversity research: The Biodiversity Exploratories. Basic and Applied Ecology, 11, 473–485.

Fisher, B., Bradbury, R. B., Andrews, J. E., Ausden, M., Bentham-Green, S., White, S. M., & Gill, J. A. (2011). Impacts of species-led conservation on ecosystem services of wetlands: understanding co-benefits and tradeoffs. Biodiversity and Conservation, 20, 2461–2481.

Fisher, B., Turner, R. K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. Ecological Economics, 68, 643–653.

Fontana, V., Radtke, A., Walde, J., Tasser, E., Wilhalm, T., Zerbe, S., & Tappeiner, U. (2014). What plant traits tell us: Consequences of land-use change of a traditional agro-forest system on biodiversity and ecosystem service provision. Agriculture, Ecosystems and Environment, 186, 44–53.

Ford, H., Garbutt, A., Jones, D. L., & Jones, L. (2012). Impacts of grazing abandonment on ecosystem service provision: Coastal grassland as a model system. Agriculture, Ecosystems and Environment, 162, 108–115.

Francioni, M., Toderi, M., Catorci, A., Pancotto, D., & D'Ottavio, P. (2014). Agri-environmental measures for the conservation of semi-natural grassland: a case of study in Natura 2000 sites in Marche Region (Italy). Options Méditerranéennes A, 109, 655–659.

Giese, M., Brueck, H., Gao, Y. Z., Lin, S., Steffens, M., Kögel-Knabner, I., Glindemann, T., Susenbeth, A., Taube, F., Butterbach-Bahl, K., Zheng, X. H., Hoffmann, C., Bai, Y. F., & Han, X. G. (2013). N balance and cycling of Inner Mongolia typical steppe: a comprehensive case study of grazing effects. Ecological Monographs, 83, 195–219.

Hancock, M. H., & Legg, C. J. (2012). Diversity and stability of ericaceous shrub cover during two disturbance experiments: one on heathland and one in forest. Plant Ecology and Diversity, 5, 275–287.

Harrison, P. A., Berry, P. M., Simpson, G., Haslett, J. R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Llorente, M., Geamănă, N., Geertsema, W., Lommelen, E., Meiresonne, L., & Turkelboom, F. (2014). Linkages between biodiversity attributes and ecosystem services: a systematic review. Ecosystem Services, 9, 191–203.

Hussain, A. T., & Tschirhart, J. (2013). Economic/ecological tradeoffs among ecosystem services and biodiversity conservation. Ecological Economics, 93, 116–127.

Jax, K., & Heink, U. (2015). Searching for the place of biodiversity in the ecosystem services discourse. Biological Conservation, 191, 198–205.

Joubert, L., Pryke, J. S., & Samways, M. J. (2014). Annual burning drives plant communities in remnant grassland ecological networks in an afforested landscape. South African Journal of Botany, 92, 126–133.

Kearns, C. A., & Oliveras, D. M. (2009). Environmental factors affecting bee diversity in urban and remote grassland plots in Boulder, Colorado. Journal of Insect Conservation, 13, 655–665.

Kimoto, C., DeBano, S. J., Thorp, R. W., Taylor, R. V., Schmalz, H., DelCurto, T., Johnson, T., Kennedy, P. L., & Rao, S. (2012). Short-term responses of native bees to livestock and implications for managing ecosystem services in grasslands. Ecosphere, 3, 1–19.

Koniak, G., Noy-Meir, I., & Perevolotsky, A. (2011). Modelling dynamics of ecosystem services basket in Mediterranean landscapes: a tool for rational management. Landscape Ecology, 26, 109–124.

Lamarque, P., Meyfroidt, P., Nettier, B., & Lavorel, S. (2014). How ecosystem services knowledge and values influence farmers' decision-making. PloS one, 9, e107572.

Lavorel, S., Colloff, M. J., Mcintyre, S., Doherty, M. D., Murphy, H. T., Metcalfe, D. J., Dunlop, M., Williams, R. J., Wise, R. M., & Williams, K. J. (2015). Ecological mechanisms underpinning climate adaptation services. Global Change Biology, 21, 12–31.

Lavorel, S., Grigulis, K., Lamarque, P., Colace, M. P., Garden, D., Girel, J., Pellet, G., & Douzet, R. (2011). Using plant functional traits to understand the landscape distribution of multiple ecosystem services. Journal of Ecology, 99, 135–147.

Leiber, F., Jouven, M., Martin, B., Priolo, A., Coppa, M., Prache, S., Heckendorn, F., & Baumont, R. (2014). Potentials and challenges for sustainable grassland utilisation in animal production. Options Méditerranéennes A, 109, 33–47.

Lindborg, R., Stenseke, M., Cousins, S. A., Bengtsson, J., Berg, Å., Gustafsson, T., Sjödin, N. E., & Eriksson, O. (2009). Investigating biodiversity trajectories using scenarios-Lessons from two contrasting agricultural landscapes. Journal of Environmental Management, 91, 499–508.

Littlewood, N. A., Stewart, A. J., & Woodcock, B. A. (2012). Science into practice–how can fundamental science contribute to better management of grasslands for invertebrates? Insect Conservation and Diversity, 5, 1–8.

Loucougaray, G., Dobremez, L., Gos, P., Pauthenet, Y., Nettier, B., & Lavorel, S. (2015). Assessing the effects of grassland management on forage production and environmental quality to identify paths to ecological intensification in mountain grasslands. Environmental Management, 56, 1039–1052.

Mace, G. M., Norris, K., & Fitter, A. H. (2012). Biodiversity and ecosystem services: a multilayered relationship. Trends in Ecology and Evolution, 27, 19–26.

Marriott, C. A., Fisher, J. M., Hood, K., & Pakeman, R. J. (2010). Impacts of extensive grazing and abandonment on grassland soils and productivity. Agriculture, Ecosystems and Environment, 139, 476–482.

Medina-Roldán, E., Paz-Ferreiro, J., & Bardgett, R. D. (2012). Grazing exclusion affects soil and plant communities, but has no impact on soil carbon storage in an upland grassland. Agriculture, Ecosystems and Environment, 149, 118–123.

Millennium Ecosystem Assessment (2005). Ecosystems and human well-being: synthesis. Washington, DC: Island Press.

Miller, M. E., Belote, R. T., Bowker, M. A., & Garman, S. L. (2011). Alternative states of a semiarid grassland ecosystem: implications for ecosystem services. Ecosphere, 2, 1–18.

Odum, H. T. (1996). Environmental Accounting: Emergy and Environmental Decision Making. New York: Wiley.

Oñatibia, G. R., Aguiar, M. R., & Semmartin, M. (2015). Are there any trade-offs between forage provision and the ecosystem service of C and N storage in arid rangelands? Ecological Engineering, 77, 26–32.

Peringer, A., Siehoff, S., Chételat, J., Spiegelberger, T., Buttler, A., & Gillet, F. (2013). Past and future landscape dynamics in pasture-woodlands of the Swiss Jura Mountains under climate change. Ecology and Society, 18, 11.

Petz, K., Alkemade, R., Bakkenes, M., Schulp, C. J., van der Velde, M., & Leemans, R. (2014a). Mapping and modelling trade-offs and synergies between grazing intensity and ecosystem services in rangelands using global-scale datasets and models. Global Environmental Change, 29, 223–234.

Petz, K., Glenday, J., & Alkemade, R. (2014b). Land management implications for ecosystem services in a South African rangeland. Ecological Indicators, 45, 692–703.

Porqueddu, C., Ates, S., Louhaichi, M., Kyriazopoulos, A. P., Moreno, G., del Pozo, A., Ovalle, C., Ewing M. A., & Nichols, P. G. H. (2016). Grasslands in 'Old World' and 'New World' Mediterranean-climate zones: past trends, current status and future research priorities. Grass and Forage Science, 71, 1–35.

Reed, M. S. (2008). Stakeholder participation for environmental management: a literature review. Biological Conservation, 141, 2417–2431.

Reed, M. S., Stringer, L. C., Dougill, A. J., Perkins, J. S., Atlhopheng, J. R., Mulale, K., & Favretto, N. (2015). Reorienting land degradation towards sustainable land management: Linking sustainable livelihoods with ecosystem services in rangeland systems, Journal of Environmental Management, 151, 472–485.

Roche, L. M., O'Geen, A. T., Latimer, A. M., & Eastburn, D. J. (2014). Montane meadow hydropedology, plant community, and herbivore dynamics. Ecosphere,5, 1–16.

Sanderson, M. A., Goslee, S. C., Soder, K. J., Skinner, R. H., Tracy, B. F., & Deak, A. (2007). Plant species diversity, ecosystem function, and pasture management - a perspective. Canadian Journal of Plant Science, 87, 479–487.

Schaich, H., Kizos, T., Schneider, S., & Plieninger, T. (2015). Land change in eastern Mediterranean wood-pasture landscapes: the case of deciduous oak woodlands in Lesvos

(Greece). Environmental Management, 56, 110–126.

Schaldach, R., Wimmer, F., Koch, J., Volland, J., Geißler, K., & Köchy, M. (2013). Model-based analysis of the environmental impacts of grazing management on eastern Mediterranean ecosystems in Jordan. Journal of Environmental Management, 127, S84–S95.

Schröter, M., van der Zanden, E. H., van Oudenhoven, A. P. E., Remme, R. P., Serna-Chavez, H. M., de Groot, R. S., & Opdam, P. (2014). Ecosystem Services as a contested concept: a synthesis of critique and counter-arguments. Conservation Letters, 7, 514–523.

Sircely, J., & Naeem, S. (2012). Biodiversity and ecosystem multi-functionality: observed relationships in smallholder fallows in Western Kenya. PloS one, 7, e50152.

Steiner, J. L., Engle, D. M, Xiao, X., Saleh, A., Tomlinson, P., Rice, C. W, Cole, N. A., Coleman, S. W., Osei, E., Basara, J., Middendorf, G., Gowda, P., Todd, R., Moffet, C., Anandhi, A., Starks, P. J., Ocshner, T., Reuter, R., & Devlin, D. (2014). Knowledge and tools to enhance resilience of beef grazing systems for sustainable animal protein production. Annals of the New York Academy of Science, 1328, 10–17.

Tarrasón, D., Ravera, F., Reed, M. S., Dougill, A. J., & Gonzalez, L. (2016). Land degradation assessment through an ecosystem services lens: Integrating knowledge and methods in pastoral semi-arid systems. Journal of Arid Environments, 124, 205–213.

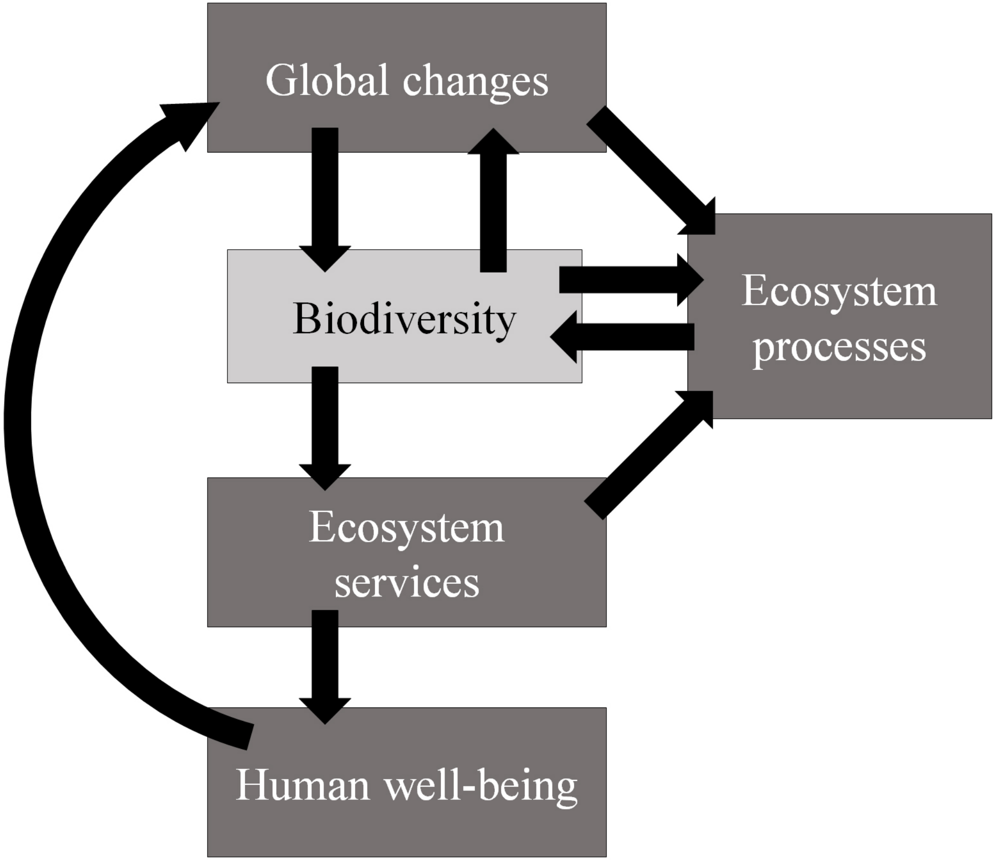
TEEB (2010). The economics of ecosystems and biodiversity. Ecological and economic foundations. Edited by Kumar, P. London and Washington: Earthscan.

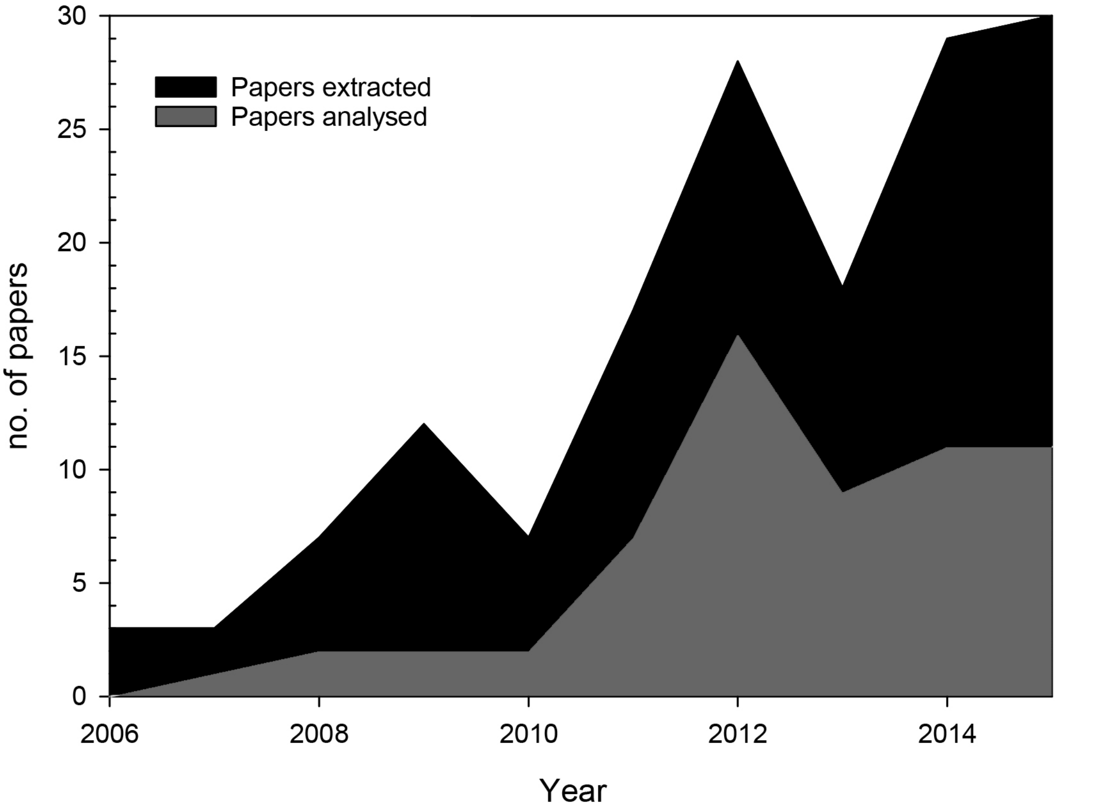
Van Horn, D. J., White, C. S., Martinez, E. A., Hernandez, C., Merrill, J. P., Parmenter, R. R., & Dahm, C. N. (2012). Linkages between riparian characteristics, ungulate grazing, and geomorphology and nutrient cycling in montane grassland streams. Rangeland Ecology and Management, 65, 475–485.

van Wilgen, B. W., Reyers, B., Le Maitre, D. C., Richardson, D. M., & Schonegevel, L. (2008). A biome-scale assessment of the impact of invasive alien plants on ecosystem services in South Africa. Journal of Environmental Management, 89, 336–349.

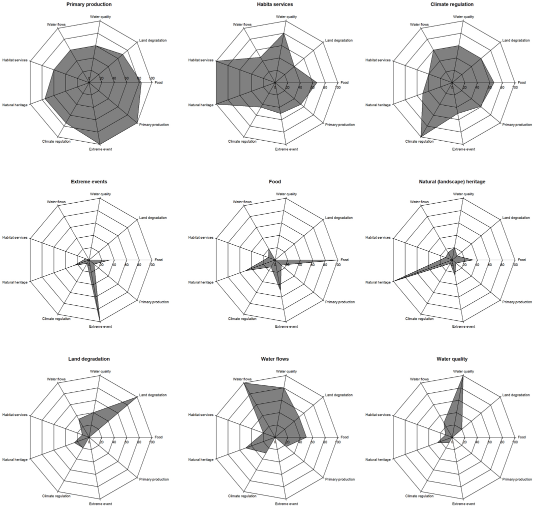
von Döhren, P., & Haase, D. (2015). Ecosystem disservices research: A review of the state of the art with a focus on cities. Ecological Indicators, 52, 490–497.

Zeng, C., Wu, J., & Zhang, X. (2015). Effects of grazing on above-vs. below-ground biomass allocation of alpine grasslands on the Northern Tibetan Plateau. PloS one, 10, e0135173.

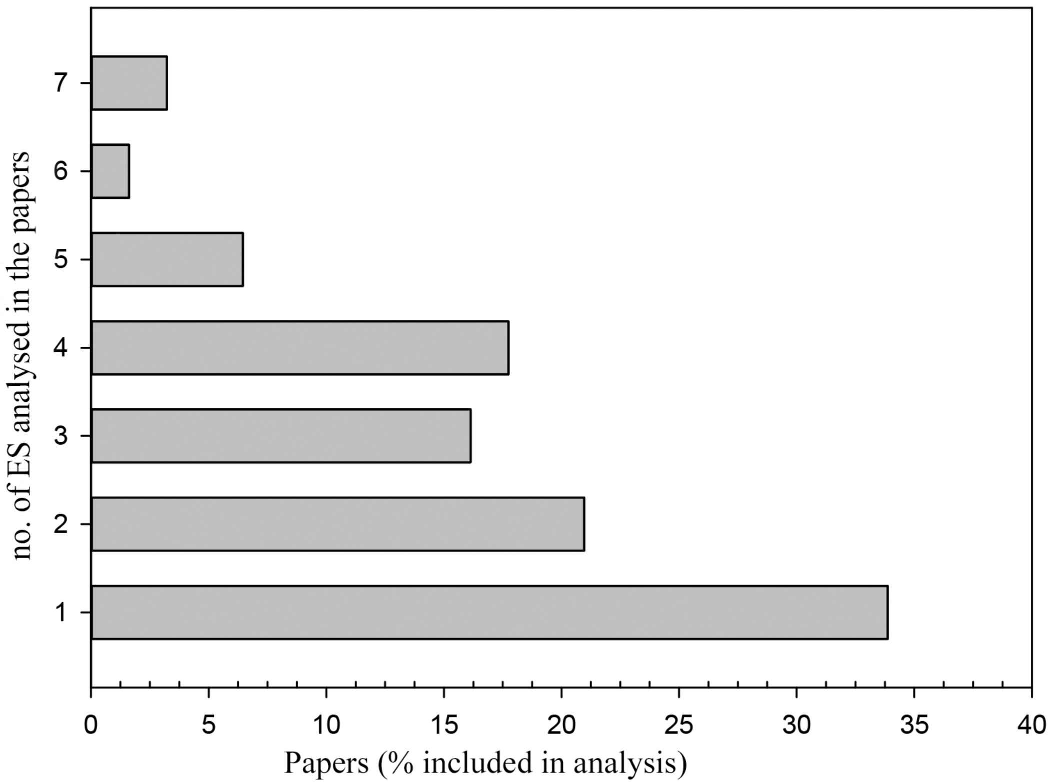

Global changes
Biodiversity
Ecosystem processes
Ecosystem services
Human well-being



Papers extracted
Papers analysed
no. of papers
Year
0
5
10
15
20
25
30
2006
2008
2010
2012
2014



Primary production
Habita services
Climate regulation
Extreme events
Food
Natural (landscape) heritage
Land degradation
Water flows
Water quality
Water quality
Land degradation
Food
Primary production
Extreme event
Climate regulation
Natural heritage
Habitat services
Water flows
0
20
40
60
80
100



no. of ES analysed in the papers
7
6
5
4
3
2
1
0
5
10
15
20
25
30
35
40
Papers (% included in analysis)

Table 1. Papers dealing with ecosystem services provided by grazing systems returned by the basic string from the Web of Science™ and after selection according to the review criteria. Each paper can deal with more than one ecosystem service.

Ecosystem services group	Ecosystem service	Description	Papers		
			Extracted[1] (n)	Satisfying analysis criteria[2] (n)	(%)
Supporting	Maintenance of soil structure and fertility	Nutrient cycling on farms and across landscapes; soil formation	12	n.a.	n.a.
	Primary production	Improving vegetation growth/ cover	72	39	63
	***Habitat services** (as part of supporting services)*				
	Maintenance of life cycles of species	Habitat for species, especially migratory species	78	35	56
	Habitat connectivity	Seed dispersal in guts and coats	2	n.a.	n.a.
	Maintenance of genetic diversity	Gene pool protection and conservation	0	0	0
Provisioning	Food	Meat, milk, eggs, honey, wool, leather, hides, skins, etc.	12	6	10
	Fertiliser	Manure and urine for fertiliser	9	n.a.	n.a.
	Fuel	Manure and CH_4 for energy, manure biogas, etc.	11	n.a.	n.a.
	Power	Draught animal power	0	0	0
	Genetic resources	Basis for breed improvement and medicinal purposes	10	n.a.	n.a.
	Biotechnical/ medicinal resources	Laboratory animals, test organisms, biochemical products	0	0	0
Regulating	Waste recycling and conversion of non-human edible feed	Recycling of crop residues, household waste, swill, primary vegetation consumption	1	n.a.	n.a.
	Land degradation and erosion prevention	Maintenance of vegetation cover	26	10	16
	Water quality regulation/ purification	Water purification/ filtering in soils	8	5	8
	Regulation of water flows	Natural drainage and drought prevention, influence of vegetation on rainfall, timing/ magnitude of run-off/ flooding	44	15	24
	Climate regulation	Soil carbon sequestration, greenhouse gas mitigation	60	31	50

	Moderation of extreme events	Avalanche and fire control	19	4	6
	Pollination	Yield/ seed quality of crops and natural vegetation; genetic diversity	17	n.a.	n.a.
	Biological control and animal/ human disease control	Destruction of habitats of pest and disease vectors; yields	3	0	0
Cultural	Opportunities for recreation	Eco/ agro-tourism, sports, shows and other recreational activities involving specific animal breeds	50	n.a.	n.a.
	Knowledge systems and educational values	Traditional and formal knowledge about breeds, grazing and socio-cultural systems of the area	23	n.a.	n.a.
	Cultural and historic heritage	Presence of the breed in the area helps to maintain elements of the local culture that are valued as part of the local heritage; cultural identity	21	n.a.	n.a.
	Inspiration for culture, art and design	Traditional art/ handicraft; fashion; cultural, intellectual and spiritual enrichment and inspiration; pet animals, advertising	12	n.a.	n.a.
	Natural (landscape) heritage	Values associated with landscape as shaped by animals themselves or as a part of landscape; e.g., aesthetic values, sense of place, inspiration	39	4	6
	Spiritual and religious experience	Values related to religious rituals and the human life-cycle, such as religious ceremonies, funerals or weddings	0	0	0

[1], 155 papers extracted from the Web of Science™, for a total of 529 findings;

[2], 62 papers, for 149 findings, satisfying the analysis criteria.

n.a., not analysed

Table 2. Basic and additional strings used for the extraction of the papers, according to the keywords included in the Food and Agriculture Organisation report (Hoffman et al., 2014).

Ecosystem service analysed	**Extraction string**
Ecosystem services (basic string)	*"ecosystem service*" and ("grassland*" or "rangeland*" or "shrubland*" or "scrubland*") and "grazing"*
Primary production	*("primary production" or "vegetation growth" or "vegetation cover" or "vegetation" or "NPP" or "net primary production")*
Habitat services	*("species" or "habitat" or "life cycle")*
Food and other livestock related products	*("meat" or "milk" or "honey" or "wool" or "leather" or "hide" or "skin" or "wax")*
Land degradation and soil erosion	*("land degradation" or "erosion" or "cover crop*" or "vegetation cover")*
Water quality regulation/ purification	*("water quality" or "water regulation" or "water purification" or "water filtering in soil")*
Regulation of water flows	*("water" or "natural drainage" or "drought prevention" or "runoff" or "rainfall" or "flooding")*
Climate regulation	*("climate" or "soil carbon" or "greenhouse gas*" or "GHG" or "CO_2" or "CH_4" or "N_2O")*
Moderation of extreme events	*("avalanche*" or "fire" or "extreme event*")*
Natural (landscape) heritage	*("landscape" or "aesthetic" or "inspiration")*