sustainability

MDPI

Article

Investigating 'Land-Use Trajectories' in Mediterranean Rural Areas with Official Statistics and a Multiway Factor Analysis

Marco Maialetti [1], Clio Ciaschini [2], Giovanni Quaranta [3], Rosanna Salvia [3], Donato Scarpitta [4], Stefano Bigiotti [5], Francesco Maria Chelli [2,]* and Luca Salvati [6]

ISSN: 2071-1050

1 Independent Researcher, I-00195 Rome, Italy; avv.marcomaialetti@gmail.com
2 Department of Economics and Social Science, Polytechnic University of Marche, Piazza R. Martelli 8, I-60121 Ancona, Italy; c.ciaschini@univpm.it
3 Department of Mathematics, Computer Science and Economics, University of Basilicata, I-85100 Potenza, Italy; giovanni.quaranta@unibas.it (G.Q.); rosanna.salvia@unibas.it (R.S.)
4 Independent Researcher, I-84067 Santa Marina, Italy; scarpittadonato@libero.it
5 Department of Agricultural and Forest Science (DAFNE), Tuscia University, Via S. Camillo de Lellis, I-01100 Viterbo, Italy; stefano.bigiotti@unitus.it
6 Department of Methods and Models for Economics, Territory and Finance (MEMOTEF), Faculty of Economics, Sapienza University of Rome, Via del Castro Laurenziano 9, I-00161 Rome, Italy; luca.salvati@uniroma1.it
* Correspondence: f.chelli@univpm.it

Abstract: While displaying diversified economic values, agro-ecosystems remain a relevant component of rural landscapes in Southern Europe. Coupled with the expansion of ecologically fragile areas because of climate warming, intensification and simplification of rural landscapes—e.g., in lowland—represent frequent trajectories of rural land-use change (RLUC) in the Mediterranean region and demonstrated to harm ecosystem functionality and ecological quality, especially in a context of socioeconomic transformations of landscapes. Additionally, an incipient 'extensivation' of geographically remote and economically marginal agricultural systems was also observed, likely following depopulation and land abandonment. The present study elaborated in this direction, providing an integrated RLUC evaluation scheme based on a multivariate analysis of land-use indicators derived from official statistics. This approach was applied to a continuous, long-term RLUC monitoring of a rural landscape in an ecologically complex Mediterranean region (Latium, Central Italy) experiencing multiple trends (e.g., lowland urbanization, crop intensification in gently sloping areas, and land abandonment/depopulation in steep zones) with diversified environmental implications. Based on administrative inventories, such evaluation was carried out over fifty years (1970–2020) in the study area, considering trends over time in selected crop surfaces at the municipal scale as inputs of a multiway factor analysis (MFA). This analysis quantifies stability in the main rural land-use types and possible changes in the dominant farming systems. Simplified indicators of land configuration (namely a crop intensity index and a rural woodland index reflecting 'intensification' or 'extensivation' of local farming systems) made available at the same spatial and temporal scales completed the informative picture corroborating MFA results. Taken together, our findings delineate multiple changes in rural landscapes, discriminating land-use trajectories in coastal and inland districts. These development trajectories were basically dependent on processes of (i) land abandonment in relict and remote areas, (ii) crop intensification in dynamic rural districts, and (iii) fringe urbanization along the coastal strip.

Keywords: agro-ecosystems; indicators; crop intensification; exploratory data analysis; Italy

Citation: Maialetti, M.; Ciaschini, C.; Quaranta, G.; Salvia, R.; Scarpitta, D.; Bigiotti, S.; Chelli, F.M.; Salvati, L. Investigating 'Land-Use Trajectories' in Mediterranean Rural Areas with Official Statistics and a Multiway Factor Analysis. *Sustainability* **2024**, *16*, 7644. https://doi.org/10.3390/su16177644

Academic Editor: Gema Cárdenas

Received: 30 July 2024
Revised: 1 September 2024
Accepted: 2 September 2024
Published: 3 September 2024

1. Introduction

Land-use change is the result of economic and political decisions and, to a lesser extent, an outcome of environmental and social considerations [1]. Since the way land is used involves many potential trade-offs, some of them can reflect negative impacts, causing degradation of soil, water, and biological resources and total (or partial) loss in ecosystems' services [2]. Other trade-offs lead to a positive expansion of urban land into productive soils, one of the most powerful development processes in advanced economies [3]. In recent times, diachronic analysis of land-use structures assumed a renewed academic and normative relevance, together with the identification of the main causes and consequences underlying both short-term and long-term landscape changes and societal transformations [4]. Landscape transformations reflect a sudden, while observable, change in the anthropogenic (namely, economic) use of land [5], including activities such as agriculture, pasture, or plantation/forestry, and strictly differ from the broader notion of "land cover", which delineates the biophysical characteristics of land, irrespective of human action [6].

Land-use change may affect land cover, while changing land cover may similarly influence land use [7]. In this perspective, land use has been regarded as one of the major factors connected to human actions, and represents a basic component of global change [8], having sometimes strict interactions with climate warming and environmental degradation [9]. Land conversion negatively affects the external environment, raising concerns about multiple ecological issues such as biodiversity loss and alteration in ecosystems' services, waterlogging, increasing air and soil temperatures, flooding, and pollution [10]. Land use deeply influences rainfall regimes since it relates to the intrinsic balance between hydrogeological cycles and surface energy [11]. Different land-use types affect surface reflectance and roughness, causing a sudden alteration in air and soil temperature, absorbing in turn solar energy, and thus regulating sensible heat variations in a different way [12].

Understanding how humans and the environment interact requires a holistic comprehension of landscape dynamics based on quantitative data and diachronic, fine-grained observations [13]. Land-use analysis has been performed for the landscapes on almost all of the world's continents [14], using a variety of spatial data sources across multiple time intervals and adopting diversified techniques possibly reflecting the methodological complexity and mimicking the spatio-temporal articulation at the base of such processes [15]. Understanding socioeconomic factors as a possible cause of landscape transformations is particularly useful and technically suitable when quantifying land-use change on the basis of thematic indicators [16]. Additionally, indicators allow use of descriptive statistics and maps in combination with additional, pertinent data on the scope and distribution of change, possibly covering unexpectedly long time windows and guaranteeing a particularly high level of comparability, either at regional or local observation scales [17]. In this perspective, data from agricultural censuses, usually released for a long time in both advanced countries and most of the emerging economies in the world, may provide particularly rich information for such kinds of studies [18].

While being usually considered more precise and flexible to a spatially explicit use, data collected and organized from remote sensing techniques (e.g., from elaboration of diachronic satellite imagery) may allow a multi-temporal analysis of land-use change that usually encompasses relatively short time windows. This depends on the restricted data availability, heterogeneous geographical coverage, diverging technical detail, or semantic definition of economic activities on the ground [19]. In this perspective, administrative inventories of crop area and other statistical sources focusing on the primary sector can provide lengthy time-series data on rural land-use change, hereafter RLUC [8]. Statistical inventories are basically a tool for tracking RLUC processes since (i) they allow for long-term comparisons across data, land-use types, and spatial locations, and (ii) they are mostly accessible (with no restrictions) at a variety of geographical scales (e.g., countries, administrative/geographical regions, prefectures/provinces, homogeneous economic districts, municipalities). Results from such inventories are rather simple to understand and interpret for non-technical users, such as policymakers and other local stakeholders, and to use for practitioners, allowing the construction of elementary variables, thematic indicators, and multiple composite indexes [20]. Additionally, according to Salvati and coworkers [21], an integrated analysis of such results based on multivariate techniques allows an effective scrutiny of latent patterns in RLUC, thereby producing accurate information on future trends and suggesting efficient policy actions to control, at least indirectly, habitat fragmentation and biodiversity loss [1].

Taken together, these considerations suggest that all levels of environmental governance, especially in advanced economies, should carefully consider the study of landscapes and the role it plays in ecological interactions with other productive (economic) and territorial (social) sectors when making policy decisions [22]. In the old continent, and especially in Mediterranean Europe, agro-ecosystems play a role in rural landscapes [23]. Economic development, population pressure, and climate change are intended as the main causes of declining agro-environmental quality and biodiversity loss [24]. Intended as an appropriate land-use indicator [25], quantification of landscape modifications may be performed considering their rate of change over time. More specifically, analyzing land-use change may contribute to delineating how socioeconomic and political initiatives are connected, trying to give further value to their intrinsic, operational interrelationships [26]. In this regard, soil planning, rural development, and sustainable management of farming systems may greatly benefit from a landscape change analysis [27].

Our contribution precisely aims at providing a multi-temporal, explorative approach to RLUCs in a paradigmatic case study of the Latium region in Central Italy. Latium is an administrative region rich in agricultural (mosaic) landscapes, rich in natural habitats and biodiversity that still assure income and wellbeing to local communities, both in remote places and in central locations close to large cities, such as Rome, the Italian capital city [28]. To fill this research objective, we analyzed time-series official statistics from agricultural censuses delineating—at the municipal level—the main land-use trends. With this aim, we considered descriptive statistics and elementary indicators, i.e., total area invested in crops, namely agricultural utilized Area (AUA), total area of farms (ATA), including crops and other surfaces (basically farm woodlands), and the total regional surface as a reference value. We subsequently derived two thematic indicators of land configuration from the same data source, considering the same spatial scale and homogeneous geographical coverage [29].

These indicators quantified, respectively, farming intensity as a proxy of crop intensification (INT) and rural woodlands as a proxy of farming "extensivation" (WOO). These were assumed to be the main landscape trends in the rural area under investigation during the study period between 1970 and 2020 [30]. We finally run a multiway factor analysis (MFA) of the spatial distribution of selected land-use types derived from the same official source [31]. Results of the multivariate analysis, covering the time window from 1970 to 2020 at the municipal scale (the elementary observation), were compared with the outcome of descriptive statistics and the two thematic indicators of land configuration (INT and WOO). This multi-step analysis' framework provided a sufficiently detailed and comparative scrutiny of long-term trends in rural land-use change [32], delineating the underlying spatial patterns and economic processes along the elevation gradient in Latium. The elevation gradient in the study area may be seen as representative of several Mediterranean regions [33], and its configuration reflects the economic polarization between industrialization of dynamic districts and the abandonment of more peripheral locations [1,4].

By integrating different techniques, the empirical results of the statistical analysis were graphically compared with trends over time in a climatic indicator (namely, a soil aridity index based on the average ratio of annual precipitation and reference evapotranspiration estimated over sufficiently long and representative time intervals). Using the United Nations Environmental Program (UNEP) classification of aridity values, data, maps, and the consequent analysis were finally scrutinized in light of multiple (rural) land-use trends [34] and may contribute to a better understanding of regional (environmental *vis à vis* socioeconomic) changes from the perspective of a truly sustainable development path. While descriptive and preliminary, our approach justifies (and reveals the intrinsic value of) the use of long-term statistical time-series, integrating different knowledge issues and multiple analysis' dimensions [35], from land use to climate change, from farming systems to agricultural economics.

2. Methodology

2.1. Study Area

Representing an elevation gradient from coastal to inland districts, the study area covers the whole of Latium municipalities, an administrative region in Central Italy experiencing a process of land-use change under the action of multiple economic and social drivers [36]. Latium is one of the twenty administrative regions of Italy and includes five provinces (Viterbo, Rieti, Rome, Latina, and Frosinone) and 378 municipalities, administering a total area of nearly 17,065 km^2 with moderately steep topography (from 0 m to 2.200 m above the sea level) and different climatic zones [37]. Three elevation belts were considered in this study, namely lowlands (average altimetry < 100 m at the sea level), uplands (100 m < altimetry < 600 m at the sea level), and mountainous districts (altimetry $\geq$ 600 m at the sea level).

During the last fifty years, Latium has been subjected to intense transformations because of urban growth, industrialization, tourism development, wildfires, intensification of agriculture in lowland and hilly areas, as well as population aging and the consequent abandonment of agricultural terraces inland [38]. Between 1970 and 2020, resident population has increased in specific areas of the region, e.g., along much of the sea coast line, the eastern part of Rome, and intermediate towns (Figure 1). This phenomenon can be explained with intense population movements from the capital city to the nearby municipalities because of various interconnected factors, possibly delineating a process of suburbanization [39].

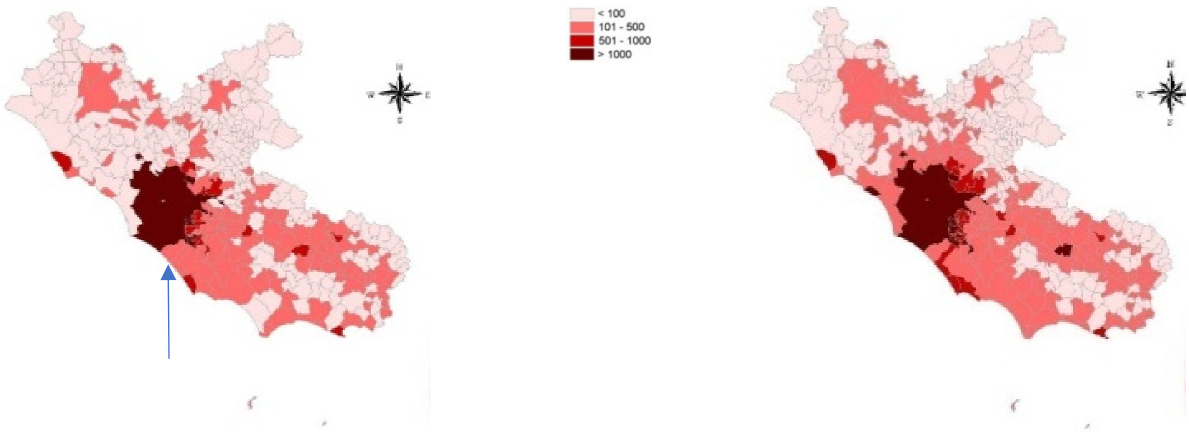

Figure 1. Population density (inhabitants/km^2) in Latium municipalities at the beginning ((**left**): 1970) and the end ((**right**): 2020) of the study period; blue arrow indicates the position of Rome's municipality.

Searching for a less crowded and polluted place to live, lower rents and housing costs, and improved mobility thanks to the expansion of roads and rail connections, are just some of the possible drivers of suburbanization [27]. Such changes had inevitably caused harmful consequences for the environment and rural landscapes at large, triggering land consumption in fringe districts [29]. In addition to direct effects such as a significant increase in air, noise, and light pollution, the construction of new buildings for housing, industries, and infrastructures, has determined an intense fragmentation of rural habitats, reflecting the economic decline of farmland mosaics [31]. These habitats have assured, for a long time, important ecosystem services and ecological functions, protecting biodiversity and agro-diversity, and guaranteeing local incomes and a relative wellbeing to rural communities [30].

2.2. Data Sources

The surface area of the most representative crops in the rural landscape of the Latium region was quantified at three survey waves in 1970, 1990, and 2020 at the municipal (Nuts-5) level, using the aggregate information released by the general Censuses of Agriculture produced and released for Italy by the National Institute of Statistics, Istat [36]. Rural land-use included eight basic classes, both annual crops (wheat, other cereals, arable land, and grasslands) and perennial crops (orchards, grapevines, and olive groves), together with the Agricultural Utilized Area (AUA) as a whole. The amount of rural woodlots within each surveyed farm was finally quantified. AUA, rural woodlots, and other minor non-agricultural use of land within farms constitute the total agricultural area (hereafter ATA), following the definition of agricultural censuses. Municipal boundaries in Latium have weakly changed between 1970 and 2020, and few new units were created within the study area [29]. To make the data collected at the municipal level fully comparable over the different censuses, we re-proportionated the surface area of each land-use type to the most recent boundaries (2020) via raster calculation in a Geographic Information System (GIS) environment [18].

2.3. Elementary Variables and Thematic Indicators

Considering the eight classes mentioned above, elementary variables were calculated as the per cent share of each land-use surface in the Agricultural Utilized Area (AUA) of each municipality [40]. Additionally, two simplified land-use indicators (hereafter INT and WOO) have been introduced and calculated, respectively, as proxies of farming "intensification" and "extensivation" [21], at the same spatial and temporal scale (covering all municipalities of the Latium region for 1970, 1990, and 2020). Providing insights, together, on environmental quality of rural landscapes and long-term processes underlying land-use change [41], application of the same experimental design as far as spatial and temporal coverage is concerned, assured a substantial comparability of the empirical results, irrespective of the statistical technique adopted here to analyze data [18,21,40].

Such indicators were respectively calculated as the relative share (i.e., proportion from 0 to 1) of (i) intensive crops' surface area in total municipal AUA (INT), and (ii) rural woodlands (i.e., woodlots specifically insisting in the surveyed farm area) in total municipal AUA (WOO). More specifically, the crop intensity indicator focuses on the agricultural area invested in supposedly intensive crops (i.e., potatoes, vegetables, vines, citrus fruits, fruit trees). Based on earlier evidence, INT can be used to monitor the evolution of landscapes associated with intensive forms of agriculture as well as to obtain information on the degree of land exploitation [21]. At the same time, a diachronic time-series of the WOO indicator can be used to estimate the evolution of remote landscapes in rural areas because the extension of woodland in a farm's area is considered a proxy of extensive cropping systems [40].

As a matter of fact, they form a biodiversity-rich landscape matrix typical of remote districts of Central Italy, mixing herbaceous and tree crops (olive groves and vineyards) with shrubs, pastures, and grasslands. Both indicators were frequently used in national monitoring schemes informing local, regional, or communitarian policies [40], and were supported by extensive evidence from academic literature (see [21] and references therein). Despite being economically viable and highly productive from the perspective of the primary sector, this landscape matrix assures, in turn, ecosystem services and ecological functionality, the conservation of biodiversity stock, and local communities' wellbeing [42].

2.4. Statistical Data Analysis

A multiway factor analysis (MFA) of the per cent share of eight rural land-use types (see above) in total agricultural landscape—whose measure was made available at the municipal level—was run considering three representative years (1970, 1990, and 2020) along the time window investigated in this study. MFA is a generalization of the well-known principal component analysis (PCA), whose main goal is to analyze (possibly large) sets of input variables (in our case, land-use types) collected on the same set of observations (in our case, municipalities), basically organized into a two-way input table [43]. As a generalization of PCA to three-way input matrices (thus incorporating a third analysis' dimension, namely time), the objectives of MFA are (i) to compare and analyze the relationship between different data sets, (ii) to combine them into a common structure called "compromise", investigated via spectral decomposition to reveal the common structure between the observations, and finally (iii) to project each of the original data sets into the compromise to delineate communalities and discrepancies across observation units [44]. The weights used to compute the compromise matrix are chosen to make it as representative of all the data sets as possible [31].

MFA allows to evaluate if the position of the input variables (in our case, rural land-use classes) is stable or changing over time, summarizing RLUCs by projecting them into the same factor plane [43], and thus delineating graphical "trajectories" that represent the linear (or non-linear) evolution of rural land-use in the study area and the related intensity of change [41]. Direction of change (intrinsically reflected in the pattern of similarities (or differences) in the trajectories of individual land-use types) and intensity of change (reflected in the length of the single arrow connecting the relevant points projected over the same factorial plane) were the two constituting dimensions of (rural) landscape transformations in a given area [44]. They were represented over the factorial plane, distinguishing a first time interval (1970–1990) from a second one (1990–2020), with the aim of identifying possibly heterogeneous patterns of change [18].

From a technical point of view, the generalized multivariate exploratory framework of MFA, deals with three-way data matrices describing a set of observations with multiple sets of variables having similar characteristics, e.g., being fully quantitative from a statistical point of view [43]. From a descriptive (non-probabilistic) perspective, MFA combines a cross-section principal component analysis (PCA) through (i) spectral decomposition of a correlation matrix computed on the input dataset with (ii) investigation of the time-series dimension balancing data matrices' contribution to the overall variability. Input variables were standardized prior to analysis [44]. If all the sets of variables are introduced as active elements (like in a general factor analysis), i.e., without balancing their influence, a single set can contribute to the construction of the first two axes. Based on these considerations, MFA introduces a generalized, weighted factor analysis with constant weights for the variables of the same group and varying weights assigned to variables belonging to different groups. Going beyond repeated (partial) factor analyses as the number of variables' groups [32], a global analysis in an MFA perspective is defined when two (or more) sets of variables are simultaneously introduced as active ones and require balancing the influences of these sets or groups.

The influence of one set derives from its matrix structure, in the sense of its inertia distribution in the different space directions. For instance, if a set presents a high inertia in one direction, this direction will influence the first axis of the global analysis [44]. This requires a normalization of the highest axial inertia of each set. Balancing the maximum axis' inertia rather than the total inertia gives the MFA important properties that can be used in several applications. Weights are constructed in a way that the maximum axial inertia of a variable's group is equal to unity, i.e., assigning a weight equal to the inverse of the first eigenvalue of the group's factor analysis to each within-group variable [43].

As an exploratory analysis not grounded on hypothesis testing, the selection of significant dimensions (hereafter, axes) in the MFA was based on *a-priori* eigenvalue thresholds similar to PCA [31]. At the same time, MFA provides classical outputs of a general factor analysis, including, for each axis: (i) coordinates, contributions, and squared cosines of individuals, as well as (ii) correlation coefficients between factors and continuous variables [41]. We specifically considered the trajectories of loadings (1970, 1990, and 2020) related to each input variable (land-use types) when defining the main (independent for construction) dimensions of landscape transformations in the study area [29]. MFA results thus allow an explicit evaluation of changes over time in the position of each unit since they are projected into the same factorial plane [19].

3. Results

3.1. Exploring Basic Trends in Rural Landscapes over Time

Rural landscapes in Latium underwent a substantial change in the last 50 years (Table 1). Farm density decreased from 14 farms per km^2 to 6 farms per km^2, with a substantial increase in the average farm size (from 4 ha to 6.5 ha), indicating a moderate trend toward agglomeration and scale reflected in agrarian re-composition processes. They included individual farms' fusions toward bigger activities, managing more land for productive reasons. Within rural spaces, the net surface of agricultural utilized area, AUA (i.e., the truly productive farming space, excluding rural areas that are not directly involved in crop productions), was rather stable during the study period, ranging between 67% and 71%. It means that the agricultural sector maintained its economic potential over time, balancing individual trends toward 'intensification' (with a net expansion of AUA against stable ATA) or 'extensivation' (with a net decline of AUA against stable ATA).

Table 1. Selected indicators delineating rural land-use trends in Latium, including farm concentration (per km^2), the absolute ratio of agricultural utilized area (AUA) per farm (ha), the per cent ratio of AUA to total agricultural area (ATA) and the per cent ratio of ATA to the total regional surface area of Latium by year.

Variable	**1970**	**1990**	**2020**
Farm density	13.8	13.0	5.8
AUA/Farm	4.1	3.7	6.5
AUA/ATA	67.4	68.6	70.9
ATA/Total area	84.8	71.2	52.9

However, the total agricultural area (ATA) decreased rapidly over time from 85% to 53% of the regional surface area. It means that, in Latium, nearly half of the territory is actually used for non-agricultural destinations (e.g., urban, industrial, infrastructure, tourism development, forests, and other non-agricultural, non-urban land use). Being common to other European regions, especially those located in the Mediterranean countries, the inherent contraction of agricultural land corresponded with rather differentiated trends within rural landscapes, that will be explored in the following sections.

3.2. Investigating 'Intensification' or 'Extensivation' Processes in Rural Spaces

In line with the assumptions illustrated in Section 3.1, trends toward farming 'intensification' or 'extensivation' in Latium regions indicated substantial stability or, in both cases, a weak decline between 1970 and 2020 (Table 2). Considering, on a comparative basis, the two indicators of INT and WOO together, calculated as relative proportions (from 0 to 1), it is clear how more than 6–7 out of 10 hectares of Agricultural Utilized Area (AUA) were classified as intensively farmed (INT). The proportion was relatively stable or weakly declining from 0.66 (1970) and 0.67 (1990) to 0.62 (2020). At the same time, assuming rural woodlands as a part of the agricultural total area (ATA) not forming the AUA stock, it is also clear how the surface area of woodlots within Latium farms represented a substantial share of the ATA. In other words, 5.9 ha of rural woodlands out of 10 ha of AUA were observed in the Latium region for 1970, 5.7 ha out of 10 ha for 1990, and 5.3 ha out of 10 ha for 2020. At the (aggregate) regional level, these findings indicate a substantial balance of 'intensification' and 'extensivation' processes against the overall decline of agricultural surfaces over time, possibly meaning that economic dynamics of rural development may adjust to the available land resources.

Table 2. Statistical distribution of farmland intensity (INT) and rural woodland (WOO) indicators (relative proportion in total area); INT and WOO, respectively, reflect economic processes and trends leading to "intensification" or "extensivation" of Latium farms, Central Italy, by year and elevation belt.

Elevation Belt	INT			WOO		
	1970	1990	2020	1970	1990	2020
Lowlands	0.84	0.89	0.90	0.15	0.17	0.15
Uplands	0.77	0.78	0.74	0.30	0.38	0.32
Mountains	0.42	0.41	0.33	1.24	1.02	0.99
Total	0.66	0.67	0.62	0.59	0.57	0.53

More specifically, Table 2 compares the average values of the two selected indicators (INT and WOO) by elevation belt in Latium. A moderate increase of INT (reflecting higher crop intensity) was observed in already intensified contexts, such as lowland districts. In 1970, 8.4 out of 10 hectares of lowland AUA were classified at high crop intensity, rising to 9 hectares out of 10 hectares of AUA in 2020. A significantly lower level of intensification was observed in mountainous districts, since 4.2 hectares out of 10 ha of AUA were classified as farming-intensive in 1970 and only 3.3 hectares in 2020. Upland districts maintained an intermediate level of crop intensification, being rather stable over time and ranging between 0.77 (1970), 0.78 (1990), and 0.74 (2020).

The reverse pattern was observed in the distribution and extension of rural woodlands in active farms. While being extensively represented in mountainous districts, a moderate reduction of woodlots' surface area coincided with a reduction in the economic importance of local-scale (within-farm) forestry, possibly shifting to regional clear-cutting operations in public woodlands, likely to be more economically viable because of the predominance of scale and agglomeration forces. As a matter of fact, in the mountain elevation belt, rural woodlands' extension overpassed the total AUA in 1970 (24% more) and was aligned with the total AUA in 2020. Conversely, the extension of rural woodlands remained almost constant in respect with the corresponding AUA (15–17%) in lowlands, displaying instead a slight increase in hilly areas. These districts were experiencing vastly differentiated paths of rural development, in-between agricultural "extensivation" and sparse signals of production recovery, especially in some dynamic areas along the fringe of intermediate towns.

The explicit geography of INT and WOO was illustrated in Figures 2 and 3 at the three study years. The highest values of INT (Figure 2) were recorded along the Tyrrhenian coastal strip (INT > 0.75), with the only exception of Monti della Tolfa, a hyper-rural, depopulated district close to the sea in-between Viterbo and Rome provinces. Inland districts were instead classified at medium-low crop intensity (0.25 < INT < 0.75), unless Ciociaria (Frosinone province) and Sabina (Rieti province), two territories with long-established farming systems and very traditional agronomic practices and productions (olive, wine, vegetables, livestock). The geography of low-intensity farming systems (INT < 0.25) precisely follows the elevation gradient, being concentrated in mountainous districts inland.

The distribution of the WOO indicator in Latium municipalities was mapped in Figure 3 diachronically for 1970, 1990, and 2020. According to the elevation gradient, the highest values of WOO (>1) were observed in inland, mountainous districts of the Apennines chain (Rieti province) where farmland mosaics are frequently intermixed with some (deciduous) woodlots within the farm boundaries, especially in sloping areas. On average, more than one hectare of woodlands was available to farmers for each hectare of utilized agricultural land in such districts. Values of WOO below 0.25 were systematically observed in lowland districts of Viterbo and Latina provinces and in the large part of Rome province because of the increasing human pressure due to intense urbanization. In line with the aggregated results presented in Table 2, maps revealed that WOO maintained almost stability along coastal areas over the study period, where woodlots' surface area represented less than 10% of the rural land-use classes in several municipalities with flat orography.

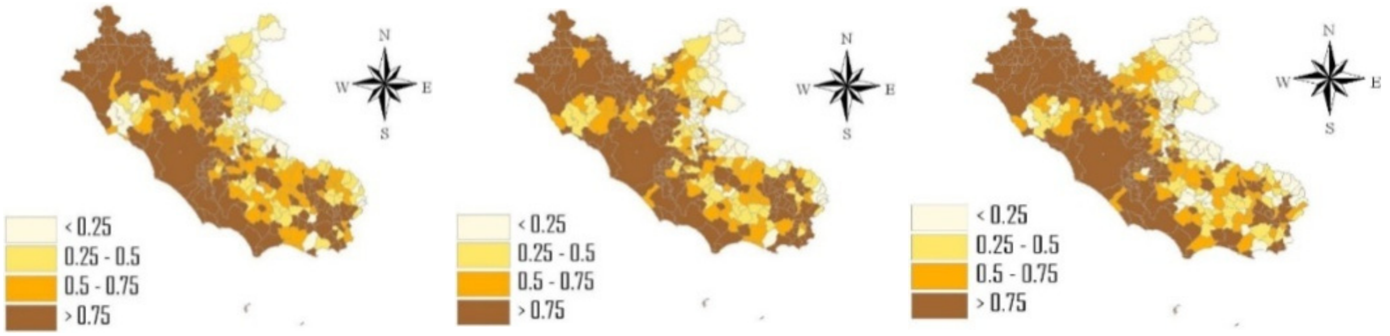

Figure 2. The spatial distribution of cropland intensity indicator (INT) expressed as relative proportion in Latium municipalities as a proxy of farm systems' intensification, by year ((**left**): 1970; (**middle**): 1990; (**right**): 2020); see text for details.

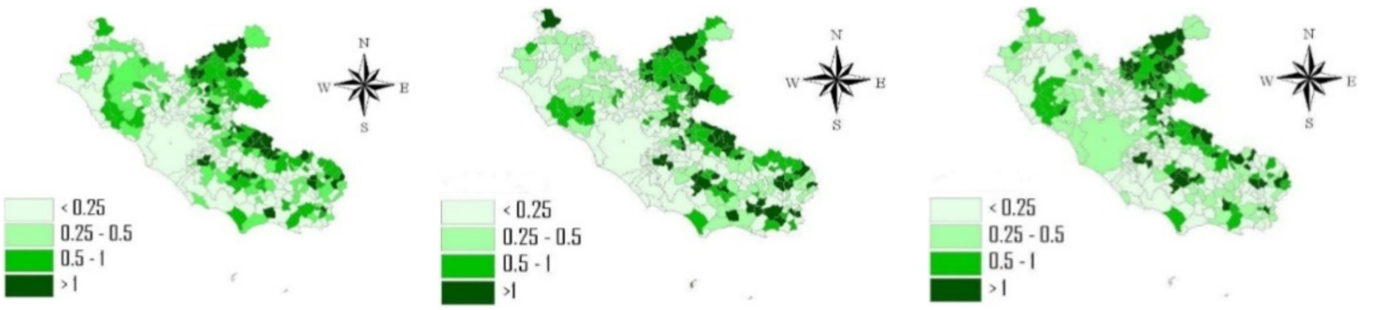

Figure 3. The spatial distribution of the rural woodland indicator (WOO) as a proxy of farming systems' extensivation in Latium municipalities, by year ((**left**): 1970; (**middle**): 1990; (**right**): 2020); see text for details.

While 'intensification' and 'extensivation' processes evolved under a balanced path over time at the regional scale (Latium), a more detailed analysis considering provinces and elevation belts delineates different trajectories of rural development. A strong competition on land was observed in lowland districts and favored crop intensification; a lower level of competition was instead recorded in mountainous districts, leveraging land abandonment and on-farm forestry, taken as a signal of 'extensivation'. As a matter of fact, the empirical results of a non-parametric correlation analysis between INT and WOO values (Figure 4) delineate a substantial, negative relationship between the two processes along the elevation gradient from lowlands to mountainous districts, reflecting an intense 'land competition' between 'intensification' and 'extensivation' processes. These results also confirm the ability of both INT and WOO indicators to depict the progressive 'intensification' or 'extensivation' of local agricultural systems if monitored over sufficiently long time intervals. Crop intensity, as a proxy of a progressive intensification of farming systems, was associated with a decline in rural forestry at the same observation scale (namely, province and elevation belt). This is also due to the inherent depopulation of mountainous municipalities and the consequent abandonment of cultivated land in remote districts. However, in more urbanized districts, the two indicators have shown less intense dynamics, likely because of the negative impact of urbanization on both agricultural processes.

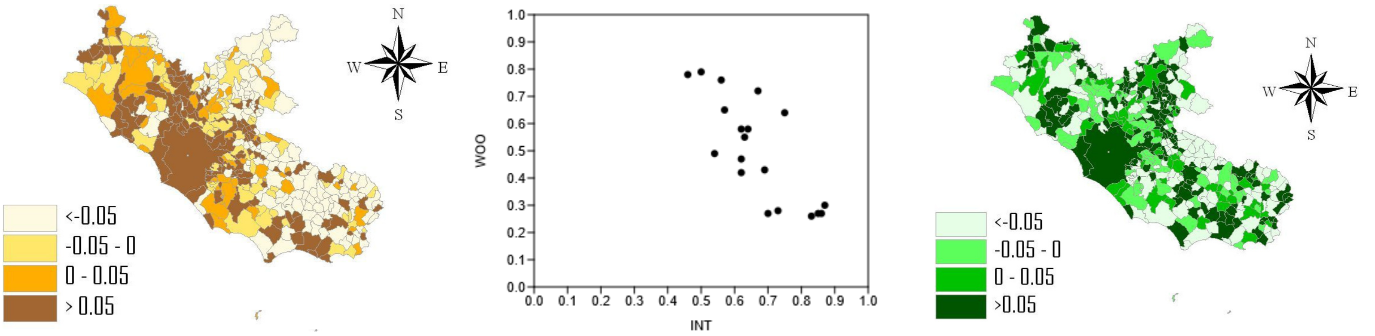

Figure 4. The relationship between the average INT and WOO indicators' values in Latium provinces and elevation belts at the beginning (1970) and end (2020) of the study period (**middle**); the relationship illustrated in the central scatterplot was significantly negative (Spearman rank correlation test, non-parametric $r_s = 0.59$, $p < 0.05$); left and right maps respectively indicate the per cent share of change in both INT (**left**) and WOO (**right**) during the study period, 1970–2020.

3.3. Results of a Multiway Factor Analysis Illustrating Rural Land-Use Trajectories in Latium, 1970–2020

A multiway factor analysis (MFA), an exploratory multivariate technique delineating and summarizing land-use changes (namely, 'trajectories' over 1970–1990 and 1990–2020), extracted two principal axes (i.e., research dimensions with a specific relationship with each individual rural land-use class), respectively accounting for 25% and 14% of the total variance. This extraction was associated with a magnification index of 2.6, which indicates a particularly appropriate analysis based on the input matrix. Considering the total number of input variables (n = 8) and observations (n = 378 municipalities), the remaining axes (or, better, factors) were considered as providing, individually, a less relevant contribution to the total data matrix variance. Therefore, the analysis concentrated on the first two axes regarded as the most important, independent dimensions of landscape transformation in the investigated rural space. Standardized correlations among MFA matrices (depicting the intensity and spatial direction of overall changes in rural land use during 1970–1990 and 1990–2020) were, respectively, 0.66 and 0.78 for 1970–1990 and 1990–2020, meaning that the geographical structure of rural land-use change was more similar for 1990–2020 than for 1970–1990. These results confirm the intense transformations of both urban and rural landscapes observed between 1970 and 1990 in Latium as a result of accelerated demographic dynamics, late industrialization, and tourism concentration in coastal areas competing with traditional agriculture for land.

Considering together land-use types such as wheat, other cereals, vegetables, grasslands, vineyards, olive groves, orchards, and the amount of agricultural utilized area (AUA) as an input variable delineating background trends in the region, MFA graphical results (Figure 5) identify distinctive changes over time in the surface area invested into arable land and tree crops (olive, vine, fruits). Axis 1, explaining the largest part of the variance illustrated in the MFA plot, segregated land-use types according to an agronomic gradient distinguishing traditional tree crops (e.g., olive groves, vineyards, orchards) associated with the positive values of axis 1, and selected annual (herbaceous) crops, such as wheat, other cereals, and grasslands, negatively associated with axis 1. Axis 2 distinguished the aggregated dynamics of AUA and, less evidently, of orchards along the positive side of the axis from the explicit dynamics of the remaining land-use types, more or less intensively associated with the negative side of axis 2.

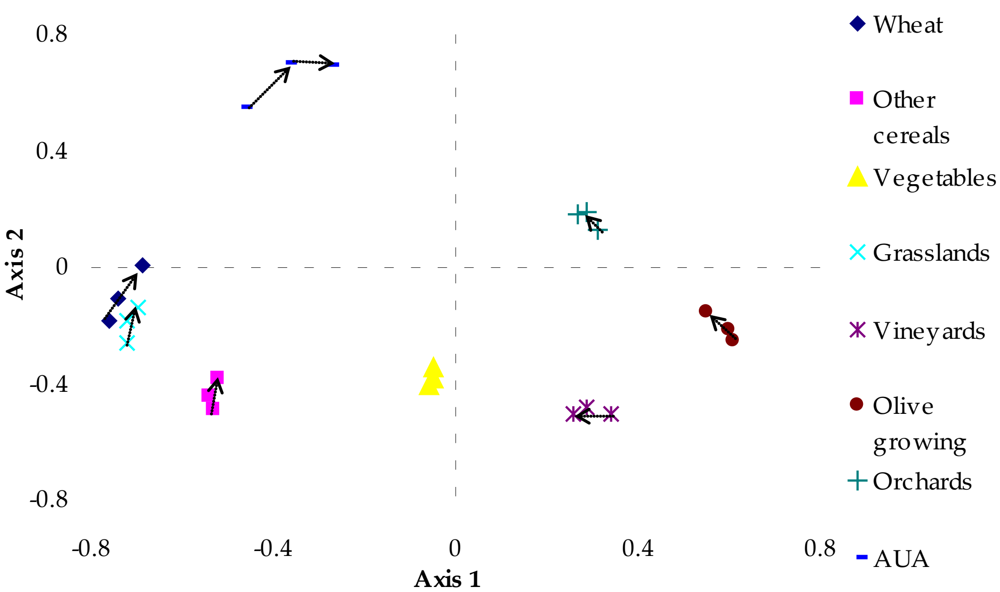

Figure 5. Results of a multiway factor analysis of rural land-use change (1970, 1990, 2020) in Latium region (AUA means agricultural utilized area, and indicates the extent of rural landscapes with economic value); the main agricultural types of land-use were considered here from comparable information released by agricultural censuses over time.

The most relevant axes of MFA clearly delineate a similar trajectory of change in both tree crops (orchards, vineyards, and olive groves)—being closely associated and showing a common trend toward less negative values of axis 1. This trajectory indicates (more or less intense) dynamics toward declining surface areas. Although being represented along the reverse side of the axis, wheat and, less evidently, other cereals, grasslands, and vegetables showed a declining trajectory over time. Considering the intensity of change (graphically estimated with the respective arrow's length), wheat and olive groves experienced a rapid transformation, with decreasing surface areas against the evolving rural landscape. Moderate transformations were observed for vineyards, grasslands, and other cereals. Minor transformations were instead recorded, based on the same graphical criterion, for orchards and vegetables. A similar, but likely more intense, trend was observed for AUA along axis 2. Explicit dynamics of this aggregate land-use type indicate a mixed trajectory, basically more intense along the first observation period (1970–1990) and less intense, while not completely linear, along the second time period (1990–2020). This trend suggests a rather complex evolution of the agricultural surface area toward (more or less intense) declines over time, in line with the information derived from descriptive statistics (Section 3.1), and thematic indicators/correlation analysis (Section 3.2).

The empirical results from MFA, as they were illustrated in Figure 5 and briefly described above, can be read in light with another statistical evidence of change, e.g., considering an indicator of climate warming of interest for agronomic practices and agricultural productions. This indicates soil aridity—a value that informs, together, about the reduction of total rainfall and the synchronic increase of reference crop evapotranspiration because of local warming. Wheat, a rain-fed crop moving along the first MFA axis toward positive values, showed an evident decrease in the invested surface areas at the regional scale and a relocation from their traditional sites in Latium (i.e., plains) to mountainous areas—according to recent literature evidence [32]. This individual process of landscape transformation can be related to the increasing aridity of flat areas, as documented in Figure 6. As a matter of fact, the two maps in Figure 6 delineate a particularly high 'average' soil aridity index (IA < 0.95) estimated at the beginning of the study period (1961–1970) along the coastal rim from Rome to Viterbo (the driest district in Latium), with increasing IA values, representative of more humid climate conditions, in mountainous locations of Rieti and Frosinone provinces.

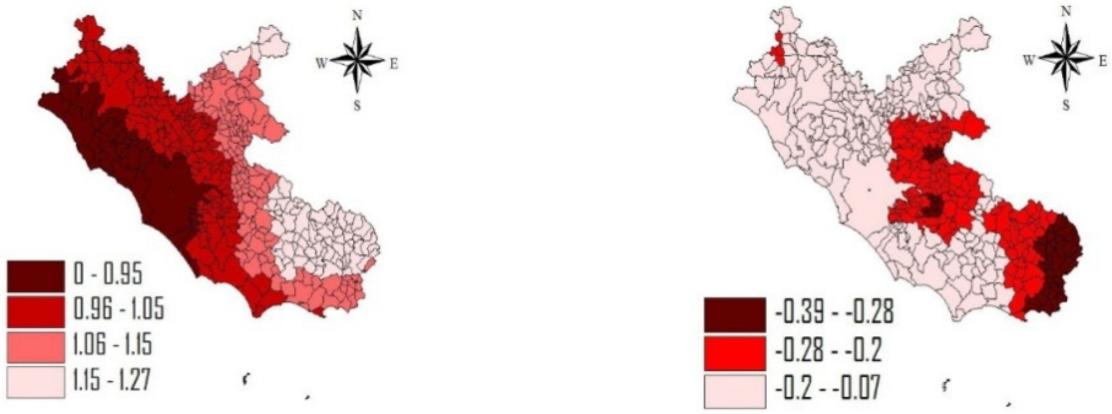

Figure 6. Average values of a soil aridity indicator (1961–1970), calculated as the ratio of total rainfalls to total potential evapotranspiration on an annual basis, by municipality in Latium ((**left**); smaller values indicate a higher level of soil aridity); per cent change over the study period, namely the last fifty years, 1970–2020 (**right**); decreasing values of the indicator means higher soil aridity as a consequence of climate change and local warming, with impact on regional agricultural systems.

Similarly to wheat, a comparable change over time was observed for olive groves, grasslands, and, partly, vineyards, and may be possibly associated with a progressive aridity observed between 1970 and 2020 in traditional and highly specialized rural districts, such as Sabina (Rieti province) for olive groves, Castelli Romani (Rome province) for vineyards, and Ciociaria (Frosinone province) for grasslands. Decreasing surface areas of traditional land use (such as cereals and olive groves in Latium) and a more localized spreading of some high-intensity crops (such as vegetables) may reduce the quality of rural landscapes, especially in areas featuring a 'historical attitude' to agricultural production under traditional farming systems, e.g., the so-called 'Agro Romano' land close to Rome, a soil being continuously cultivated since antiquity. Moreover, it could negatively affect rural biodiversity and pose questions on the long-term sustainability of local agricultural systems continuously exposed to global change.

4. Discussion

Landscape patterns are a product of multiple physical, ecological, and cultural processes operating over a relatively large geographical coverage [45]. Geology, topography, soils, human disturbance, and land use all have an impact on how the various landscape features are arranged and spatially related. Structure (the spatial arrangement of landscape features), ecological functions (how ecological processes function within that structure), and change dynamics (such as disturbance and recovery) are the defining characteristics of landscapes [46]. Agro-ecosystems, assumed as key components of rural landscapes in Europe, play a crucial role in maintaining biological diversity and supporting local economies, especially in countries with a millenary tradition of primary productions, such as in the Northern Mediterranean basin [47]. However, intense land-use change following agricultural intensification or cropland abandonment in rural areas mixed with more general processes of urbanization, industrialization, and tourism concentration leading to landscape simplification in the surrounding, non-rural districts poses significant challenges to the ecological stability and functionality of these ecosystems in a context of climate warming [23].

Brought on by various economic activities that may have a significant impact on a number of human life events, these changes often take place gradually, but they can have a significant effect on ecosystems since they are linked to losses in species' diversity and animal/plant populations [35]. In this ambit, a truly difficult aspect of land science deals with the intimate comprehension and forecasting of landscape change [2]. Rural land-use changes, and especially those resulting in cropland intensification, may have ecological consequences and, thus, require continuous monitoring to ensure the long-term sustainability of agricultural productions and the safe functioning of agro-ecosystems [40]. In fact, intensive agricultural landscapes were demonstrated to be often sensitive to soil degradation and poor in biological diversity [5]—not only for their conditions of isolation and fragmentation—but, in a broader sense, for the intrinsic effect of human pressure (e.g., increasing urbanization, soil and water pollution, industrialization, tourism development, increased road accessibility, and infrastructure expansion). One of the objectives of the agro-environmental measures introduced in the Common Agriculture Policy (CAP) of the European Union targets the mitigation of any ecological pressure stemming from agriculture intensification of rural landscapes [27].

Assuming these challenges are crucial in a refined comprehension of local vs. regional land-use trends along sufficiently long time windows, the present study provides a simplified framework for the evaluation of RLUC. It was based on the integration of three operational steps (descriptive statistics, elementary indicators, and an exploratory multivariate analysis), which have been tested on a rural landscape in an extensive Mediterranean region [39]. This analysis was carried out on a single data source (agricultural censuses), assuring the requested temporal coverage [3]. Long-term monitoring involved the use of administrative inventories and simplified land configuration indicators. In particular, the cropping intensity index and the rural forest index were used to estimate 'intensification' and 'extensivation' dynamics in local farming systems [35]. MFA was further applied to the same empirical data with the aim of describing stability (or change over time) in land-use types [30].

The study revealed multiple trajectories of rural landscape change that vary significantly between coastal and inland districts [28]. In lowlands, agricultural intensification and marginal urbanization were assumed as the main driving forces of landscape transformation, while farm abandonment was a dominant process at the base of landscape fragmentation in more remote districts [21]. This process led, mostly in intermediate districts, to a latent process of land 'extensivation' associated with the expansion of rural forests in areas where agriculture was progressively abandoned [37]. The empirical evidence from our study also highlights the different impacts of these changes on the environmental quality at large [32]. The intensification of agriculture in lowlands has possibly led to ecological simplifications of the landscape matrix, negatively affecting ecosystems' functionality [33]. Conversely, inland 'extensivation' has had a mixed effect, allowing the recovery of natural vegetation, but sometimes limiting the biodiversity specific to traditional agro-ecosystems [36].

The thematic indicators illustrated in this study, either quantifying crop intensification or rural woodland expansion as a result of land abandonment processes in traditionally agricultural districts, may provide detailed information at both regional and local scales based on official statistics and national land-use inventories [8]. In combination with other statistics, such information may describe land-use changes over time and estimate possible gains (or losses) in environmental quality [6]. In the study area, both indicators reflect the principal trends in land use anticipated at a larger scale [5]. As found for similar indicators derived from administrative inventories, both quantities were easily calculated from statistical data sources available at local scales (e.g., through the national censuses of agriculture) and frequently updated, e.g., every ten years [9]. Moreover, our contribution suggests an integrated evaluation of the different aspects of RLUC based on an MFA approach [41]. Such procedure allows a summary analysis of RLUC based on long time-series data, delineating—in a simplified graphical form—land-use 'trajectories' focusing on the intrinsic dimension of linear (or non-linear) development over time, in line with the mainstream literature of landscape science [12–14].

The novelty of this contribution lies in the integrated evaluation of rural land-use change based on comparable statistical inventories encompassing sufficiently long time intervals that are not directly covered from other information sources, such as remote sensing or field surveys [7]. Based on such a data source, the proposed framework may represent a basic tool for political actions (e.g., rural development strategies) aimed at mitigating environmental degradation at the most appropriate geographical and administrative scale, moving from regional to local intervention levels [17]. Assuming measurement of both size and spatial organization of both natural and anthropogenic habitats as an easier task, this rationale can be mentioned behind the inclusion of land-use change in a specific analysis of the environmental effects of agriculture on food and bio-based goods [22].

As a future research line, multidisciplinary studies on land-use change should increasingly relate to (and cope with) different fields, e.g., sociology, geography, demography, and economics [42]. In this perspective, an additional topic that is indirectly associated with the results of the present contribution is the continuous expansion of cities [46]. Urbanization is demonstrated to play a crucial role in RLUC [18]. The disproportionate land conversion in housing and urban facilities immediately leads to a sudden decrease in agricultural areas, not only along the fringe but also in more remote territories [19]. Therefore, the loss of agricultural land is possibly associated with a limited awareness of the mechanisms at the base of RLUC [5]. Social, economic, and environmental issues result in the loss of agricultural land [1,4], as our approach was able to underline specifically for Rome's prefecture, a specific portion of the study area experiencing massive expansion of urban settlements between 1970 and 2020 [33]. Following such empirical evidence, our monitoring scheme indirectly assesses urbanization prospects as an increasingly fast process of housing and human intervention with direct and indirect impacts on agricultural lands [28,32,36]. As envisaged in our empirical results—both via indicators and MFA—rural transformations in peri-urban areas, as a consequence of RLUC [25], may impact agricultural productions, social and economic conditions of remote locations, and the effectiveness of Common Agricultural Policy measures at large [48,49].

5. Conclusions

Land-use change is assumed here as a mixed (environmental and socioeconomic) process involving (and being, in turn, affected by) multiple territorial conditions. To monitor RLUC changes in a Mediterranean region, we provided a valuable assessment of rural land-use dynamics in a context of climate change and increasing socioeconomic pressure, implementing an integrated statistical approach based on data collected over fifty years (1970–2020) at the municipal scale. By highlighting regional differences and the ecological implications of RLUC, our research contributes to a better understanding of how land management policies can be adapted to support long-term ecological and economic sustainability. Based on empirical results, deeper research on the specific impact of different forms of RLUC on ecosystem services is recommended. It would also be useful to extend the assessment to other Mediterranean regions with the aim of confirming the generality of the findings and to develop land management policies that are widely applicable to different socioeconomic contexts. In this perspective, the outcomes of this study definitely support integrated land management strategies that account for regional variability and promote agricultural practices that protect ecological diversity. This is essential for maintaining functional (and resilient) rural landscapes in the face of climate change.

Additionally, changes in rural land use are hypothesized to affect the structure and functions of traditional (and, possibly, high-biodiversity) agricultural ecosystems and farming mosaics. In this perspective, it is challenging to monitor the different components of biodiversity on a local, regional, and global basis. The present monitoring scheme, based on freely and widely accessible data sources that are comparably released in many advanced economies and emerging countries, may contribute to such deserving issues. The official dissemination of geographical data on rural land-use trends at a sufficiently detailed spatial resolution and covering appropriately long time windows contributes to assessing, at least indirectly, landscape quality, as the two indicators presented in this study specifically demonstrate. The empirical results of this kind of study may finally guide political action that can improve sustainable land management under climate aridity and local warming, e.g., reducing soil degradation in ecologically fragile areas.

Author Contributions: Conceptualization, C.C. and F.M.C.; methodology, L.S.; software, M.M.; validation, D.S., M.M. and S.B.; formal analysis, G.Q.; investigation, R.S.; resources, G.Q.; data curation, D.S.; writing—original draft preparation, L.S. and F.M.C.; writing—review and editing, G.Q. and R.S.; visualization, M.M.; supervision, S.B.; project administration, C.C.; funding acquisition, D.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Official statistics released by the Italian National Statistical Institute (Istat) were used in this study.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Antrop, M. Changing patterns in the urbanized countryside of Western Europe. *Landsc. Ecol.* **2000**, *153*, 257–270. [CrossRef]
2. Zipperer, W.C. Species composition and structure of regenerated and remnant forest patches within an urban landscape. *Urban Ecosyst.* **2002**, *64*, 271–290. [CrossRef]
3. Sirami, C.; Nespoulous, A.; Cheylan, J.P.; Marty, P.; Hvenegaard, G.T.; Geniez, P.; Schatz, B.; Martin, J.L. Long-term anthropogenic and ecological dynamics of a Mediterranean landscape: Impacts on multiple taxa. *Landsc. Urban Plan.* **2010**, *96*, 214–223. [CrossRef]
4. Antrop, M. Landscape change and the urbanization process in Europe. *Landsc. Urban Plan.* **2004**, *67*, 9–26. [CrossRef]
5. Jiang, L.; Zhang, Y. Modeling urban expansion and agricultural land conversion in Henan Province, China: An integration of land use and socioeconomic data. *Sustainability* **2016**, *8*, 920. [CrossRef]
6. Kerckhof, A.; Spalevic, V.; Van Eetvelde, V.; Nyssen, J. Factors of land abandonment in mountainous Mediterranean areas: The case of Montenegrin settlements. *SpringerPlus* **2016**, *5*, 485. [CrossRef]
7. Tonini, M.; Parente, J.; Pereira, M.G. Global assessment of rural-urban interface in Portugal related to land cover changes. *Nat. Hazards Earth Syst. Sci.* **2018**, *18*, 1647–1664. [CrossRef]
8. Kerr, J.T.; Cihlar, J. Land use and cover with intensity of agriculture for Canada from satellite and census data. *Glob. Ecol. Biogeogr.* **2003**, *12*, 161–172. [CrossRef]
9. Lubowski, R.N.; Plantinga, A.J.; Stavins, R.N. What drives land-use change in the United States? A national analysis of landowner decisions. *Land Econ.* **2008**, *84*, 529–550. [CrossRef]
10. Wu, Y.; Li, S.; Yu, S. Monitoring urban expansion and its effects on land use and land cover changes in Guangzhou city, China. *Environ. Monit. Assess.* **2016**, *188*, 54. [CrossRef]
11. Bielsa, I.; Pons, X.; Bunce, B. Agricultural abandonment in the North Eastern Iberian Peninsula: The use of basic landscape metrics to support planning. *J. Environ. Plan. Manag.* **2005**, *48*, 85–102. [CrossRef]
12. Su, S.; Wang, Y.; Luo, F.; Mai, G.; Pu, J. Peri-urban vegetated landscape pattern changes in relation to socioeconomic development. *Ecol. Indic.* **2014**, *46*, 477–486. [CrossRef]
13. Thompson, J.D. Plant Evolution in the Mediterranean. *Plant Evol. Mediterr.* **2007**, *32*, 35–43. [CrossRef]
14. Theobald, D.M.; Romme, W.H. Expansion of the US wildland-urban interface. *Landsc. Urban Plan.* **2007**, *83*, 340–354. [CrossRef]
15. Badia, A.; Serra, P.; Modugno, S. Identifying dynamics of fire ignition probabilities in two representative Mediterranean wildland-urban interface areas. *Appl. Geogr.* **2011**, *31*, 930–940. [CrossRef]
16. Badia-Perpinyà, A.; Pallares-Barbera, M. Spatial distribution of ignitions in Mediterranean periurban and rural areas: The case of Catalonia. *Int. J. Wildl. Fire* **2006**, *15*, 187–196. [CrossRef]
17. Arena, S.; Roda, I.; Chiacchio, F. Integrating Modelling of Maintenance Policies within a Stochastic Hybrid Automaton Framework of Dynamic Reliability. *Appl. Sci.* **2021**, *11*, 2300. [CrossRef]
18. Duvernoy, I.; Zambon, I.; Sateriano, A.; Salvati, L. Pictures from the other side of the fringe: Urban growth and peri-urban agriculture in a post-industrial city (Toulouse, France). *J. Rural Stud.* **2018**, *57*, 25–35. [CrossRef]
19. Cecchini, M.; Zambon, I.; Pontrandolfi, A.; Turco, R.; Colantoni, A.; Mavrakis, A.; Salvati, L. Urban sprawl and the 'olive' landscape: Sustainable land management for 'crisis' cities. *Geojournal* **2018**, *84*, 237–255. [CrossRef]
20. Busch, G. Future European agricultural landscapes-What can we learn from existing quantitative land use scenario studies? *Agric. Ecosyst. Environ.* **2006**, *114*, 121–140. [CrossRef]
21. Salvati, L.; Macculi, F.; Toscano, S.; Zitti, M.; Ceccarelli, T. Comparing indicators of intensive agriculture from different statistical sources. *Biota* **2007**, *8*, 51–60.
22. Hamedani, S.R.; Kuppens, T.; Malina, R.; Bocci, E.; Colantoni, A.; Villarini, M. Life cycle assessment and environmental valuation of biochar production: Two case studies in Belgium. *Energies* **2019**, *12*, 2166. [CrossRef]
23. Plieninger, T.; Schaich, H.; Kizos, T. Land-use legacies in the forest structure of silvopastoral oak woodlands in the Eastern Mediterranean. *Reg. Environ. Chang.* **2011**, *11*, 603–615. [CrossRef]

24. Kosmas, C.; Karamesouti, M.; Kounalaki, K.; Detsis, V.; Vassiliou, P.; Salvati, L. Land degradation and long-term changes in agro-pastoral systems: An empirical analysis of ecological resilience in Asteroussia—Crete (Greece). *Catena* **2016**, *147*, 196–204. [CrossRef]
25. Marucci, A.; Colantoni, A.; Zambon, I.; Egidi, G. Precision farming in hilly areas: The use of network RTK in GNSS technology. *Agriculture* **2017**, *7*, 60. [CrossRef]
26. Petit, C.C.; Lambin, E.F. Impact of data integration technique on historical land-use/land-cover change: Comparing historical maps with remote sensing data in the Belgian Ardennes. *Landsc. Ecol.* **2002**, *17*, 117–132. [CrossRef]
27. Zasada, I. Multifunctional peri-urban agriculture—A review of societal demands and the provision of goods and services by farming. *Land Use Policy* **2011**, *28*, 639–648. [CrossRef]
28. Salvati, L.; Ferrara, A.; Chelli, F. Long-term growth and metropolitan spatial structures: An analysis of factors influencing urban patch size under different economic cycles. *Geogr. Tidsskr. Dan. J. Geogr.* **2018**, *118*, 56–71. [CrossRef]
29. Attorre, F.; Bruno, M.; Francesconi, F.; Valenti, R.; Bruno, F. Landscape changes of Rome through tree-lined roads. *Landsc. Urban Plan.* **2000**, *49*, 115–128. [CrossRef]
30. Salvati, L.; Gemmiti, R.; Perini, L. Land degradation in Mediterranean urban areas: An unexplored link with planning? *Area* **2012**, *44*, 317–325. [CrossRef]
31. Biasi, R.; Brunori, E.; Smiraglia, D.; Salvati, L. Linking traditional tree-crop landscapes and agro-biodiversity in central Italy using a database of typical and traditional products: A multiple risk assessment through a data mining analysis. *Biodivers. Conserv.* **2015**, *24*, 3009–3031. [CrossRef]
32. Recanatesi, F.; Clemente, M.; Grigoriadis, E.; Ranalli, F.; Zitti, M.; Salvati, L. A fifty-year sustainability assessment of Italian agro-forest districts. *Sustainability* **2016**, *8*, 32. [CrossRef]
33. Bajocco, S.; Ceccarelli, T.; Smiraglia, D.; Salvati, L.; Ricotta, C. Modeling the ecological niche of long-term land use changes: The role of biophysical factors. *Ecol. Indic.* **2016**, *60*, 231–236. [CrossRef]
34. Bianchini, L.; Egidi, G.; Alhuseen, A.; Sateriano, A.; Cividino, S.; Clemente, M.; Imbrenda, V. Toward a Dualistic Growth? Population Increase and Land-Use Change in Rome, Italy. *Land* **2021**, *10*, 749. [CrossRef]
35. Salvati, L.; Petitta, M.; Ceccarelli, T.; Perini, L.; Di Battista, F.; Scarascia, M.E.V. Italy's renewable water resources as estimated on the basis of the monthly water balance. *Irrig. Drain.* **2008**, *57*, 507–515. [CrossRef]
36. Sanderson, E.W.; Jaiteh, M.; Levy, M.A.; Redford, K.H.; Wannebo, A.V.; Woolmer, G. The Human Footprint and the Last of the Wild: The human footprint is a global map of human influence on the land surface, which suggests that human beings are stewards of nature, whether we like it or not. *Bioscience* **2002**, *52*, 891–904. [CrossRef]
37. Cavallo, A.; Marino, D. Understanding changing in traditional agricultural landscapes: Towards a framework. *J. Agric. Sci. Technol.* **2012**, *2*, 971–987.
38. Falcucci, A.; Maiorano, L.; Boitani, L. Changes in land-use/land-cover patterns in Italy and their implications for biodiversity conservation. *Landsc. Ecol.* **2007**, *22*, 617–631. [CrossRef]
39. Delfanti, L.; Colantoni, A.; Recanatesi, F.; Bencardino, M.; Sateriano, A.; Zambon, I.; Salvati, L. Solar plants, environmental degradation and local socioeconomic contexts: A case study in a Mediterranean country. *Environ. Impact Assess. Rev.* **2016**, *61*, 88–93. [CrossRef]
40. Perrin, C.; Nougarèdes, B.; Sini, L.; Branduini, P.; Salvati, L. Governance changes in peri-urban farmland protection following decentralisation: A comparison between Montpellier (France) and Rome (Italy). *Land Use Policy* **2018**, *70*, 535–546. [CrossRef]
41. Trisorio, A. *Measuring Sustainability: Indicators for Italian Agriculture*; National Institute of Agricultural Economics (INEA): Rome, Italy, 2004.
42. Zambon, I.; Colantoni, A.; Carlucci, M.; Morrow, N.; Sateriano, A.; Salvati, L. Land quality, sustainable development and environmental degradation in agricultural districts: A computational approach based on entropy indexes. *Environ. Impact Assess. Rev.* **2017**, *64*, 37–46. [CrossRef]
43. Meireles, C.; Goncalves, P.; Rego, F.; Silveira, S. Estudo da regeneração natural das espécies arbóreas autóctones na Reserva Natural da Serra da Malcata. *Silva Lusit.* **2005**, *13*, 217–231.
44. Lavit, C.; Escoufier, Y.; Sabatier, R.; Traissac, P. The act (statis method). *Comput. Stat. Data Anal.* **1994**, *18*, 97–119. [CrossRef]
45. Coppi, R.; Bolasco, S. *Multiway Data Analysis*; North-Holland Publishing Co.: Amsterdam, The Netherlands, 1989.
46. Höchtl, F.; Lehringer, S.; Konold, W. "Wilderness": What it means when it becomes a reality—A case study from the southwestern Alps. *Landsc. Urban Plan.* **2005**, *70*, 85–95. [CrossRef]
47. Modugno, S.; Balzter, H.; Cole, B.; Borrelli, P. Mapping regional patterns of large forest fires in Wildland–Urban Interface areas in Europe. *J. Environ. Manag.* **2016**, *172*, 112–126. [CrossRef] [PubMed]
48. Scarascia-Mugnozza, G.; Oswald, H.; Piussi, P.; Radoglou, K. Forests of the Mediterranean region: Gaps in knowledge and research needs. *For. Ecol. Manag.* **2000**, *132*, 97–109. [CrossRef]
49. European Environment Agency. *Towards Agro-Environmental Indicators. Integrating Statistical and Administrative Data with Land Cover Information*; Topic Report No. 6; European Environment Agency: Copenhagen, Denmark, 2001.