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Impacts of Changing Livestock Farming Practices on the Biocultural Heritage and Landscape Configuration of Italian Anti-Apennine

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Abstract: This research article focuses on the evolution of a Mediterranean landscapes and the intricate interplay between natural and human-induced processes in the context of the Italian Anti-Apennine mountains. The study employs a multi-temporal approach to analyze changes in land use and landscape ecology, livestock activities, and agro-pastoral practices over seven decades. We noted a 18% decrease in animal units, particularly in goat and pig farming, accompanied by a 10% reduction in horse populations. Farmers' adaptation strategies involve increasing animals per farm, aligning with broader agricultural trends toward intensification and specialization. In parallel, we observed a 22% reduction in grassland surfaces juxtaposed with an overall 15% increase in woodlands and shrublands, a 13% decreasing trend in habitat edge, and an overall 18% increase in patches aggregation at the landscape scale. The decline in anthropogenic pressures linked to depopulation triggered secondary successions, resulting in a 25% increase in homogeneous closed woodlands. These landscape alterations contribute to a 19% decrease in ecosystem heterogeneity and complexity, favoring ecological connectivity for forest-linked species but posing challenges for open meadow species. This, coupled with the loss of biocultural heritage, including traditional settlements dating back to the Bronze Age and Roman times, as well as pastoral traditions and knowledge, underscores the need to rethink future development strategies with a focus on retaining younger generations and preventing the loss of crucial ecosystem services.

Keywords: Mediterranean landscape; land use change; agro-pastoral practices; livestock management; biocultural heritage; sustainability; human-induced processes; land cover dynamics; rural landscapes; historical resource management; landscape ecology

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1. Introduction

The features of Mediterranean landscapes, as well as those observed in other biogeographic regions, result from the intricate interplay between natural and human-induced processes. These processes stem also from distinctive historical resource management patterns at specific locations [1]. With its amalgamation of economic, political, social, cultural, and environmental dynamics across time and space, the modern Mediterranean landscape predominantly embodies a biocultural, multifunctional essence. The term "biocultural" is defined in this research as the comprehension of cultural landscapes arising from enduring biological and social interactions within a community, molding both the biological and material aspects of the landscape [2]. In this role, it stands as a crucial and effective platform for the convergence of biological and cultural diversity, ultimately enhancing human well-being via ecosystem services, particularly within rural areas [3].

Early human cultural progress took place in the Mediterranean Basin, where deforestation and controlled fire usage served as primary methods for creating space for farming and raising livestock. These practices molded the surroundings and the connected biodiversity for over 10,000 years before the present [4]. But the effects of human actions on natural environments have shifted in recent times due to the expansion of populations and the escalation of economic development [5].

In Italy, changes in the landscape of fertile soils are attributed, in part, to urbanization and intensification of agricultural activity. Conversely, the decline of traditional agro-pastoral practices, such as livestock grazing, has led to land abandonment which prompted a process of passive rewilding [6] by spontaneous restoration of woodlands in less fertile marginal regions since World War II, notably in the Alpine [7] and in the Apennines areas [8].

The discontinuation of traditional agro-pastoral methods also results in the forfeiture of several ecosystem services [9], including those related to the maintenance of biodiversity [10] (e.g., habitats [11], plant [12–14] and wildlife [15–17] species and communities [18,19]), landscape attractiveness [20], biocultural heritage [21–23], the accompanying viable economic models [24,25], as well as the pastoral knowledge, as it plays a crucial role in the management and sustainability of pastoralism-based systems [26–28].

Emphasizing shifts in physical-environmental and socio-economic attributes holds significant intrigue within spatial studies. This approach facilitates comprehension not only of the existing territorial arrangement but also the ability to anticipate its forthcoming configuration [29,30].

Multi-temporal landscape analysis involves the comparison of information spanning various time periods within the same region. Its purpose is to ascertain the location and character of alterations over time. This method offers a robust means of spatial examination, yielding a holistic and comprehensive perception of the territory. It furnishes valuable components for a precise interpretation of the genesis of the present-day landscape and its evolution. By studying the historical interactions between humans and the natural productive resources within a specific area, it becomes feasible to pinpoint the enduring influential factors that serve as pivotal constituents of the landscape [29–33].

Extensive endeavors have been focused on examining the consequences of alterations in land cover for a substantial period. Transformations in the landscape spanning multiple decades, induced by socio-economic elements like the desertion of crops in less productive regions, necessitate the utilization of alternative data resources, such as aerial photography [34–36], which provides a longer timespan and more detailed spatial resolution. Throughout both historical and modern literature, the term 'agricultural landscape' has been employed to denote the distinctiveness from natural and urban landscapes. Nevertheless, recent years have witnessed a surge in studies that define the agro-pastoral landscape [37]. These studies have successfully illuminated the subtle nuances that distinguish landscapes shaped by the combined interplay of animal husbandry, forestry, and cultivation [38,39].

Recent investigations into land use/land cover alterations in central Italy involved the analysis of historical and contemporary remote sensing-derived maps [40]. These studies, based on multitemporal cartographic comparison, highlighted a progression of the forest at the expense of agricultural and pastoral surfaces linked to their abandonment, but lack in-depth analysis regarding how this abandonment also impacts the biocultural heritage and the ecosystem structure and functionality. The conservation status of biocultural heritage is a key co-indicator of territorial change trajectories, and its stability, as well as ecosystem functionality, are of global interest as they align with the conservation initiatives of the Convention on Biological Diversity (CBD), IUCN, UNESCO World Heritage List (WHL), the FAO's Globally Important Agricultural Heritage Systems (GIAHS) program, and the European Common Agricultural Policy in sustaining High Nature Value (HNV) farming systems. Both landscapes abundant in biocultural diversity and functional complex ecosystems frequently arise under the stewardship of small-scale or peasant farmers, as well as traditional livestock keepers and pastoralists [3].

To achieve a more comprehensive understanding of landscape dynamism under the combined effect of soil utilization, traditional farming methods, and livestock activities, this study, carried out in the Italian Anti-Apennine mountains, strives to accomplish three principal objectives: (*i*) assess the trajectory of land use alteration in recent decades searching for possible drivers, (*ii*) describe the landscape ecology dynamisms and its possible impact on biodiversity and human activities, and (*iii*) assess changes within the agro-zootechnical framework and the linked loss of biocultural heritage.

2. Materials and Methods

2.1. Study Area

The study area (3570 hectares, 41°39′48″ N, 12°59′9″ E, Figure 1) was selected in the upper reaches of the Lepini Mountains (at elevations ranging from 600 to 1300 m above sea level), a mountain range situated within the Anti-Apennines of the Lazio region in central Italy, between the provinces of Latina and Rome. The region boasts a temperate climate characterized by moderate temperatures and abundant rainfall across all seasons of the year [41].

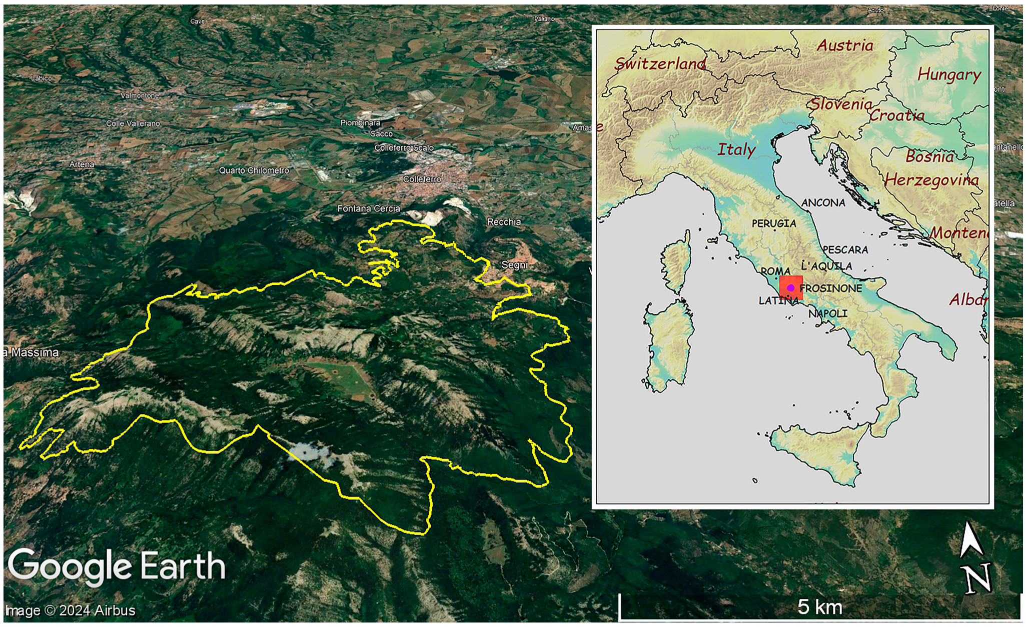

Figure 1. The study area.

Two primary land features are depicted: a karst polje containing pyroclastic material situated at an elevation of approximately 800 m asl. (i.e., an extensive depression formed due to prolonged erosion and dissolution, referred to as Campo di Segni, spanning approximately 150 hectares), encircled entirely by an unbroken limestone cliff that reaches an altitude of 1100 m asl.

The base of the karst polje presents a level and highly fertile terrain, characterized by soils reminiscent of the Mediterranean 'Terre Rosse' [42]. Sometimes the 'Terre Rosse' prevents water from infiltrating the underlying limestone, resulting in small lakes locally referred to as '*volubri*' [43]. As a result of these attributes, this area has been utilized for agro-pastoral activities since ancient times, dating back to the Bronze Age. Accordingly, the earliest human settlements within the study area can be traced back to this era [44].

Substantial urban development occurred during the Roman era, coinciding with its strategic positioning within the Sacco River valley [45]. Subsequently, the area underwent further expansion during its affiliation with the Holy See, culminating in heightened prominence and local self-governance until the Second World War.

Until then, the pastoral economy was based on transhumance, which greatly influenced the formation of many distinctive aspects of these areas. The study area, characterized by mountain pastures, was continuously utilized by shepherds from spring to autumn of each year. Subsequently, they would leave the area through transhumance, covering distances of 40–70 km to reach the Pontine marshes, where they spent the winter. During both the transhumance and settlement periods, they engaged woodland thinning and the utilization and hydraulic arrangement of steep and arid slopes, as well as the establishment of small permanent or seasonal settlements. The fates of shepherds and livestock grazing were closely intertwined with malaria present in the Pontine marshes which covered the Pontine plain at least until their reclamation started in 1920s [46].

Since the area under consideration is of karst origin, a consistent water supply is highly unlikely. Normally, in similar karstic contexts, there is a reverse transhumance pattern: during the winter season, the high-altitude pastures (the mountains of the Anti-Apennines in Lazio reach modest altitudes and are rarely covered in snow) provide nourishment and water sources for the animals. However, during the summer, due to the limestone nature of the mountains, lack of water, and the drying of the pasture, the flocks are forced to descend towards the fields and springs in the plains.

For this reason, starting from the Roman era, a range of hydraulic engineering systems were built. These systems created to support livestock, agricultural production and the rural communities consisted of cisterns of various size and different forms with prevalence of circular shape. By conducting an extensive bibliographic investigation, as detailed in the subsequent paragraph, we successfully uncovered the architectural and construction features of the historical rural buildings associated with agricultural and livestock activities. These findings are exhaustively described in Section 3.2 entitled "Evolution of agro-livestock landscape" as the outcomes of the bibliographic research.

Since the beginning of the 1800s, most of the territory within the study area is under public ownership, and local inhabitants possess rights ('*uso civico*') to engage in cultivation, grazing, and forest cutting activities. The animals are either owned by the same breeders or placed in '*soccida*', a sort of agistment, that is, an Italian type of agricultural contract in which one party (the '*soccidante*' or grantor) grants the use of their livestock or animals to another party (the '*soccidario*' or stockman) for temporary breeding or pasturing purposes. This contract may involve economic collaboration between the two parties and can be used to optimize agricultural resources and available land. Grazing is permitted exclusively from 21 March to 21 October each year by virtue of legal provisions and the grazing plan. This permission is governed by agreements known as '*fida pascolo*' contracts, and a nominal fee is levied for grazing rights.

The earliest reliable quantitative data available on grazing livestock in the study area are from the late 1970s (1977 and 1978). Data prior to and following that period (up to 2010) are not available due to deterioration of paper documents or inaccuracies in cataloging.

2.2. Data Collection of Past and Actual Agro-Livestock Management

A bibliographical investigation was conducted, utilizing the following resources:

- The historical archive of the Segni municipality: the municipality granted access to its extensive historical records, comprising notarial records originating from the early 14th century. It should be noted, though, that only a limited number of documents since the 1970s contain details about agro-pastoral pursuits;
- Agricultural Assistance Centres (CAA) of Segni;
- National Central Library of Rome;
- Photographs sourced from public archives, libraries, and residents of Segni.

Over the course of a 15-month duration spanning from 2017 to 2018, a series of comprehensive on-site assessments were conducted. These inspections facilitated the acquisition of intricate insights into both the agro-ecological and socio-cultural systems.

Surveys and photographic documentation, including drone-assisted imagery, were meticulously carried out within the grazing zones. Special emphasis was placed on refining details around enclosures, animal shelters, watering locations, fencing arrangements, and the implements utilized by farmers. With a citizen science approach, interviews with local farmers were also undertaken.

The main focus of these interviews centered on understanding the way livestock farming is conducted in the area. Questions explored the types of breeds being raised, the number of livestock grazing, and the best technical approaches customized for the specific traits of the region.

Regarding the social aspect, the questions were designed to uncover the farmers trends in the area. This method aimed to understand the extent of farmers decline that had occurred and the resulting changes, especially concerning possible links to ecological and natural elements. These interviews also proved to be valuable resources for interpreting potential upcoming situations and possibilities for both conserving and developing the land.

The historical reference timeframe spanned from the period following the Second World War to 2018. The present zootechnical composition, encompassing species and intended production, was obtained from the National Zootechnical Registry—Statistics. (https://www.vetinfo.it/j6_statistiche/#/, accessed on 15 March 2019). We did not deem it necessary to delve deeper, as the current land use map was generated using images obtained from Google Earth Pro in the year 2016.

2.3. Land Use Classification and Diachronic Analysis

The 1954 land cover map was reconstructed using aerial photographs taken during a GAI flight by the Italian Aeronautic Group using a Faichild camera (mod. T11, Fairchild Camera and Instrument Co., New York, NY, USA) equipped with a Metrogon lens (SN 52-020-xp 290, Bausch & Lomb, Vaughan, ON, Canada). The scale of the photographs was approximately 1:35,000, with planimetric accuracy ranging from 5 to 7 m and a resolution of up to 0.5 m. These images were digitized using the photogrammetric scanner at the Italian Geographic Military Institute, utilizing a scanning resolution of 2400 dpi.

Subsequently, the individual images underwent orthorectification using the Geomatica OrthoEngine modules (PCI Geomatics, Version Banff, SP2, 29 July 2020). The orthorectification process utilized a mosaic of Google images as a reference, employing an average of 12 control points until the mean squared error was reduced below 2 m.

The orthorectification procedure relied on a 40 m Digital Elevation Model (DEM) sourced from the National Geoportal, which was appropriately resampled to a resolution of 10 m. To establish correspondence between image and ground coordinates, a non-parametric model was implemented [47,48]. The georeferencing system used was the WGS84 associated with the UTM projection.

The current land use map for the year 2016 was generated using images sourced from Google Earth Pro. The interpretation process followed the methodology outlined in the work of Gasperini et al. [49].

The land use and land cover categories (Table 1 and Figure 2) were determined based on the interpretation of historical photographs. Consequently, while recent images allowed recognition of compositional types like trees, shrubs, and herbaceous formations, these distinctions were not made. However, for herbaceous formations, it was feasible to outline areas corresponding to sinkhole depressions that exhibited distinct tonal variations. Among tree formations, identification of fruit chestnut groves was achieved by analogy with more recent remote sensing layers. Tree and shrub density classes were differentiated due to their distinct recognizability and relevance for evolutionary analysis.

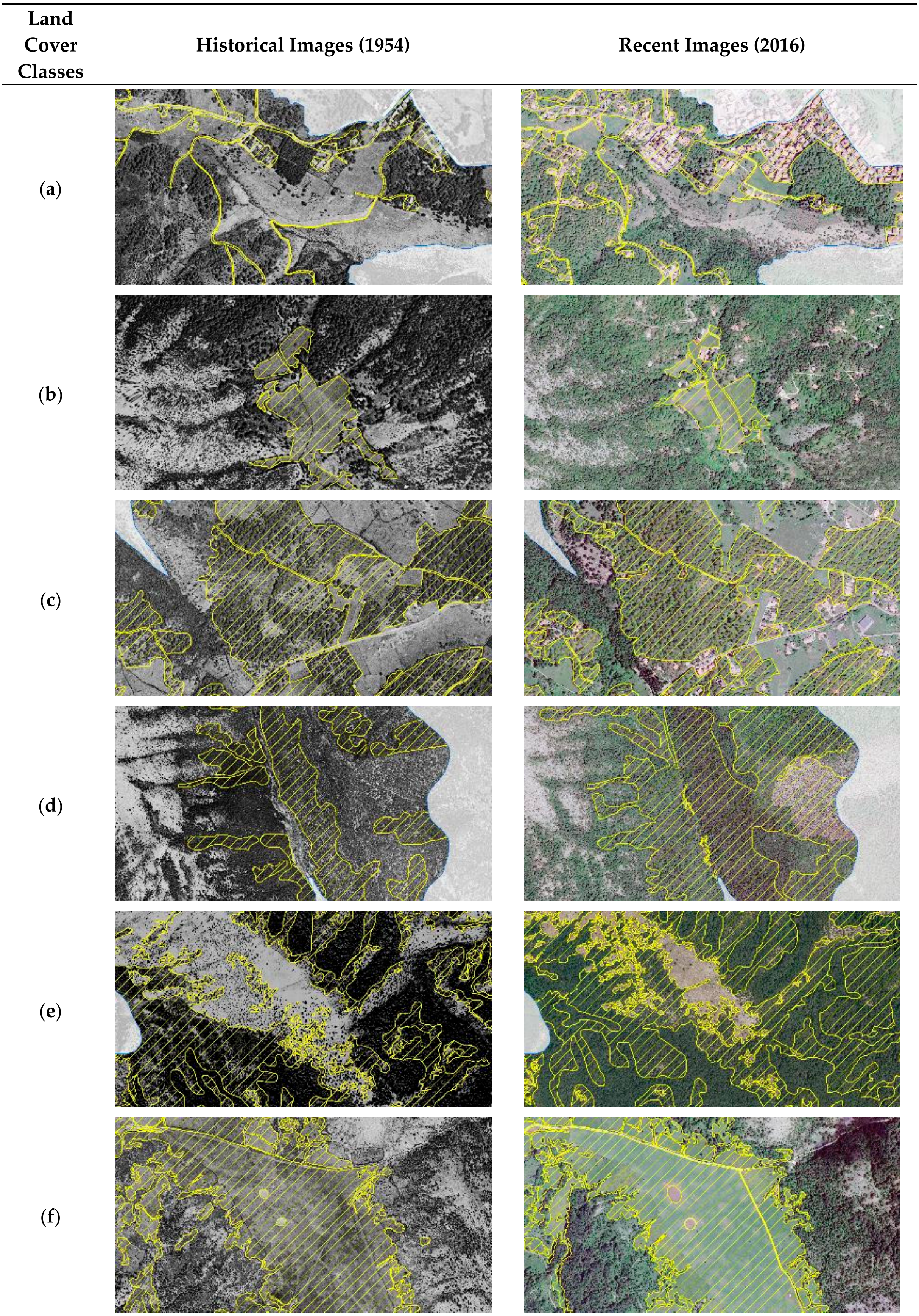

Figure 2. *Cont.*

(**g**)

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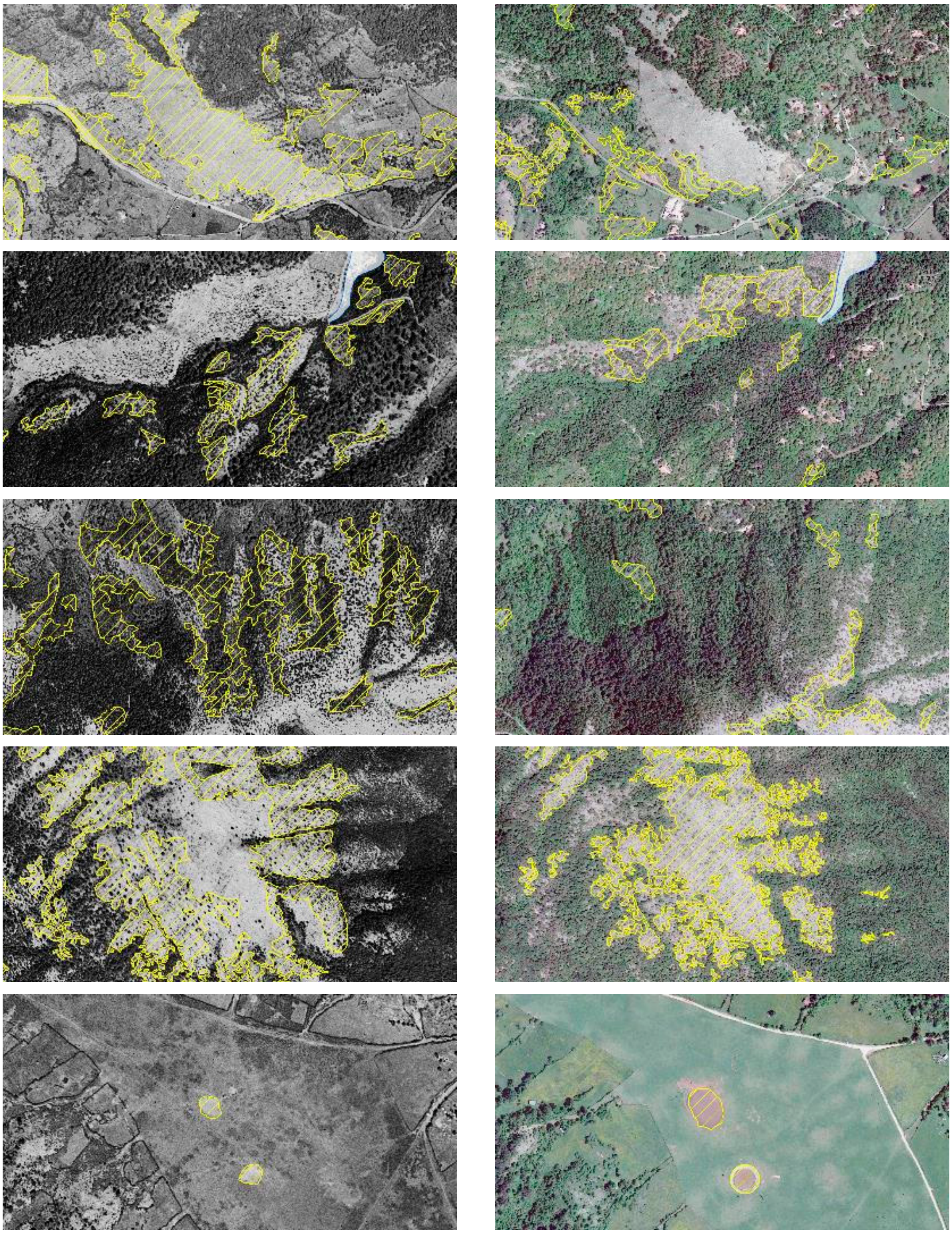


Figure 2. Examples of photointerpretation of land cover classes from 1954 (left) and 2016 (right) images. (**a**) Urbanized, buildings, roads; (**b**) agricultural areas; (**c**) chestnut groves; (**d**) dense deciduous forests; (**e**) sparse deciduous forests; (**f**) sinkholes grasslands; (**g**) grasslands; (**h**) mosaic of open and shrub areas; (**i**) shrublands; (**j**) grasslands with scattered shrubs and trees; (**k**) water.

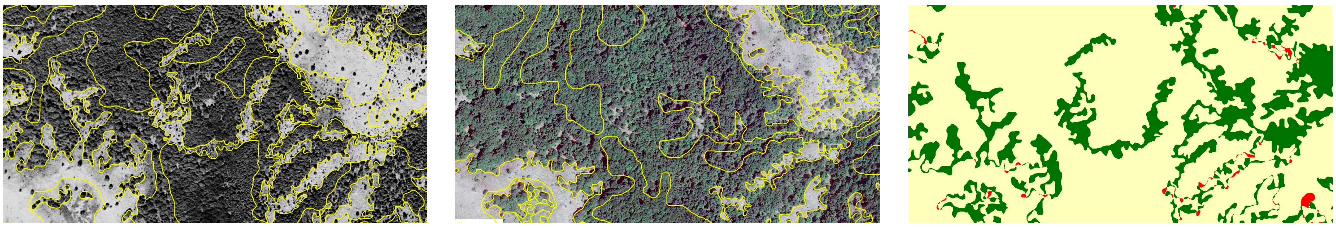
Table 1. Land cover classes and description.

	Land Cover Class	Land Cover Description
(a)	Urbanized, buildings, roads	Anthropogenic areas
(b)	Agricultural areas	Croplands
(c)	Chestnut groves	Chestnut plantations for fruit production
(d)	Dense deciduous forests	Deciduous woods with full or nearly full crown density
(e)	Sparse deciduous forests	Deciduous woods with low canopy cover
(f)	Sinkholes grasslands	Herbaceous formations characteristic of sinkholes
(g)	Grasslands	Open grasslands
(h)	Mosaic of open and shrubs areas	Grasslands with sporadic and fragmented shrubs and trees
(i)	Shrublands	Shrubs and bushes
(j)	Grasslands with scattered shrubs and trees	Mosaic in which there is at least 50% shrubland cover
(k)	Water	Areas with still or flowing water

Adhering to the method detailed in Pallotta et al. [50], the cartographic juxtaposition of the two land cover layers facilitated the characterization of dynamics in terms of naturalness increasing (rewilded areas) or decreasing, in accordance with the subsequent definitions:

- Areas affected by passive rewilding, e.g., former arable lands or grasslands in abandoned sites, etc.;
- Areas that remained in the same category;
- Areas that have undergone a regression, e.g., grasslands turned into arable land or shrublands turned into grasslands, etc.

An example is given in Figure 3.



(**a**) (**b**) (**c**)

Figure 3. Land cover dynamics from 1954 (**a**) to 2016 (**b**); rewilded areas (in green), no changes (in yellow) and de-naturalized areas (in red) (**c**).

Aiming to assess the land cover transition, a cross-tabulation matrix has been computed using the overlay function of ArcGIS Pro 3.0. At this scope, the land cover of the study area has been rearranged in a simplified manner aggregating (*i*) urban, buildings, and roads in a single class named artificial areas, (*ii*) all the herbaceous covers in a single grasslands class, and (*iii*) all the wooded surfaces in the forest class.

This analysis includes gains, losses, persistence, and net change during the period 1954–2016. The matrix displayed categories at two time points. Diagonal elements showed category persistence, while off-diagonal ones indicated transitions. Land-cover changes were assessed using detailed and simplified LULC maps. Gains were differences between column totals and persistence, while losses were differences between raw totals and persistence. Total change was gains plus losses, representing overall variation. Net change, gains minus losses, showed real class variation. Land cover classes' propensity to transition was gauged via loss-to-persistence (Lp) and gain-to-persistence (Gp) ratios. Lp and Gp >1 meant stronger transition tendencies [51]. Comprehensive propensity (Cp) was net change to persistence ratio, indicating net increase or decrease compared to persistence, with higher values suggesting a greater inclination for change.

2.4. Landscape Configuration

Changes in surface, shape, and arrangement of patches can significantly alter landscape ecology [52]. To assess the consistency of changes, we selected two metrics available in FRAGSTATS [53]: one at the class level, "Edge Density" (ED), and one at the landscape level, "Aggregation Index" (AI).

The ED represents the total length of the edge of a land cover class divided by the unit area. We focused on the edge between closed vegetated areas (forests and shrublands) and open habitats (grasslands and croplands) computing the ED of closed natural vegetation. According to Forman and Godrom [54], the edge effect has a considerable influence on environmental conditions and organisms inhabiting a habitat. It is known that it can affect temperature, humidity, light, and wind exposure, and consequently, the distribution and the abundance of living organisms, both vegetables and animals, driving ecosystem dynamisms and human–wildlife interaction risk such as road accidents, agricultural damages, and livestock predation [55–59].

The AI is considered highly effective in quantifying, as the inverse, the degree of the overall landscape fragmentation and heterogeneity [60]. This index varies from 0 to 100, with higher values indicating higher aggregation level and low fragmentation as inverse. In synthesis, AI measures how frequently a patch of a land cover type or habitat is found adjacent to another of the same type compared to a random arrangement. A high AI indicates that the patches of each land cover type tend to be clustered together within the landscape, while a low AI suggests that they tend to be sparsely distributed. For AI computation, the land cover types (Table 1) have been rearranged aggregating urban, buildings, and roads in artificial surfaces and all the wooded surfaces in a single forest class.

To provide continuous data for the selected indices, a moving window with a radius of 564 m, corresponding to a one square kilometer area, was used [61].

3. Results

3.1. Presence of Livestock

In 1977, a total of 644.7 animal units (AU, [62]) (comprising 334 cows, 230 horses, 39 pigs, 210 sheep, and 120 goats) were allocated to 62 farmers. As indicated by some interviewed farmers, it is plausible that the reported count of animals declared may have been lower than the actual herded numbers, because there was not a constant updating of births and deaths, which is only performed during the annual censuses.

Throughout the past ten years, allocations have been guided by explicit resolutions from the Municipal Council. Starting from 2012, allocations are established according to the extent of pasture/grazing land encompassed by the Forest Management and Land Use Plan.

As per information provided by the local office of the Agricultural Assistance Centers, the year 2018 saw an approximate count of 150 non-purebred equines within the study area. Additionally, there was a herd of around 30 purebred Esperia ponies, which also includes a stud farm. Three sheep farmers are present in the region, with one of them tending to around 180 pure Sopravissana sheep, while the remaining two collectively manage a flock of approximately 150 sheep (crossbreeds). There are ten farmers who rear a total of 200 beef cattle of Podolica lineage crossed with specialized beef breeds (i.e., Limousine or Charolaise).

The count of farmers has witnessed a reduction exceeding 50% between 1977 and 2018, whereas the quantity of Animal Units (AUs) being reared has encountered a decrease of approximately 20% when contrasted with the levels observed in the 1970s. This indicates that, on average, farmers have augmented the quantity of animals being reared, with the mean figure rising from approximately 10.37 AUs per farm in 1978 to 18.31 AUs per farm in 2018 (Table 2).

In terms of livestock density, it has stabilized at approximately 0.8 livestock units per hectare (AU/Ha) over the past six years. This change followed the update of the grazing plan embedded within the Forest Management and Land Use Plan of the Municipality of Segni in 2013. Prior to this revision, the livestock density was slightly below 0.6 AU/Ha, primarily attributed to a larger expanse being designated as pastureland, rather than a reduced count of reared animals.

Table 2. Allocation of grazing contracts in 1977, in 1978, and from 2010 to 2018 given by Segni Municipality.

Years	Farmers	Allocated Surface (Ha)	AU	AU/Ha
1977	62	ND	644.7	ND
1978	60	ND	622.4	ND
2010	25	845.1	473.2	0.56
2011	25	835.1	463.9	0.56
2012	25	838.1	433.7	0.52
2013	23	479.1	420.2	0.88
2014	24	502.1	421.6	0.84
2015	25	553.3	468.2	0.85
2016	26	569.3	499.3	0.88
2017	28	670.5	500.3	0.75
2018	28	671.3	512.8	0.76

3.2. Evolution of Agro-Livestock Scenario

The Roman hydraulic systems created to support livestock and agricultural production and the rural communities consisted of cisterns, some of considerable size, with a circular (Figure 4), square, or rectangular shape. They were constructed using local stones, both in the countryside and along mountain slopes, with water diversion systems made of stones to channel water into the reservoirs. The bottom was sealed using the technique of '*cocciopesto*' [63]. Close to the cistern, a single-basin watering trough was positioned, which the herder filled by drawing water from the cistern using a bucket attached to a rope. This action was conducted conveniently from a built-in position at the cistern's edge, known as the '*bocca di pozzo*'. The pavement surrounding the watering troughs prevented the degradation of the trampled ground by animals and the consequent formation of muddy areas, known as the '*purgatory*'. According to accounts from herders who still utilize these traditional cisterns, in cases where herds from multiple owners converged for watering, two separate entrances, located on opposite sides, allowed for controlled animal flow using a rotational system. This ensured that the two groups of animals never came into direct contact. A schematic representation is presented in Figure 4.

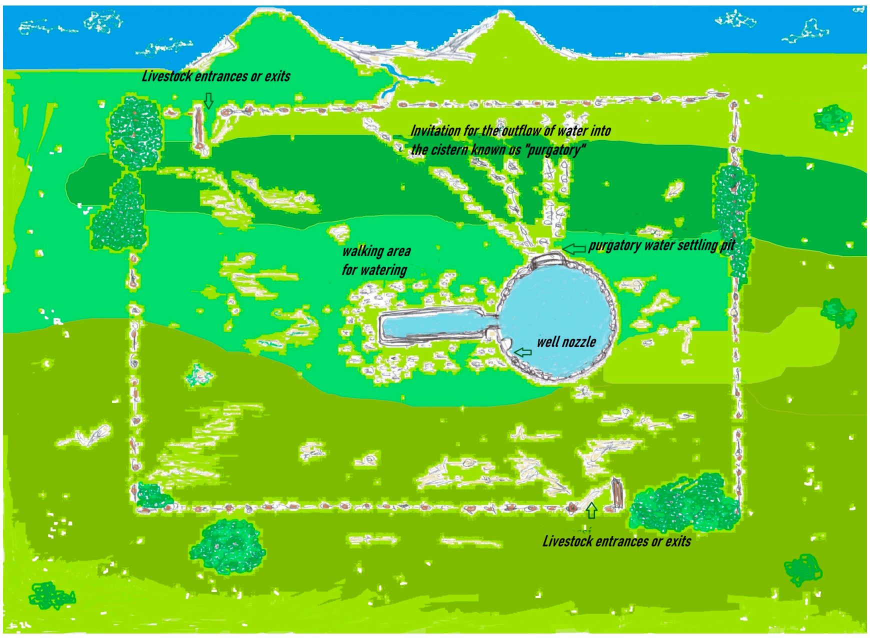


Figure 4. Schematic depiction of a traditional water reservoir and watering system.

A cluster of settlements also emerged with a dedicated purpose of animal management to safeguard against intrusion into cultivated areas. Dry-stone walls predominantly delineated the demarcation between pastoral and cultivated domains, concurrently serving as markers for property demarcation and as safeguards against soil erosion (see Figure 5).

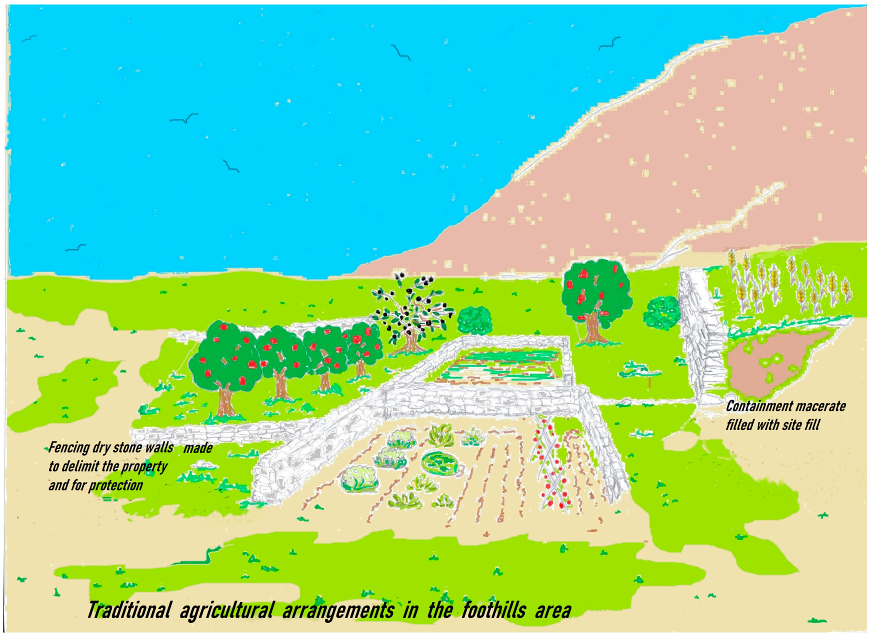


Figure 5. Schematic representation of the utilization of dry-stone walls for safeguarding crops from grazing animals, delineating property boundaries, and mitigating hydrogeological disturbances.

The feeding management was primarily founded on forages, encompassing green grass, shrubs, hay, and leaves from tree branches that were intentionally pruned. According with availability, animals also eat twigs, barks, buds, fruit, shoots, seedlings, withered leaves, roots, bulbs, and rhizomes. Fodder resources outside the mountain area have also been used, as reported in Fagiolo et al. [64].

In areas with gentler slopes and higher fertility, a minimum of one haymaking session involving mowing takes place from around mid-May to early June. The provision of grazing grass or fodder for haymaking was regulated by employing '*cése*,' the dimensions of which varied, spanning from one hectare to a maximum of ten. The '*césa*' was a cleared parcel of land, enclosed by a dry-stone wall to manage (forbid/permit) the entry of animals as needed.

The specific spatial arrangement of certain grazing areas could lead to overgrazing or undergrazing effects, significantly impacting the vegetation. The flatter areas with richer soil, as well as those with more favorable microclimatic conditions, were the ones most frequently utilized, thereby having a less pronounced impact on woodland dynamics.

Pastoral settlements involved a combination of a circular hut and a second ellipsoid or rectangular hut: the former usually served as the temporary residence of the shepherd-farmer (locally referred to as '*capanna lepina*', Figure 6), while the latter sheltered the raised animals. Additional small houses could be added for agricultural tools, cheese production, or hay storage. These huts had a stone base and a thatched roof. The perimeter wall was built dry, without binders, using large, uncut stones and with considerable thickness. The entrance opening was covered by a wooden lintel. The roof had the characteristic conical vegetal structure, reinforced by a sturdy framework of branches, and covered with a thick layer of mountain straw.

Figure 6. Reconstruction of a '*capanna lepina*' used by shepherds during the summer transhumance in the Piana di Segni. This type of construction took inspiration from the simpler hut to that of the Pontine Plain (locally referred to as '*lèstra*').

In these settings, whole families could stay for longer periods, possibly even the entire summer season. This practice was particularly common before the reclamation efforts of the 1920s when many transhumant shepherds originated from the Pontine Plain. This choice also served as a means to avoid malaria during the summer months [46].

The crucial turning point for the agro-silvo-pastoral landscape occurred during the Second World War. From this time onwards, a gradual but unmistakable reduction in the farming population became evident, despite a concurrent rise in the number of animals tended by each shepherd. This transition has marked the evolution from subsistence production to a more entrepreneurial approach, which, however, has altered the traditional livestock husbandry systems. The main changes are presented in Table 3 and Figure 7.

Table 3. Significant changes occurred in the agro-silvo-pastoral system.

	Historical Management	Current Management
Type of animals	Beef cattle: dual/triple-purpose breeds such as the '*Podolica*' and '*Maremmana*', and their crossbreeds; no selective breeding. Horses: '*Pony di Esperia*', a small local rustic horse breed, and hybrid horses for work and meat production. Goats: '*Grigia Ciociara*' and its hybrids, better suited to local conditions. Sheep: '*Sopravissana*' breed. Pigs: mainly the '*Maiale Nero dei Monti Lepini*' and crosses with other local varieties.	Beef cattle: '*Podolica*' crossed with specialized meat breeds like '*Limousine*' and '*Charolaise*', or these latter breeds in their pure form. Horses: primarily '*Pony di Esperia*', a small local rustic horse breed, and hybrid horses for work and meat production. Sheep: '*Sopravissana*' breed.

Table 3. *Cont.*

	Historical Management	Current Management
Breeding technique	Seasonal transhumance: livestock engaged in seasonal migrations to the Pontine plain, notably the marshy '*Macchia di Terracina*,' and returned to the mountains in late spring. Regulation through '*soccida*' and '*fida pascolo*'. Transhumance practices involved various animals such as cattle, goats, pigs, and horses. Breeding selection: no deliberate breeding selection, and the management approach focused on fulfilling local animal needs rather than overall improvement of zootechnical aspects. Animal containment: dry-stone walls complemented by wooden fences, often with the wall serving as the base and the fence positioned behind or placed on top.	Semi-grazing approach: animals are kept in facilities downstream or other convenient locations close to farmer's residence for easier management, with the primary goal of generating supplementary income. Regulation through '*fida pascolo*'. Breeding selection: limited to breeds raised in purity. Animal containment: barbed wire fences and dry-stone walls where they still exist.
Reproduction management	Natural mating. Births concentrated in March, with some also calving in May and June. Abundant milk for the offsprings ensured by transhumance during the peak period of vegetative lushness. Regular heat cycles.	Natural mating: the use of natural mating persists, but crossbreeding with premium breeds (i.e., Limousine and Charolaise for cows). Births concentrated in May or June, in proximity of the dry season. Limited milk production, sometimes not even sufficient for the calves. Unregular heat cycles, reduction in fertility.
Feeding management	Seasonal grazing/browsing supported by transhumance. Preserved forage: hay made from unpassed grass arranged in traditional hayricks. They typically consist of a conical or pyramidal stack of hay bales placed in a way that allows air circulation to dry the hay effectively. The shape of the hayrick helps shed rainwater and prevents the hay from rotting.	Transhumance: the practice of transhumance is not observed. Grazing/browsing is limited to a few areas near the stable pens. Preserved forage: the traditional method of using hayricks for hay storage is no longer in use. Round or square bales are used. Occasional use of industrial feed.
Watering management	Water sources: Roman-era cisterns, wells and fountains, '*volubri*'	Water sources: bathing tubs discarded from homes, Roman-era cisterns and '*volubri*' when still present.
Breeding facilities	Pastoral settlements: '*capanna lepina*', '*léstra*', '*cése*'. '*Cése*' plots were utilized for various purposes, including cultivation, horticultural crops, animal shelters, and storage.	Sheet metal huts: traditional settlements have been substituted with sheet metal huts due to their practicality and cost-effectiveness. '*Cése*' plots were still utilized as animal shelters, and occasionally for cultivating vegetable crops
Animal-derived products	Both fresh and preserved milk and meat. Animals utilized also for labor (draft, pulling, displacements).	Sheep are used to produce milk, while cattle are primarily raised for meat. Horses are sold either for meat or for recreational purposes.
Utilization of animal-derived products	Family consumption. Cows were milked in the presence of the calf to facilitate the release of oxytocin. The surplus milk not consumed by the calf in May and June was milked for self-consumption. This was facilitated by docile cows known as '*mungane*,' which were accustomed to milking. Both fresh and home-produced products were sold partially to private individuals.	Sale to third parties. Genetic improvement of beef cattle enables higher yields.

Table 3. *Cont.*

	Historical Management	Current Management
Mode of product sales	Annual fairs: fairs were held annually, both during the summer and autumn seasons. These events also provided platforms for selling livestock. Direct sales to traders: alternatively, direct sales were made to traders. In this method, the livestock was sold in bulk to these intermediaries.	Prevalence of direct sales: direct sales have gained prominence, driven by a reduction in the number of fairs and markets. These traditional outlets might not always be economically viable.
Significance of animal husbandry	Ownership and livestock farming: it was a common occurrence for the livestock farmer to be the proprietor of the animals being raised. Economic role: pivotal role in shaping the local economy of the region.	Secondary income
Workers/Staff/Employees	Full-time family members only.	Only the members of the family unit work part-time.
Main crops associated with livestock farming	The '*Cése*' plots were utilized for a variety of cultivations (wheat, legumes, and vegetable crops)	The '*Cése*' system remains in operation in areas where it is present for cultivating vegetable crops, primarily intended for family consumption.

Type	Traditional Settlements	Current Settlements
(**a**) Watering facilities		
(**b**) Dry-stone wall		
(**c**) Sheds for hay/tools.		

Figure 7. Examples of traditional (**left**) and contemporary (**right**) settlements used for livestock farming.

3.3. Land Cover Evolution

The data illustrate land cover changes between 1954 and 2016 across distinct categories (Table 4, Figures 8 and 9). Urban areas have experienced a substantial increase from 34.87 hectares to 134.11 hectares (284.72%), signifying important urbanization. Conversely, agricultural areas displayed a decrease from 544.98 hectares to 432.88 hectares (−20.57%) as well as grasslands that underwent a considerable reduction from 1450.38 hectares to 731.82 hectares (−49.50%). In contrast forested surfaces notably expanded from 1535.47 hectares to 2266.37 hectares (47.56%). The marginal rise in water areas from 0.62 hectares to 1.15 hectares (85.48%) suggests minor changes in aquatic features.

Table 4. Transition matrix for of land cover classes (Total change = Gains + Losses; Net change = Gains − Losses; Swap = Total Change − Net Change; Lp = Losses/Persistence; Gp = Gains/Persistence; Cp = Net Change/Persistence). Characters in Bold represent the actual used hectares. The characters in Normal represent the rate of changes through time.

Land Cover Classes	Urban Areas	Agricultural Areas	Forests	Grasslands	Waters	Total 1954	Losses	Total Change	Net Change	Swap	Lp	Gp	Cp
Urban areas	**29.15**	1.11	3.64	0.97	0.00	34.87	5.72	110.68	99.24	11.43	0.20	3.60	3.40
Agricultural areas	74.39	**375.10**	64.12	31.37	0.00	544.98	169.88	227.65	−112.10	339.75	0.45	0.15	−0.30
Forests	11.12	15.90	**1471.67**	36.77	0.01	1535.47	63.80	858.49	730.90	127.59	0.04	0.54	0.50
Grasslands	19.46	40.77	726.93	**662.71**	0.52	1450.38	787.67	856.78	−718.57	1575.35	1.19	0.10	−1.08
Waters	0.00	0.00	0.00	0.00	**0.62**	0.62	0.00	0.52	0.52	0.00	0.00	0.84	0.84
Total 2016	134.11	432.88	2266.37	731.81	1.15	3566.32							
Gain	104.96	57.78	794.69	69.11	0.52								

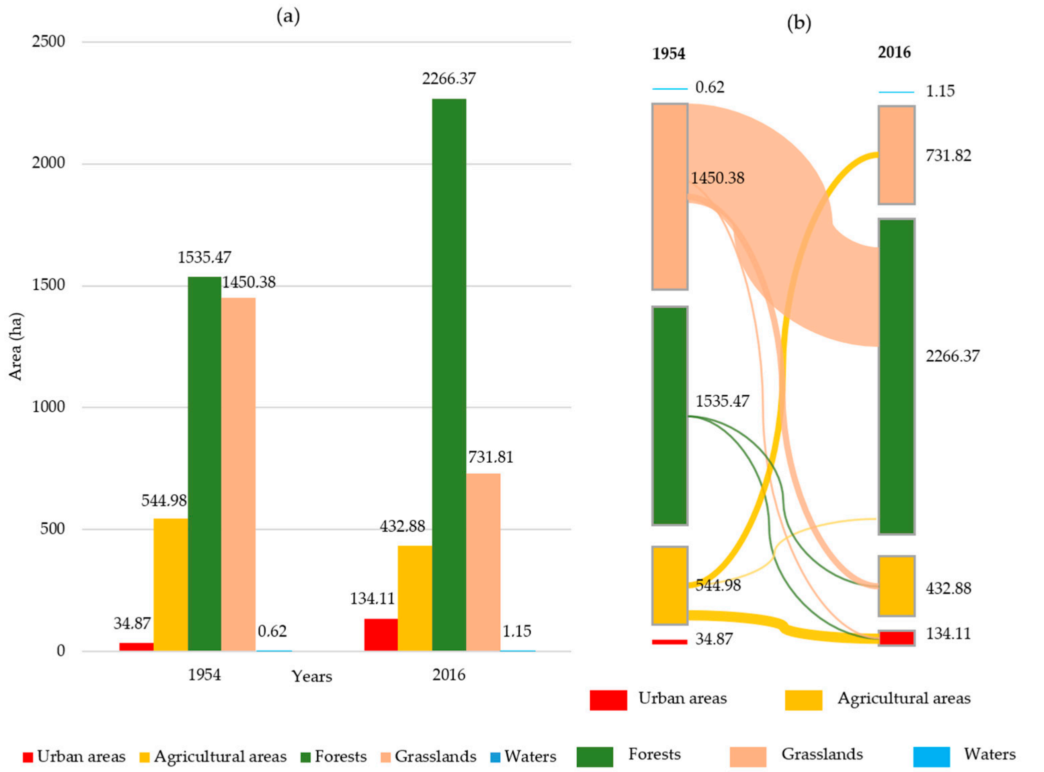


Figure 8. The (**a**) areas of different land use types and (**b**) land use transfer trajectories, 1954–2016.

The data reveal notable variations in land cover proportions relative to the total area. Urban extents witnessed a substantial increase in proportion, rising from 0.87% in 1954 to 3.35% in 2016. Agricultural regions experienced a decline from 13.70% in 1954 to 10.82% in 2016. Forested areas expanded their share from 38.55% in 1954 to 56.66% in 2016. Conversely, grasslands saw a significant decrease from 36.64% in 1954 to 18.29% in 2016. Water areas exhibited minimal shifts, with their proportion changing from 0.02% in 1954 to 0.03% in 2016.

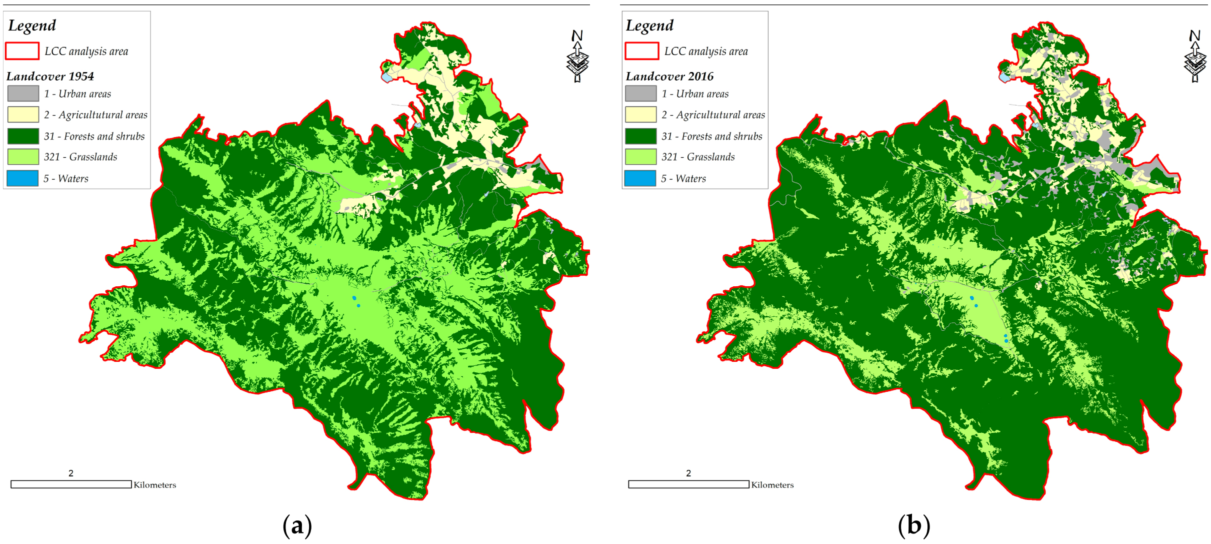


Figure 9. Grouped land cover maps for (**a**) 1954 and (**b**) 2016.

When assessing the swap values, grasslands are notably prominent as the most dynamically fluctuating categories, undergoing significant alterations primarily involving reductions in comparison to forested regions. Through an analysis of Lp, Gp, and Cp, the grasslands category emerges as the most dynamically active, displaying a proclivity for change, and notably, for diminishing its extent, given that Gp < 1.

Urban areas arise as highly dynamic categories, experiencing substantial shifts involving acquisition, mainly from agricultural and grassland regions. These urban areas exhibit the most pronounced inclination for change, notably resulting in an expansion of their spatial coverage, with Gp > 1.

In the absence of other conspicuous factors, these dynamics are propelled by the abandonment of agro-silvo-pastoral activities, as secondary pastures are reclaimed by forests and certain flatter areas better connected to road infrastructures undergo urbanization.

It is of interest to deduce insights from ancillary data, which elaborate on specific land uses that have experienced changes (Tables 5 and S1, Figure 10).

Artificial zones have expanded, predominantly through new constructions and buildings encroaching upon agricultural lands (36.54 hectares), chestnut groves (37.85 hectares), woodlands (11.11 hectares), and previously grazed areas (19.46 hectares).

Table 5. Summary of detailed land covers in 1954 and 2016. The table also shows the difference in terms of Area (Ha) and Percentage (%).

Land Cover Classes	Area (ha) 1954	Area (ha) 2016	Difference (ha)	Area (%) 1954	Area (%) 2016	Difference (%)
Urbanized, buildings and roads	34.87	134.11	+99.24	0.98	3.76	2.78
Agricultural	173.39	146.50	−26.89	4.86	4.11	−0.75
Chestnut groves	371.59	286.38	−85.21	10.42	8.03	−2.39
Dense deciduous forests	496.33	744.17	+247.84	13.92	20.87	6.95
Sparse deciduous forests	1039.14	1522.20	+483.06	29.14	42.68	13.55
Wooded pasture	0.00	4.57	+4.57	0.00	0.13	0.13
Sinkholes grasslands	164.60	120.47	−44.13	4.62	3.38	−1.24
Grasslands	366.69	289.31	−77.38	10.28	8.11	−2.17
Mosaic of open and shrub areas	462.78	182.41	−280.37	12.98	5.11	−7.86
Shrublands	127.59	60.25	−67.34	3.58	1.69	−1.89
Grasslands with scattered shrubs and trees	328.72	74.81	−253.91	9.22	2.10	−7.12
Waters	0.62	1.15	+0.53	0.02	0.03	0.01
Total	3566.32	3566.32	0.00	100.00	100.00	0.00

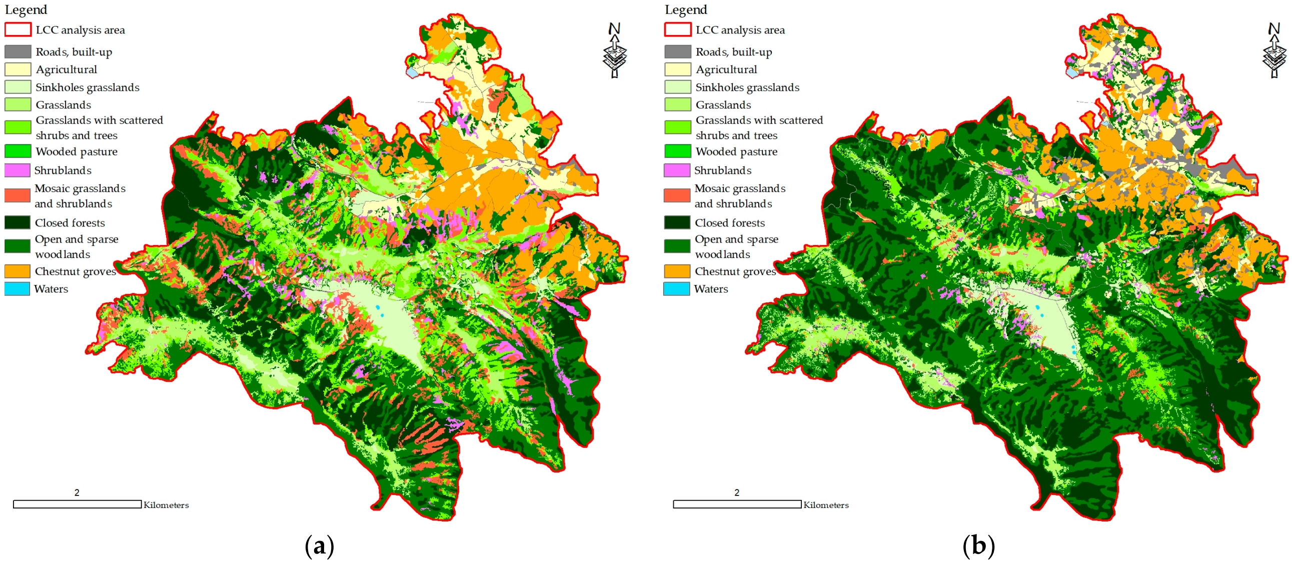


Figure 10. Detailed land cover maps for (**a**) 1954 and (**b**) 2016.

Agricultural cultivation areas have contracted, primarily due to new human settlements and partly due to the establishment of chestnut groves (14.06 hectares). A considerable proportion has entered re-afforestation processes, transforming into areas with presence of shrubs (11.82 hectares) or directly into forests (5.91 hectares).

Chestnut groves, a characteristic arboreal crop in the region, have experienced a reduction in their extent (−85.21 ha), with around 18.08 hectares transitioning into naturalized woodland or shrub due to cultivation abandonment. Some were uprooted to accommodate human settlements (0.7 hectares) and agricultural zones (7.67 hectares).

Within the context of augmented woodland areas, a distinction must be drawn between dense forests (those with full or nearly full crown density) and open, sparse forests. Dense forests increased from 496.3 hectares in 1954 to 744.2 hectares in 2016, indicating a growth rate of 49.9%. This shift is primarily attributed to the densification of sparse forests, contributing a net gain of 339.08 hectares. Simultaneously, approximately 76.42 hectares of grasslands, shrub- and scrub-covered pastureland transitioned into dense forests. Regarding sparse woodlands, they too underwent an overall expansion (+483.06 hectares, +146.5%), driven by the natural progression from grasslands with scattered shrubs and trees (241.66 hectares), shrub and scrublands (86.18 hectares), and mixed grassland and shrubland patterns (235.57 hectares).

Due to the conversion to woodland, the substantial expanse of pastures existing in 1954 (1450.38 hectares) was nearly halved to 731.81 hectares. Among pasture categories, the transitions most prominent were grasslands with scattered shrubs and trees (about 52%), scrub and shrublands (67.5%), and the mixed grassland and shrubland mosaic (71.7%). Sinkholes and open grasslands accounted for approximately 13.7% and 17.6%, respectively. About 20.5% of shrub and scrublands have already evolved into dense forest. This is because grazing has been discontinued in these areas, due to the remoteness of the watering and storage sites for animals and the greater difficulty in managing them.

Basically, the grasslands most convenient to use and easiest to reach, have been maintained. Waters underwent minimal change (+0.3%), attributable to the construction of an artificial reservoir of approximately 3000 square meters at Piana di Segni.

The passive rewilding processes, which have led to the transformation of open areas (agricultural or grasslands) into shrubs, bushes, and woods, connecting patches previously fragmented and increasing naturalness, are extremely evident with an overall loss of the agro-ecomosaic diversity and complexity.

Within the northern part of the study area, characterized by lower altitude than the mean of the study area, the 5.55% of the natural areas have been transformed into croplands and urban areas. Differently, within the central and southern part of the study areas, predominantly mountainous, the 19.81% of the study area has been subjected to passive rewilding dynamism. Overall, the 74.64% of the study area has not changed, maintaining the 1954 land use (Figure 11).

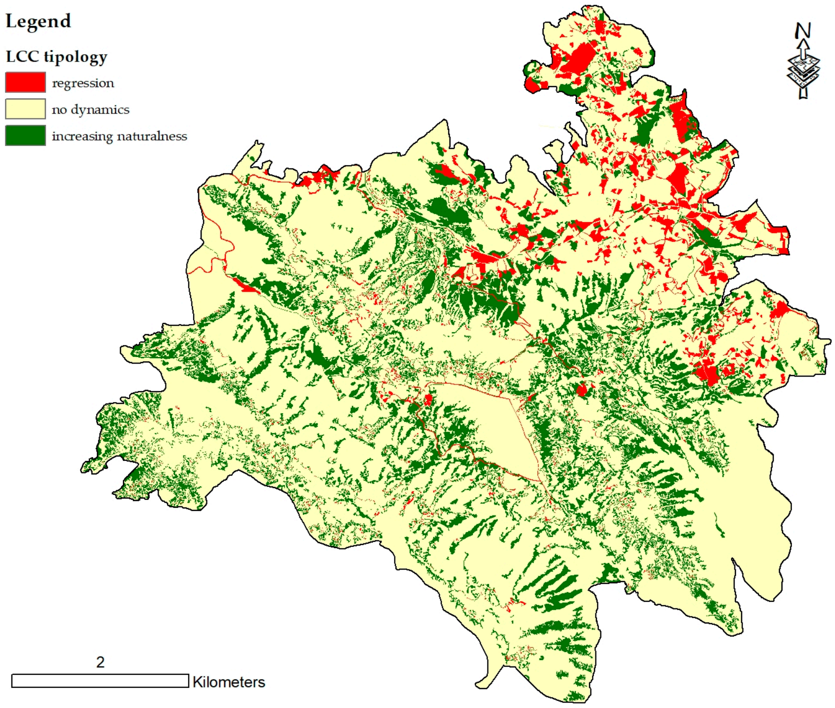


Figure 11. Map illustrating rewilded (increasing naturalness) areas, de-naturalized areas, and regions unaffected by change between 1954 and 2016.

3.4. Evolution of Landscape Configuration

Landscape metrics comparison between 1954 and 2016 is shown in Table 6, indicating a potential alteration in landscape patterns.

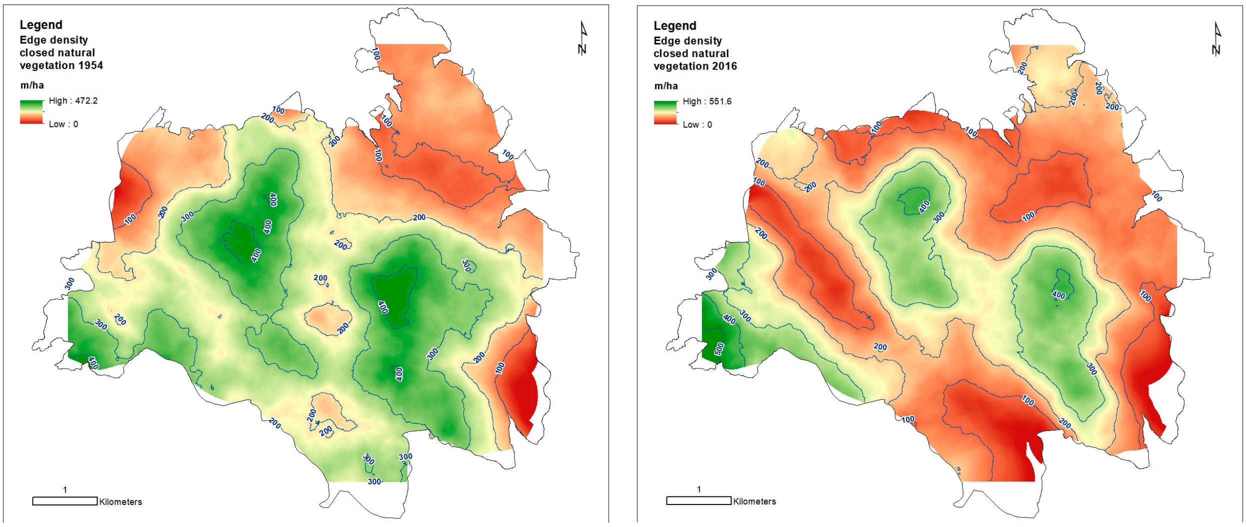
Table 6. Landscape metrics comparison between 1954 and 2016. Closed natural vegetation is intended as forests plus shrubs.

	Min	Max	Mean	Std
ED closed natural vegetation 1954 (m/ha)	0	472.2	235.2	90.5
ED closed natural vegetation 2016 (m/ha)	0	551.6	196.1	102.2
AI 1954	82.8	99.2	91.2	3.0
AI 2016	82.9	99.9	92.9	3.2

In 1954, the edge density (ED: m/ha) of closed formations ranged from 0 to 472.2 m/ha 235.2 ± 90.5 (mean ± SD) m/ha (Table 6). In 2016, it ranged from 0 to 551.6 m/ha, 196.1 ± 102.2 (Table 6) showing a decreasing trend particularly evident in the figure below (Figure 12).

The highlighted ED dynamic suggests that the changes in land use practices, occurred between 1954 and 2016, have impacted not only the landscape composition as documented in the paragraphs above but also its structure with an overall loss of ecotone and of transition bands between closed and open areas.

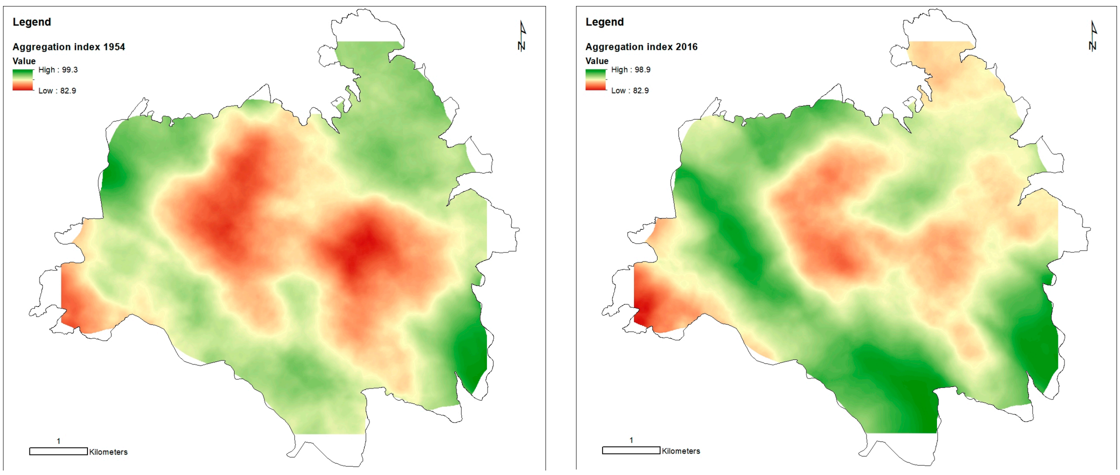
In 1954, the AI ranged from 82.8 to 99.2 (91.2 ± 3.0). In 2016, the range extended from 82.9 to 99.9 (92.9 ± 3.2).



(**a**) (**b**)

Figure 12. Maps illustrating the edge variation between closed (forests plus shrublands) and open areas (grasslands plus croplands) in the time lapse between 1954 (**a**) and 2016 (**b**).

Consistently with the observed ED decreasing, also AI confirms a change in the spatial arrangement and distribution of landscape elements. Although the simple comparison of the AI values does not suggest an important shifting, the maps below (Figure 13) describe a substantial rearrangement of the patches of the same land cover types within the landscape, showing a clear tendency to aggregation in the southern and central part of the study area and an opposite tendency to fragmentation in the northern one. This observation is consistent with the different suitability for human activities and settlements of this sectors. Indeed, while the central and southern parts are marginal mountainous sectors subjected to abandonment by humans' activities and a consequent passive rewilding of open grasslands towards closed formations, the northern one is a plain area subjected to urbanization and growing anthropic exploitation increasing landscape fragmentation.



(**a**) (**b**)

Figure 13. Maps illustrating the dynamism in landscape fragmentation, computed by the Aggregation Index (AI), between 1954 (**a**) and 2016 (**b**).

4. Discussion

4.1. Patterns in Landscape Ecology

Consistently with the results of previous studies, this research confirms that the decrease in anthropogenic pressures, such as grazing and agro-silvo-pastoral activities [65], linked to the progressive depopulation of marginal (mountainous) contexts [66,67] triggered secondary successions which closed the existing spaces between disjoined forests or shrubs patches creating homogeneous closed woodlands (forests plus shrublands). This process, known as passive rewilding, is driving the landscape changes such as a (*i*) decrease in grasslands surfaces versus the overall increase in woodlands and shrublands (Tables 4 and 5; Figures 8–11), (*ii*) a decreasing trend of the edge (ED) between closed and open habitats (Table 6, Figure 12), and (*iii*) an overall increase in patches aggregation at the landscape scale (Table 6, Figure 13).

Regarding the AI, it is noteworthy that its increase is on the rise in the central and southern regions of the study area, characterized by mountainous terrain (Table 6, Figure 13). Conversely, there is a discernible decline in the northern regions, particularly in plain areas that have undergone urbanization and prolonged conversion to croplands (Table 6, Figure 13).

Similarly, in the same mountainous area, Smiraglia et al. [68] documented an increase in landscape intricacy within Mediterranean climate units and an opposite reduction in complexity within temperate climate units, examining the boundary dynamics of patches during the period 1954 to 2000. In addition, we observed that the depopulation-passive rewilding process is more pronounced in areas that are challenging to access and lack infrastructure to support livestock farming (such as roads, fences, watering points, etc.). Furthermore, the trend toward these changes remains an ongoing process and is likely to persist in the coming years in the absence of significant modifications to socio-productive aspects.

The overall pattern of the landscape dynamism described within the study area also aligns with the trajectory previously outlined by Blasi [31] for the western Lepini chain, by Statuto et al. [69] within a rural expanse in southern Italy (Basilicata region), by Pallotta et al. [50] within the summits of the Abruzzo, Lazio, and Molise National Park as well as in a substantial portion of the Apennine region [8,40,70,71].

These patterns lead to a decrease in ecosystem heterogeneity and complexity, favoring (*i*) the ecological connectivity for species linked to forests, such as wild ungulates and wolves, through continuous wooded corridors and (*ii*) the loss of habitat suitability for ecotonal or open meadow species of conservation concern [72,73] otherwise. Indeed, according to Recio et al. [74], rewilding can exacerbate human–wildlife conflicts favoring ungulates and presence of wolves. Otherwise, habitats aggregation can lead to decreasing species richness and overall biodiversity loss as previously suggested by Rybicki et al. [75] as long as the amount of habitat remains high enough, and recently confirmed by Riva and Fahrig at the landscape scale [76].

4.2. Patterns of Fading Biocultural Heritage

The Piana di Segni, as it is more accessible compared to the rest of the mountainous group, still retains its zootechnical suitability, which, although greatly remodeled with respect to the past, makes it possible to maintain some of the typical elements of the landscape, such as the '*cese*', the '*volubri*' and part of the masonry used for the storage of tools and foodstuffs.

This aligns with Blasi [31], who noted that the depopulation trend in the Lepini Mountains is less pronounced than in other regions of the Central Apennines, where agro-pastoral activities have been entirely abandoned in recent decades. This distinction can be also attributed to the relatively moderate climatic conditions of the area (with a maximum altitude of around 1100 m above sea level and only a few days or weeks of snow annually), the presence of consistent natural water reservoirs, available fodder production areas (such as Valle del Sacco, Valle dell'Amaseno, and the Pianura Pontina), and the proximity of towns (such as Segni, Colleferro, Cori, etc.).

After the sensitive decrease recorded between the 1970s and 2010 (Table 2), the count of animal units has shown limited fluctuation over the last 8 years. The decreasing trend mainly involved goat and pig farming, accompanied by a significant reduction in the horse population which are primarily browsers and exerting a notable influence on the shrub component of vegetation, contributing to its management [65]. Moreover, pigs play a pivotal role in mitigating the renewal of gametes by consuming acorns and other tree seeds. Furthermore, the reduced presence of breeders leads to the reduction in the efforts in brush removal, favoring forest advancement, as also argued by Quaranta et al. [77].

The decline in the count of farmers juxtaposed with a relatively modest reduction in animal units confirm a well-known adaptation strategy. Farmers appear to have augmented the number of animals per farm over time in response to changing market demands and economic incentives. This transformation aligns with broader agricultural trends characterized by intensification and specialization, where farmers seek to maximize returns per unit area, also in the case of multi-species livestock farming [78].

The stabilization of livestock density around 0.8 AU/Ha in recent years suggests a balance between available grazing resources and the number of animals being reared. The shift in livestock density following the update of the grazing plan underscores the role of ecological considerations in shaping land use practices. The equilibrium achieved indicates a prudent management approach that avoids overgrazing, which can lead to environmental degradation, and underutilization of available grazing resources. This is also because Italian law prohibits the restoration of secondary pastures once they have been reforested. Furthermore, this adjustment occurred because of the decrease in actual grazing areas and thus does not reflect the original/correct carrying capacity.

Traditional rural landscapes harbor a biocultural heritage that has been accumulated by rural communities over time, evolving through generations in a harmonious coexistence with nature. As a matter of fact, the historical significance of transhumance as a livelihood strategy is evidenced by its influence on settlement patterns, land reclamation, and water management. The integration of hydraulic engineering structures, such as cisterns and watering troughs, demonstrates the innovative approaches adopted since ancient times by communities to overcome challenges posed by the rugged terrain and limited water resources. Unfortunately, differently from the partially conserved “cese” and “volubri”, these artefacts, which are the most important historical part of the local biocultural heritage, are being lost due to lack of maintenance and replacement with unsightly bathtubs.

Similarly, the abandonment of buildings and rural structures made of dry-stone walls has a negative impact on both the beauty of the landscape and the preservation of significant archaeological evidence.

The factors contributing to decline mirror those previously discussed for the landscape, including additional constraints on the restoration and preservation of cultural assets, given their oversight by the cultural heritage authority.

4.3. The Role of Agricultural and Environmental Policies

According to Zolin et al. [79], the processes described above were facilitated by the Common Agricultural Policy (CAP) of the European Union, which draws inspiration from the Treaty of Rome of 1957, which initially did not prioritize territorial, environmental, and socio-economic disparities. The original goals set in 1957 were not modified, but, by 1975, the Council of the European Economic Community recognized areas with natural handicaps through Directive 75/268/EEC, addressing mountain and hill farming and farming in less favored areas. The initial omission of these considerations in the CAP objectives was later addressed in response to evolving agricultural and regional needs, but the trend has not ceased, especially in areas with extreme territorial and climatic conditions such as the one under investigation in this study.

More recently, the enforcement of EU legislation, including EU Regulation No. 1305/2013, which pertains to support for rural development through the European Agricultural Fund for Rural Development, focusing on the preservation of natural areas. This, coupled with the prohibition of reclaiming open spaces presently occupied by forests, has exacerbated the problem of abandonment.

The CAP’s efforts to enhance the resilience of rural communities and counteract the depopulation process encounter various challenges [80], including the inadequacy of payment schemes acknowledged for farmers in less favored areas (LFAs) due to incomes lower than those achievable for other activities or locations [81].

The EU environmental policy, formulated in environmental action programs since the early 1970s, despite having sustainability development goals, has exacerbated the abandonment rate. This is often to be attributed to an excessively restrictive or bureaucratic approach in obtaining authorization for the construction of facilities or even for simply carrying out agricultural activities, as envisaged, for example, by the Habitats Directive.

The relationship with wildlife is not trivial, especially regarding conflicts with the increasing populations of ungulates and predators, such as the wolf. These conflicts can significantly impact farmers' incomes in the absence of adequate defensive strategies, which are often expensive and demanding from a management perspective.

Recently, multifunctional farming is becoming an economically effective alternative for increasing the resilience of the rural community and slow down the depopulation process also in remote rural areas [82,83], promoting both farm-related (agricultural production and/or processing) and farm-diverse activities connected to other ecosystems services such as rural nature-based tourism and landscape enhancement and maintenance [84].

An emerging contrasting idea, substantially based on the mistrust of a system kept in balance by sustainable human exploitation, considers rural depopulation an opportunity to be encouraged rather than opposed because can provide, favoring wilderness, the chance to start many economic activities based on wildlife tourism [74].

5. Conclusions

Consistently with previous studies, we detected a clear landscape dynamism driven by the progressive abandonment of mountainous marginal regions. This process is dominated by the progressive passive rewilding of grasslands, and we highlighted the principal implications in terms of potential loss of biocultural heritage including traditional activities, structure, infrastructure and habitat, as well as animal and plant species.

The study's insights hold relevance for crafting sustainable land use strategies that balance economic development, environmental conservation, and cultural preservation in the face of evolving socio-economic dynamics.

We expect the trend of abandonment will persist, given the low profitability and labor-intensive nature of extensive pastoral activities, which are certainly unappealing to younger generations, and public policy aimed at mitigating this trend has long lasting proven ineffective in achieving the desired outcomes. At the scope to contrast the depopulation of marginal areas unsuitable for intensive agriculture and slow down the deterioration of traditional rural landscapes and complex eco-mosaics, specific agri-environmental strategies of the EU CAP promoted, for many years, the reversal of this trend subsidizing farming and extensive grazing.

However, only in recent years, particularly during the 2014–2020 CAP programming period, multifunctional farming has emerged as a viable alternative to counter rural depopulation and the associated landscape degradation. This involves integrating subsidies aimed at maintaining traditional activities with differentiated financial support through the adoption of both farm-related and diverse activities. However, it has not yielded positive outcomes, as the abandonment trend has persisted.

Current European policies on agriculture and the environment, such as the EU Green Deal, Farm to Fork strategy and others, are highly integrated and aim to accelerate the transition to a climate-neutral, resource-efficient, and regenerative economy. However, it is too early to grasp the extent of the restoration of mountain agropastoralism, as these policies have been in effect since 2022, and many measures are yet to be implemented on a national or regional scale.

In Italy, the National Strategy for Inner Areas (SNAI) embodies an innovative national policy for development and territorial cohesion. It aims to counteract the marginalization and demographic decline phenomena specific to some of the inner areas. In this case, concrete actions also still need to be initiated or completed.

The preservation of the holistic quality of an agro-pastoral system relies on a fragile equilibrium between ecological, productive, social, and aesthetic factors. It is important to note that the variables studied and presented in this study are just a subset of the elements that characterize the holistic quality of the Italian Apennine extensive system.

The notion of landscape encompasses both tangible and intangible elements shaped by human-environment interactions, emphasizing the importance of conserving cultural and historical values while adapting to changing societal demands. Upholding the integrity of the landscape, addressing both functional and aesthetic dimensions, proves essential in mountainous settings. It ensures the landscape's ability to withstand ecological disruptions, fosters the harmonious coexistence of natural and human-made elements, and enhances the emotional and perceptual satisfaction of observers.

Multifunctional agriculture, which encompasses a range of services and ecosystem functions within an agro-pastoral landscape, plays a pivotal role in maintaining this equilibrium. It contributes to the landscape's allure, cultural significance, and capacity to provide valuable ecosystem services, such as food production, soil fertility preservation, water regulation, biodiversity conservation, and ecotourism. Ultimately, this safeguards the overall quality and integrity of the agro-pastoral landscape.

However, any initiative aimed at the maintenance of traditional extensive agriculture and livestock could be intrinsically incompatible with a rewilded context since the increasing continuity of wooded ecological corridors and aggregated woodlands favor wild ungulate and apex predator abundance, driving the increase in wildlife–human conflicts. For the success of these initiatives, it seems therefore necessary that the CAP combines the promotion of extensive grazing and agriculture also supporting the adoption of effective defensive strategies. Ineffective strategies at support of the rural populations resilience pave the way for alternative strategies, already launched on an EU scale with project such as Rewilding Europe (https://rewildingeurope.com/, accessed on 7 February 2024), aimed at encouraging, in specific cases, the abandonment of marginal, commonly mountainous, areas to accelerate the involution of anthropogenic systems towards non-interfered natural systems to be exploited for wildlife tourism and related businesses. Additional research should be focused on socio-ecological and quantitative analyses to inform more efficient strategies, aimed at enhancing the incorporation of traditional livestock systems where the sites specificities preserve potential suitability for extensive multifunctional approaches.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13020243/s1, Table S1: Transition matrix of land use in the study area from 1954 to 2016.

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Institutional Review Board Statement: This study is designed as a non-interventional research initiative. Prior to administering the questionnaire, participants have been comprehensively informed that their anonymity is guaranteed throughout the research process. They have been provided with information regarding the purpose of the study, the utilization the information provided, and any potential associated risks. Ethical approval is not required for this research.

Data Availability Statement: The data presented in this study are available in Table S1.

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