Biodiversity and Conservation (2022) 31:2373–2396
https://doi.org/10.1007/s10531-022-02400-1

ORIGINAL PAPER

Biocultural diversity in the traditional landscape of Vallecorsa

Giorgia De Pasquale[1] · **Sagliocco Livia**[2]

Received: 5 October 2021 / Revised: 9 February 2022 / Accepted: 21 February 2022 /
Published online: 10 March 2022
© The Author(s) 2022

Abstract

In Italy, agricultural intensification and the abandonment of rural areas since the 1960s has led to a transformation of the traditional agricultural landscape, bringing with it a series of environmental and socio-economic issues and problems such as those linked to hydro-geological instability, a reduction in biocultural diversity and migration to urban centres, especially of the younger population. These phenomena have also led to a progressive loss of all the cultural and traditional practices related to these systems, thus contributing to a homogenization of the landscape structure due to abandonment. On the other hand, in the last years, we are witnessing a return to rural and traditional practices with the aim of recovering local cultures, especially those associated to agricultural practices, and to a more sustainable management of the territory. Vallecorsa, a municipality in central Italy, is one of the landscapes inscribed in the Italian National Register of Historical Rural Landscapes and it is still characterized by traditional agricultural practices that provide multiple benefits also in ecological terms, maintaining a specific level of biodiversity, interpreted as part of the biocultural diversity of the area. The aim of the present research is to analyse the structure of the traditional landscape of Vallecorsa and to determine its main characteristics, using landscape as the scale. Through the use of GIS software, by means of photo-interpretation and the use of DTM, the present study analyses the structure of land use, and in particular of terraced surfaces, and the associated data on area size, fragmentation, altitude and slope. The results take into account the diversity of land uses and mosaic patches, as well as terraced surfaces, and their distribution in the territory, relating them to the local biodiversity, in particular that of dry stone walls.

Keywords Land use · Geographic Information System (GIS) · Fragmentation · Agrobiodiversity · Terraced landscape · Dry-stone walls

Communicated by Mauro Agnoletti.

✉ Giorgia De Pasquale
giorgia.depasquale@uniroma3.it

[1] Department of Architecture, Roma Tre University, Rome, Italy

[2] Associate Natural Sciences Officer, UNESCO, Maputo, Mozambique

Introduction

Following the economic boom after the Second World War, traditional agricultural landscapes underwent rapid and profound changes that transformed them into uniform landscapes, in some cases completely altering their main functions (Antrop et al. 2004). Urbanisation and economic growth have contributed to the abandonment of rural areas and their transformation, generating numerous changes in the mosaic of the traditional landscape and resulting in a loss of biodiversity (Deng et al. 2017) and, in some cases, causing hydrogeological hazards (Tarolli et al. 2014). The preservation of traditional agricultural landscapes is important for their natural, cultural, and aesthetic values as well as the knowledge that is being transmitted and managed through generations (Vallés-Planells et al. 2019).

The Italian territory is characterized by a vertical landscape of mountains and hills and, historically, terraces have represented the way for managing and cultivating territories with more or less impervious slopes (Agnoletti et al. 2015). By conserving rainwater and increasing soil moisture availability and land productivity, terracing plays an important role in improving habitat conditions by being beneficial for ecosystem and biodiversity restoration (Wei et al. 2012). The construction of dry-stone walls is part of a millennium-long process of shaping steep hillsides and, particularly in Italy and in the Mediterranean area, it is one of the most widespread traditional building technique. These ingenious man-made constructions are often referred to as multifunctional systems as they assure a series of ecosystem services and socio-cultural benefits such as reducing water runoff and conserving it, controlling erosion, conserving soil, improving soil fertility and land productivity, increasing crop yields, restoring vegetation, improving biodiversity and providing aesthetic value (Wei et al. 2016; Brunori et al. 2018). Among the main functions, the regulation of excess water runoff in relation to the retention capacity of the soil in order to guarantee a correct relationship between the elements of air, soil and water in the substrate and at the same time ensure stability on the slopes with a reduction in the level of erosion, is fundamental in the arid context of the Mediterranean Basin (Roose et al. 2002). During the hottest and driest days, the dry-stone walls are able to capture the atmospheric vapour which penetrates the rocks and which at night, as the air cools, condenses and is transformed into small droplets which are then released into the soil (Laureano 2001).

Terraced landscape's biodiversity is present in at least two different levels: the diversity of species cultivated in the field, and the flora and fauna that flourish among the interstices and margins near the drystone walls (Varotto et al. 2019). Considering the benefits in terms of biodiversity, terracing and traditional dry-stone walls are particularly valuable for the proliferation of reptiles, birds and mammals as well as terrestrial plants such as ferns, lichens, vascular plants, mosses and liverworts (Collier et al. 2013, Blasi et al. 2000). Generally, it is possible to affirm that dry-stone walls host more lichens than natural rocky walls and that they have also been positively correlated with the presence of molluscan species and butterflies (Dover et al. 2000). Moreover, the UNESCO-CBD Florence Convention of 2014 recognized the agronomic and historic-cultural value of terraces and their importance for the biocultural expression of the diversity of rural areas (Agnoletti et al. 2015) and, in 2019, the "*Art of dry stone walling, knowledge and techniques*" has been inscribed in the

Representative List of the UNESCO Intangible Cultural Heritage of Humanity (UNESCO, Decision of the Intergovernmental Committee: 13.COM 10.B.10, 2014).

Landscape diversity, here determined by the presence of varied land uses and numerous mosaic patches, has an impact on ecosystem functions and, in particular, on the loss of biodiversity (Deng et al. 2017). Moreover, the presence of traditional features such as dry-stone walls and terraces results in increased landscape diversity (Naveh, 1994). Structurally complex landscapes generally provide higher levels of ecosystem services compared to simple ones and, in general, the composition of the landscape has important effects on local biodiversity, to the extent that, in some cases, it becomes more important than farming techniques (Winqvist et al. 2011). Moreover, by providing different habitat types in the overall matrix, landscape-scale heterogeneity affects species richness, particularly that of birds communities (Guyot et al. 2017).

The aim of the present study is to analyse the structure of the traditional landscape of Vallecorsa and to determine its main characteristics and elements, in particular determining the types of land use, area, fragmentation, average and maximum altitude, slope and features. In particular, the terraced surfaces are analysed, obtaining information on their distribution within the study area in order to determine the relationship between the vertical structure of the Vallecorsa landscape and the agrobiodiversity associated with the distinct altitude bands. This research therefore aims to analyse the existence of a positive correlation between the complexity and fragmentation of land uses and biodiversity, both in terms of agrobiodiversity and landscape. This study can be the basis for further research to compare neighbouring areas, which have not maintained the same landscape diversity, and assess the levels of biodiversity present, with a possible focus on the difference between terraced and non-terraced olive groves. Moreover, considering the importance of maintaining traditional systems for the preservation of agrobiodiversity, both cultivated and endemic, this study might be useful for the development of planning and management tools aimed at the preservation of local and traditional knowledge that contribute to the creation of sustainable agroecosystems similar to the one analysed in Vallecorsa.

Methods and materials

Study area

The study area (Figs. 1, 2), thus the whole municipality of Vallecorsa, is located in central Italy, more precisely in the province of Frosinone, in southern Lazio about 110 km from Rome. The area has a surface of 3970 hectares and is defined by administrative boundaries that correspond to natural features. In fact, the municipality of Vallecorsa is part of a valley whose borders run along the crests of the mountains by which it is surrounded. The altitude varies between 173 m a.s.l., coinciding with the confluence of the stream *Il Fossato*, to the top of *Cima del Nibbio* at an altitude of 1054 m a.s.l.. The surface has an average slope of 44.5% and a maximum of 190% (62°), thus reaching very extreme steepnesses (Fig. 3).

The territory of the study area is mainly characterised by two factors: a calcareous soil, rich in outcropping boulders, and aridity. The study area is located in a transitional area between the Mediterranean and the temperate macro-bioclimates. By definition, the Mediterranean macro-bioclimate is the extratropical type in which, during the hottest period of the year, there are at least two consecutive months in which precipitation in mm is less than twice the temperature: $P < 2\,T$ (Rivas-Martínez et al. 2011).

Fig. 1 View of the valley of Vallecorsa from the olive groves terraces

Fig. 2 Location of the municipality of Vallecorsa, Italy

Fig. 3 Protected areas in the municipality of Vallecorsa

For the analysis of precipitation and temperature, the most recent five-year period, from 2016 to 2020, was taken into consideration and data from the Regional Agency for Development and Innovation in Agriculture of Lazio (ARSIAL) were used (Tables 1, 2).

Table 1 Rainfalls of the municipality of Vallecorsa, 2016–2020

Rainfalls						
Month	2016	2017	2018	2019	2020	Average
January	90.2	117.6	89.8	194.2	96	117.56
February	266	84	280	119	45.2	158.84
March	96.4	51.4	390.4	23.4	192.4	150.8
April	55.8	69.8	29	129.4	45.8	65.96
May	85.2	45.2	109.4	209.4	39.2	97.68
June	86.2	19.2	50.8	3.6	182.8	68.52
July	36.2	45.8	45.8	126.8	30.4	57
August	19.8	9.6	72	15.8	49	33.24
September	111.2	108.2	38.4	116.8	151	105.12
October	118.2	49.6	183.6	141.6	204.6	139.52
November	76.6	298.6	331	645.8	89.6	288.32
December	12	324.6	177	321.8	506.8	268.44
Cumulative	1.053	1.225	1.797	2.048	1.633	1.551

Table 2 Temperatures of the municipality of Vallecorsa, 2016–2020

Temperature						
Month	2016	2017	2018	2019	2020	Average
January	8.3	4.6	8.9	4.9	7.7	6.9
February	10.1	9.2	5.5	8.3	9.4	8.5
March	9.9	11.7	8.7	11	9.5	10.2
April	15.3	12.7	15.7	12.1	13	13.8
May	16.1	17.2	16.9	12.6	17.5	16.1
June	20.4	22.8	20.6	23.3	18.8	21.2
July	24.6	24.4	23.8	24.3	23.6	24.1
August	24.2	26.4	22.9	24.9	24.1	24.5
September	19.7	18	20.3	20.1	20.4	19.7
October	16.1	15.8	16.7	16.3	13.7	15.7
November	11.7	10.1	11.7	11.7	12.2	11.5
December	8.5	6.9	8.3	9.2	8.2	8.2

The average rainfalls of each month were calculated in order to identify the months with the most and least rainfalls, and the average cumulative rainfalls was taken into account. The analysis shows that the driest months are July and August and the wettest are November and December. The annual cumulative rainfalls varied between 1053 and 2048 mm, with an average of 1551 mm.

For temperatures, average values were used to identify the coldest and warmest months on average. The coldest period is between December and February, with the lowest temperatures peaking in January. The highest temperatures are reached between July and August.

The hydrographic network is poorly developed. In the valley there are alluvial deposits of "*Il Fossato*", a stream of torrential character, made up of red earth and volcanic products of all volcans of Latium (Meloni et al. 2013).

In the last 20 years there has been an increase in the forest vegetation in the areas investigated, triggered by processes of recolonization of shrub pioneer species (Broom, Phillyrea, Lentisk, Ampelodesma, Asparagus, Dog Rose, etc.) and forest trees with anemophilous dissemination (Maples, Dogwood, Siliquastro, Acacia, etc.) on former agricultural areas; these processes seriously contribute to the increase in the number of forest fires. In addition, considering that terraced farms function as a defense against forest fires (Gonçalves et al. 2018, Socci et al. 2019), collapsed dry stone walls no longer constitute a barrier against them. In this regard, many studies cite the propensity for fire spread as a consequence of terrace abandonment.

The territory of Vallecorsa is located in a valley characterised by carbonatic mountains. The main lithotypes are limestone and limestone with flint and dolomite (Napoli et al. 2019).

The municipality of Vallecorsa falls within the special protected area "*Monti Ausoni and Aurunci*" (SPA IT6040043) and the site of community importance "*Monte Calvo e Monte Calvilii*" (SIC IT6050024) (Fig. 4). The most significant for the territory of Vallecorsa is the SPA "*Monti Ausoni ed Aurunci*" since it covers 81.4% of its territory, excluding only the valley floor area.

Given its geographical position and the peculiar conformation of the territory, Vallecorsa has not undergone the phenomenon of agricultural intensification to which other parts of the Italian territory, especially in the lowland areas of northern regions, have been exposed (Agnoletti et al. 2019). The study area, characterised by a traditional small-scale agriculture mainly linked to self-consumption with the cultivation of olive groves, vineyards and non-irrigated arable land, has therefore preserved the traditional elements of the landscape, still visible in the complex mosaic of the landscape, the terraced plots and in the dense network of wells and shelters scattered throughout the valley, testifying to the need to cope with aridity in a place with no natural sources.

The inhabitants of Vallecorsa have been able to deal with the constraints of the territory and transform the landscape, strongly characterized by an inhospitable topography and water scarcity, into a productive land. Back in the 14th century, farmers shaped the rocky surface with sledgehammers to build dry-stone walls, here called "*macère*", to make room for the cultivation of olive trees and their presence is already attested in the municipal statutes of 1327 (Municipal Statutes, Vallecorsa, 1327). Historically, men were in charge of the construction of the "*macère*" while women used to carry the fertile land from the valley floor to the terraces, through the use of baskets built with wicker or small olive branches, in order to ensure greater productivity of the soil. Different terracing systems are present in the study area due to the morphological variability of the land and the calcareous boulders emerging on the surface Oliveti terrazzati di Vallecorsa, Application dossier, National

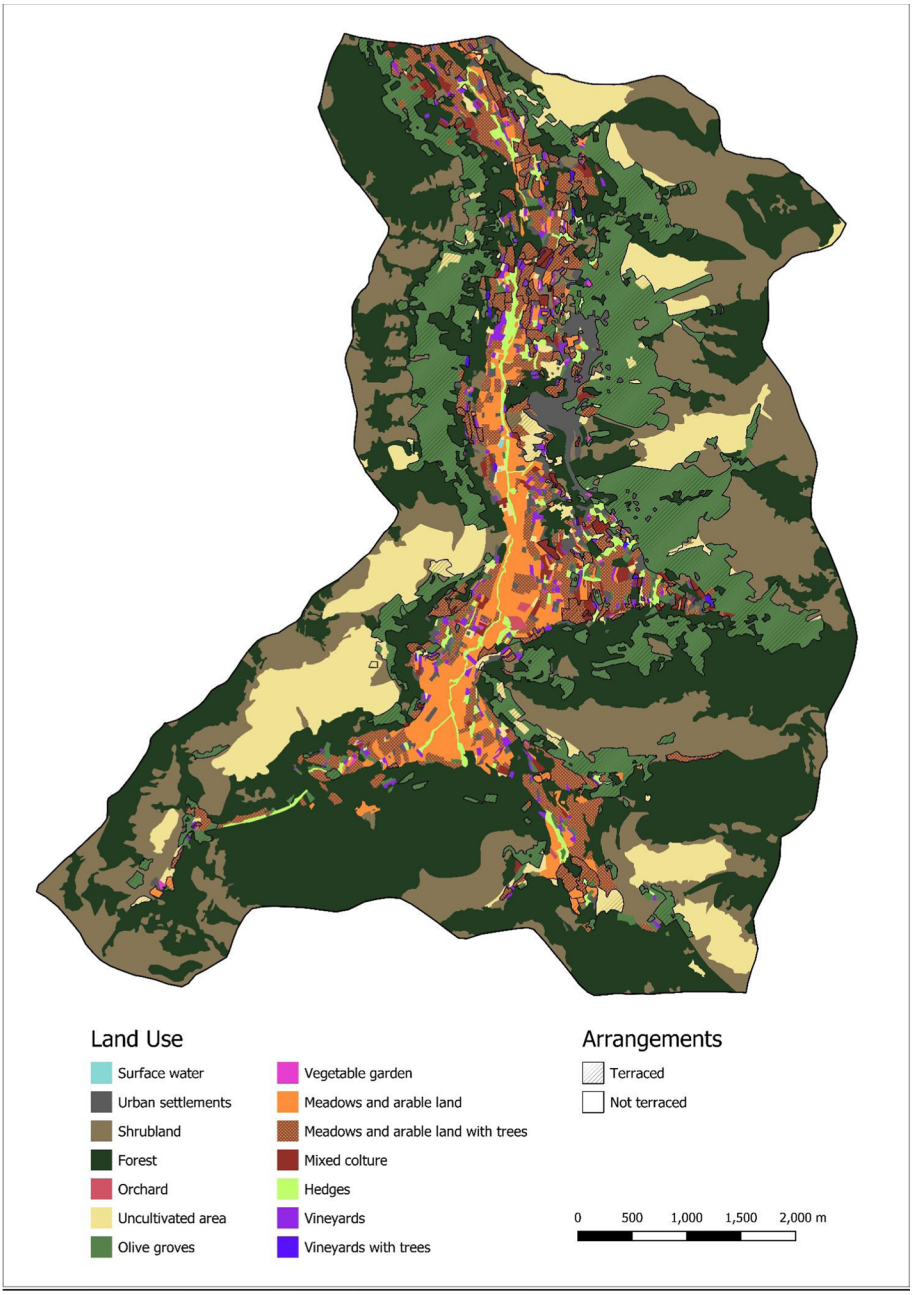

Fig. 4 Land use map of Vallecorsa

(Register of Historical Rural Landscapes). There are linear systems of terraces of different sizes depending on the slope of the land and, in some cases, where the slope or the shape of the land did not allow otherwise, small enclaves with semi-circular walls were built to

Table 3 Land uses and macro-category of the land use map

Land use	Macro-category
Meadows and arable land	Agricultural
Meadows and arable land with threes	
Mixed cultivation	
Olive groves	
Orchard	
Uncultivated area	
Vegetable garden	
Vineyard	
Vineyard with trees	
Shrubland	Forestry
Forest	
Hedges	
Urban settlements	Urban
Surface water	Unproductive

protect individual olive trees, called "*lunette"*. Towards the bottom of the valley, where the slopes are gentler, the landscape is characterised by the so-called "*ciglioni*". It is estimated that there are about 2000 km of dry-stone walls in the study area as reported in the documents supporting the UNESCO candidacy of the art of dry-stone walls (UNESCO Nomination file No. 01393, Consent of communities—Italy).

Methodology.

The first part of the research focuses on the study of the territory of Vallecorsa, and in particular of its morphological, climatic and cultural components.

The administrative boundaries of the Italian municipalities were downloaded from the ISTAT website, updated to 1 January 2021, and then the municipal boundaries of Vallecorsa were extrapolated to create the reference shape file. The study area, through the extrapolated vectorial file, has been analysed and processed through photointerpretation of Google Satellite images of 2017, through the Quick Map Service plug-in, using Quantum GIS 3.10.4 thus allowing to study the mosaic structure of the traditional agricultural landscape of the territory.

The land use map elaborated in this process counts 14 different land uses, some of which were further subdivided in "terraced" and "not terraced". Through the land use map, it was possible to identify the distinct land uses present in Vallecorsa and analyse their structure and peculiarities in terms of area, altitude, landscape distribution, state of conservation and criticality. The legend was developed following four general macro-categories (agricultural, forest, urban and unproductive) and was then expanded and adapted during the photointerpretation according to the evidence derived from the images. The Table 3 shows the macro-category distribution.

Despite being currently unproductive, the uncultivated area was included in the agricultural macro-category because it was used as pasture in the past, from which it appears to be an area suitable for agriculture, although now unused. Uncultivated areas also include grassland pastures affected by fires. Considering the difficulty in distinguishing forest

species through photointerpretation, the analysis of the various species was carried out by comparing them with the data in the SHP file of the forest type map downloaded through the GeoPortal of the Lazio Region.

The DTM (Digital Terrain Model) was downloaded from the National Environmental Information System Network of the Higher Institute for Environmental Protection and Research (ISPRA), with resolution 20 m. The DTM was used to obtain data on the altitude bands and average and maximum slope of each land use, also with the distinction between terraced and not terraced landscape. In particular, a comparison was made between the different types of olive groves in the study area to compare the average slopes of non-terraced valley floor olive groves with terraced and abandoned ones.

To better understand the landscape's texture distribution, an advanced elaboration has been carried out. The site area has been framed in a hexagonal grid, with each hexagon being 1 ha in area, using the MMQGIS plug-in. Within each hexagon, the number of patches and the amount of unique land uses were then counted. From these data, a complexity map has been elaborated, with a bivariate legend to show both information at the same time.

Finally, the last elaboration involves a multitemporal analysis focussed on the terraced olive groves areas. This analysis aims to better understands the evolution of the terraced landscape, comparing the land use map of 1954 and the land use map of 2012. The area took into consideration for this analysis is the same area of the National Register of Historical Rural Landscapes site because it covers most of the terraced olive groves, with a total surface of 716 hectares. The first land use map derives from the photointerpretation of the 1954 aerial photos from the Military Geographic Institute, while the second one derives from the photointerpretation of the Google satellite photos of 2012.

A new map, derived from the overlay of the two previous ones, was then elaborated and the polygons of this new layer were reclassified according to the possible combinations of past and current land use, i.e., the dynamics of landscape evolution. These dynamics follows some rules to show different external energy-wise changes in the landscapes, and are briefly explained below:

- Unchanged: where two land uses coincide, or the energy input required from both land uses (past and current) remain similar.
- Unchanged terraced olive groves: a subcategory of "unchanged" has been introduced to better shows this dynamic in regards of the focal argument of this research.
- Urbanization: when any kind of past land use (except urban) becomes urban.
- Intensification: when a land use with a low energy input becomes another land use with a higher energy input required (for example, a pasture becomes a crop field)
- Extensification: when a land use with a high energy input becomes another land use with a lower energy input required.
- Permanence of olive groves in a state of abandonment: while normally this dynamic will be shown as an extensification, it has been kept separate to better explain the evolution of the olive groves.
- Renaturation by secondary ecological succession: when any past land use becomes forest for secondary succession, normally due to abandonment of agricultural activities.
- Conifer reforestation: since a wide area has been artificially reforested with pinus spp., this dynamic has been separated by the natural secondary ecological succession.

The final part focuses on the importance of landscape complexity and terracing for local biodiversity and the agricultural development of an area otherwise difficult to cultivate

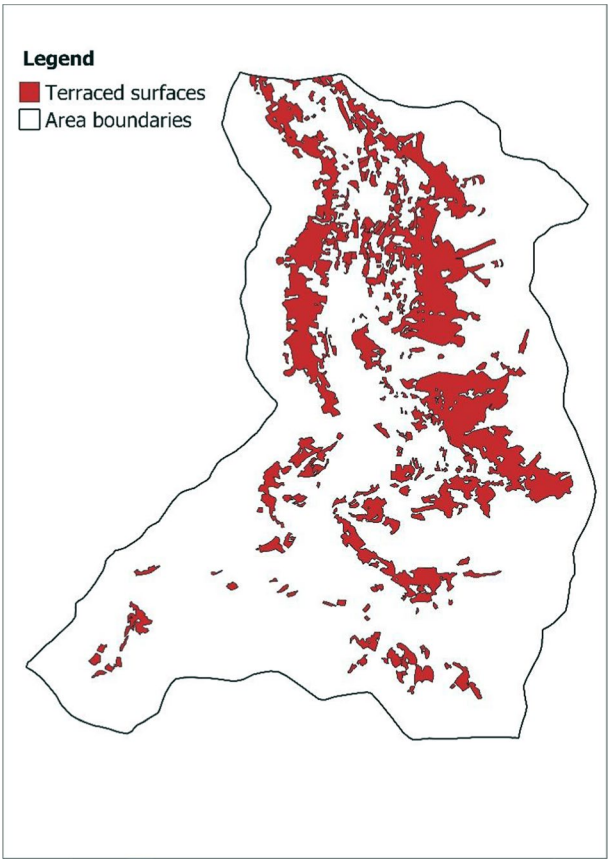

Fig. 5 Spatial distribution of the terraced surfaces

because of steep slopes and aridity. Data on animal species present in the territory have been collected through the lists of species of the Special Protected Area (SPA) "*Monti Ausoni e Aurunci*" and the application dossier for the National Register of Historic Rural Landscapes.

Results and discussion

Land use and terraced landscape

Land use analysis

The map (Fig. 5) describes the land use of the study area. In general, it is possible to observe that the territory is characterised by a high patch density that creates a very complex and heterogeneous landscape, especially at the valley floor. The ridges and slopes that descend to the bottom of the valley are mainly characterised by woods, uncultivated areas, shrubs, and terraces, which are particularly evident on the sunnier eastern slope.

Table 4 Land use of the study area distinguished in four macro-categories

Land use	Area (ha)	Area (%)	N. Patches	Average Patch Area (ha)
Agricultural	1424.95	36	1797	0.79
Forestry	2399.38	61	424	5.66
Urban	93.48	2	395	0.24
Unproductive	0.35	0	2	0.17
Total	3918.16	100	2.618	1.49

Table 5 Land use of Vallecorsa

Land use	Area (ha)	Area (%)	N. Patches
Forest	1,502.14	38	197
Shrubland	851.25	22	149
Olive grove	579.63	15	470
Uncultivated area	351.95	9	156
Meadows and arable land with trees	247.36	6	396
Meadows and arable land	145.89	4	338
Urban agglomerations and settlements	93.48	2	395
Hedges and trees	46	1	78
Vineyards	35.54	1	249
Meadows and arable land with trees and vines	19.55	0	43
Meadows and arable land with vines	16.06	0	52
Uncultivated area with trees	13.37	0	15
Meadows and arable land with olive trees	6.4	0	25
Vegetable gardens	3.25	0	34
Orchard	2.72	0	3
Vineyard with trees	2.51	0	13
Vineyard with olive trees	0.64	0	2
Surface waters	0.35	0	2
Meadows and arable land with vines and olive trees	0.09	0	1
Total	3918.16	100	2.618

The table (Table 4) shows the land use of the study area divided into macro-categories. The table shows that the area is strongly characterised by agriculture (36%) and a high incidence of forestry (61%). For the analysis of the forest component, see the table below (Table 6) on the different forest species present in the study area.

Among the most common agricultural crops are: olive groves (15%); meadows and arable land with trees (6%); meadows and arable land (4%) and vineyards (1%). Urbanisation covers only 2% of the municipal territory with the main urban agglomeration represented by the centre of Vallecorsa. The majority of the population live in the city centre with few urban expansion phenomena in the rest of the territory.

Although vineyards occupy only 35 hectares (Table 5), that is only 1% of the entire municipal area, they play an interesting role in the landscape and its fragmentation. Indeed, they are often associated with houses and urban agglomerations for family farming. This is

Table 6 Forest species of the study area

Forest species	Area (ha)	Area (%)
Holm oaks	619.33	41
Downy oak forests	593.42	40
Hornbeams	167.05	11
Chestnut groves	64.38	4
Shrublands and high scrub	22.69	2
Pseudo scrub	21.70	1
Pine forest	13.56	1
Total	1502.13	100

A comparison between the land use map given by the photointerpretation and the Geoportal of the Lazio region

confirmed by the high number of landscape patches (249) and their very small average size of 0.14 hectares.

In the study area, the forest component plays an important role covering 61% of the whole surface. For this reason it was decided to analyse which species are most present by comparing the photo-interpretation carried out for the present study with the data gathered from the Geoportal of the Lazio region. The Table 6 lists the main forest species present, the area in hectares and the percentages with respect to the whole forest surface. The prevailing forest vegetation is made up of holm oaks (41%), downy oaks (40%), hornbeams (11%) and chestnuts groves (4%). Their characteristics and distribution are described in the table according to the data of the GeoPortal of the Lazio Region.

The main function of these forest ecosystems is to protect the environment, nature and landscape and to provide a refuge for wildlife as stated in the forest management and land-use plan 2016–2025 of the Municipality of Vallecorsa. Considering that the woods in the study area belong to the special protected area "*Monti Ausoni ed Aurunci*", these woods are a natural habitat for a large number of wild animals, including species of Community importance.

Terraced landscape

The map (Fig. 5) illustrates the terraced surfaces, including those defined as "*ciglioni*", present in the study area. Of the total municipal area, 666.57 hectares are terraced, representing about 17% of the total area and 33,05 hectares are "*ciglionati*" constituting another 1% of the total surface. The Table 7 further analyses all those land uses that are partly, even minimally, terraced or "*ciglionati*". In particular, 95% of the olive groves are terraced, thus constituting the most terraced land use (Fig. 6).

Another significant percentage of terraces is present in the land use category of meadows and arable land with trees, of which 25% is terraced (about 62 hectares) and 10% is "*ciglionato"* (about 26 hectares). Although the category of meadows and arable land with olive trees is less relevant in terms of surface area, representing only 6.40 hectares, it is interesting to observe that more than half of its surface (52%) is terraced.

In a climatic and morphological context such as that of Vallecorsa, it is important to underline that, in the absence of terracing, sparse vegetation would have developed with a clear reduction in the local biodiversity and with potential hydrogeological hazards.

Table 7 Terraced and "ciglionato" land uses distributed in decreasing order per hectare of terraced area

Land use	Total area (ha)	Terraced area (ha)	Terraced area (%)	Ciglionato area (ha)	Ciglionato area (%)
Olive groves	579.63	547.92	95	0.96	0
Meadows and arable land with trees	247.36	62.34	25	25.78	10
Uncultivated area	351.95	21.41	6		
Uncultivated area with trees	13.37	7.29	55		
Meadows and arable land	145.89	6.64	5	3.46	2
Meadows and arable land with trees and vines	19.55	6.22	32	1.09	6
Meadows and arable land with vines	16.06	5.70	36	1.14	7
Meadows and arable land with olive trees	6.40	3.32	52		
Shrubland	851.25	3.05	0.36		
Vineyards	35.54	1.29	4	0.36	1
Vineyard with trees	2.51	1.19	47	0.26	11
Vegetable gardens	3.25	0.20	6		
Totale complessivo	2,272.76	666.57	17	33.05	1

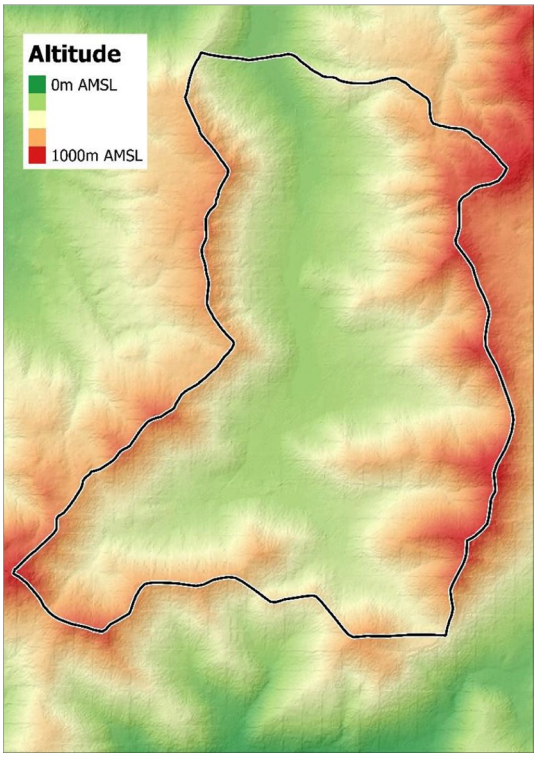

Fig. 6 Altitude of the municipality of Vallecorsa

Table 8 Olive groves and their average slope divided into terraced and abandoned categories

Land use	Terraces	Abandoned	Slope mean (%)
Olive groves			16.7
		X	36.7
	X		42
	X	X	50

Of the total 579.63 hectares of terraced olive groves in the Municipality of Vallecorsa, 94.04 hectares, corresponding to 16%, are in a state of abandonment. The data of the land use analysis carried out for the present research confirm the data collected for the preparation of the nomination dossier of the terraced olive groves of Vallecorsa to the National Register of Historic Rural Landscapes, which was carried out through photo-interpretation of aerial images of 2012. The past analysis showed a total of 484.68 hectares of terraced olive groves not in a state of abandonment, which is only slightly different from the current area of terraced olive groves not in a state of abandonment, which is 485.59 hectares.

In particular, the Table 8 shows the average percentage slope of the olive groves distinguished according to the presence of terraces and their state of conservation (abandoned or not). Terraces are most obviously encountered where the terrain is steepest. It is particularly relevant to note that the highest average slope is found in abandoned terraced olive groves, as it can be assumed that they are more difficult to access, even considering that these can reach a maximum slope of 101%. The slope of the not terraced but abandoned olive groves (36.7%) is lower than that of the terraced but not abandoned ones. Abandonment in these cases may not be due to the high slope but rather to the inaccessibility of the fields.

Vertical landscape and agrobiodiversity

By means of the DTM, it was possible to analyse the altimetric conformation of the valley, which is open to the north and then surrounded by mountain ridges reaching a height of one thousand metres along the eastern, western, and southern slopes (Fig. 7).

The diagram below (Fig. 8) analyses the main characteristics of the vertical landscape of Vallecorsa. The section has been chosen in a particularly representative segment of the agricultural landscape from which it is possible to appreciate a vast extension of terraced olive groves and understand how they fit into the territory together with the other characteristic elements of the landscape.

The summit segment, between 700 m a.s.l. and 1000 m a.s.l., is the area that was once mainly devoted to pastoral activities and today consists mainly of forests, shrubs and uncultivated areas.

Olive groves The section of the landscape that ranges on average between 340 and 650 m, but reaches a maximum altitude of 776 m, is characterised by terraced olive groves that create a horizontal pattern in the landscape. In particular, the area is characterised by olive groves of an autochthonous cultivar called "*Vallecorsana*" featuring a low-density planting system (less than 200 trees per hectare) and a low intensity of tillage. The Regional Agency for the Development and Innovation of Lazio's Agriculture (ARSIAL) includes the "*Vallecorsana*" in the census of local varieties of olive trees of the Lazio Region (ISPRA, 2017).

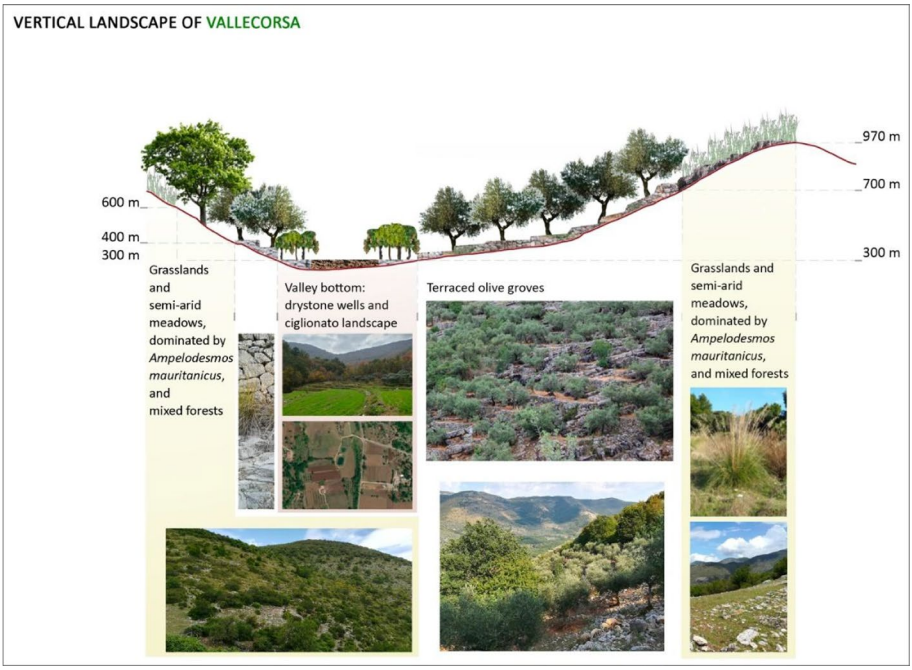

Fig. 7 The vertical landscape of Vallecorsa divided by altitude bands and corresponding land uses and landscape elements

In addition to this native cultivar, which is found exclusively in the study area, there are also the "*Carboncella*" and "*Itrana*" varieties, which are also widespread in neighbouring areas.

Despite most of the terraces host almost exclusively olive trees, it is possible to find, especially where slopes are not particularly steep, rows of vines placed in combination with olive trees to perimeter the terraced area by using the Guyot method. Moreover, among the terraces, there are also numerous spontaneous plants that find space together with the olive groves. Among these are figs, prickly pears, cherries, pears, apples, peaches, apricots, hazelnuts, walnuts, and plum trees.

Among the terraced olive groves there are also sheep and goats, which were once the backbone of the inhabitants of Vallecorsa and performed important ecological functions such as the natural fertilisation of the soil. Today, there are a total of about 500 sheep and goats throughout the study area.

Arable land The valley bottom, that ranges between 340 m (east side) and 250 m (west side), is constituted by the *ciglionato* landscape of arable land, vineyards, and vegetable gardens. The largest *ciglionato* landscape still maintain the characteristics of the arable land, while the narrower ones are now mostly used for family viticulture (Carallo and De Pasquale 2018).

In addition to the above-mentioned sheep and goats, according to ISTAT data from the 2010 agricultural census, for family and local production, there are 193 cattle, 28 buffaloes, 114 horses, 423 sheep, 75 goats, 6 pigs, 20,464 chickens and 125 rabbits in

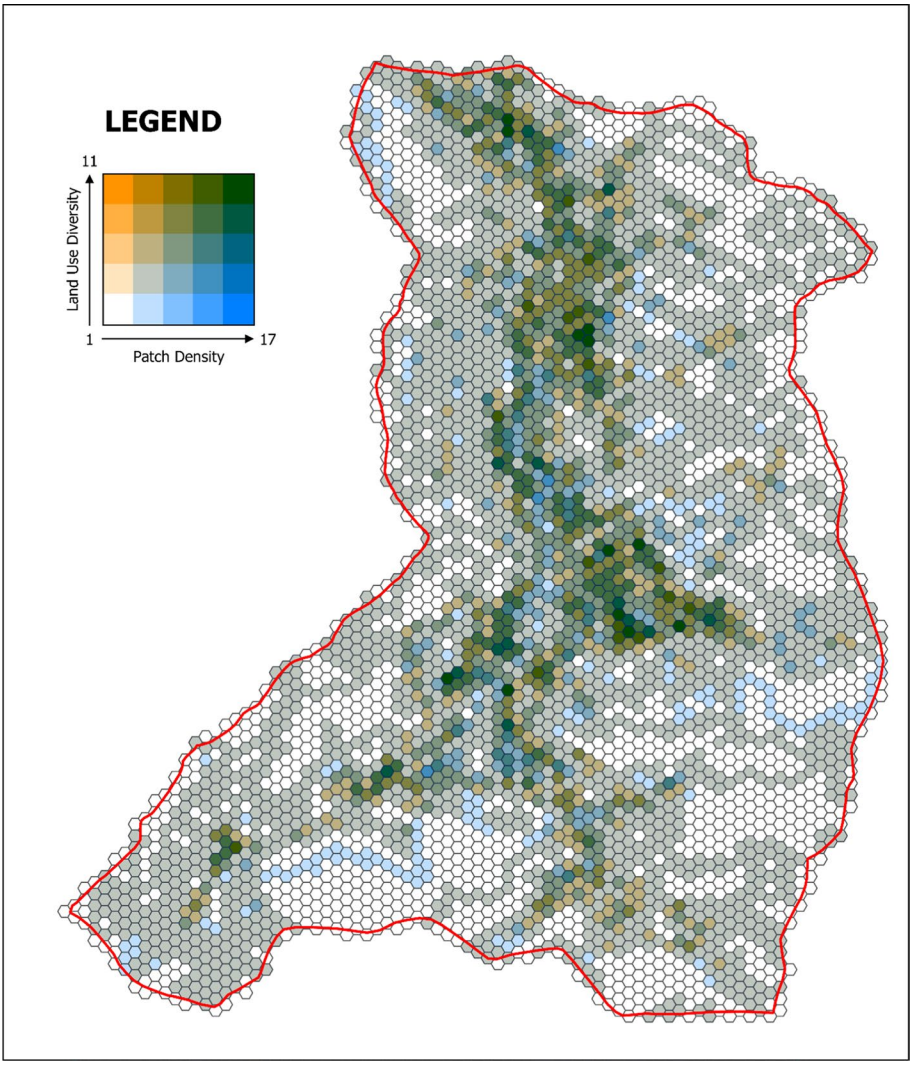

Fig. 8 The landscape complexity of the municipality of Vallecorsa

the entire municipality. This figure is significant for local agro-biodiversity but suggests that livestock farming does not play a significant role in the local economy.

The map below (Fig. 8) shows the landscape complexity, obtained from a further elaboration of the land use map based on 1 ha hexagonal grid. The complexity is identified by a bivariate scale, thus intersecting two different information in a single legend: the first information (on a white-to-blue scale) shows the number of patches that fall, even partially, within the specific hexagon; the second information (on a white-to-orange scale) shows the unique land use that can be found in that hexagon. The intersection of these two legends provides a sufficiently accurate descriptive picture of the complexity of the landscape.

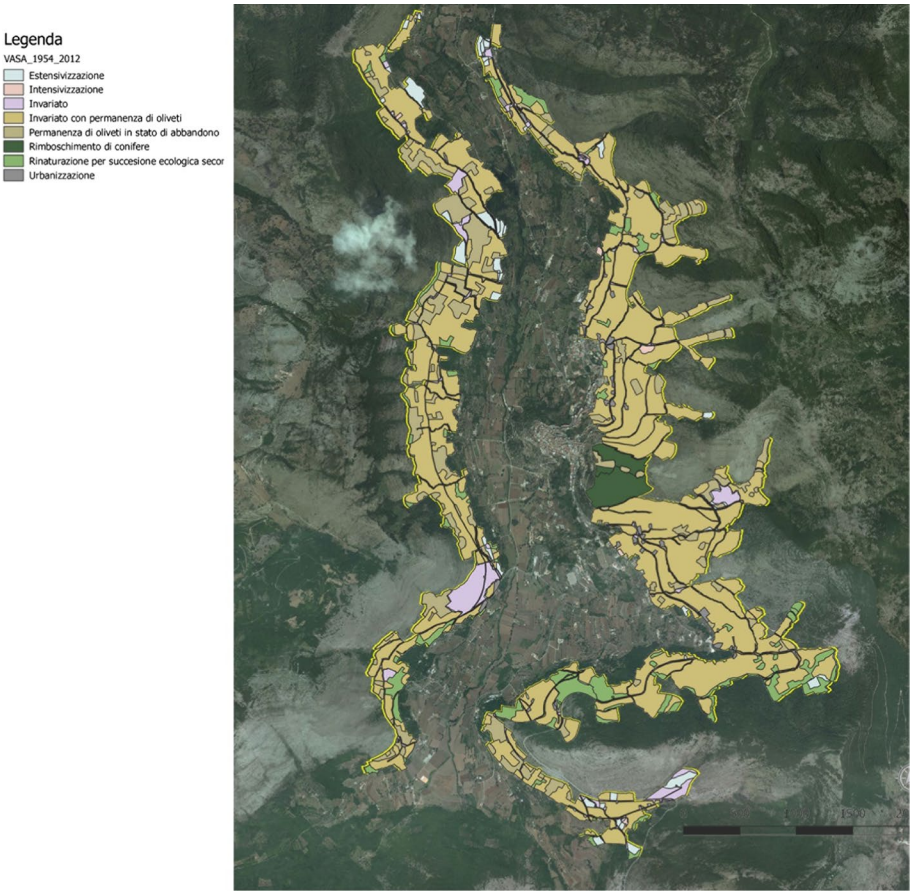

Fig. 9 Map of the dynamics of landscape evolution, Application dossier to the National Register of Historic Rural Landscape

It is not possible to have more number of land uses than the total number of patches. On the other hand, the number of land uses may be less than the number of patches if, within a hexagon, more than one patch has the same land use.

As shown, the most complex areas are found on the valley floor, but this gradually decreases along the slopes to an extremely low level of complexity in the highest areas. This result is in fact explained by the fact that, as emerged from the analysis of land use and vertical distribution of agrobiodiversity, landscape belts at higher altitudes are mainly characterised by four main land uses (forest, shrubland and terraced olive groves) and very large patches.

Multitemporal analysis

The map in Fig. 9 shows the result of the dynamic analysis for the period 1954–2012. The landscape of the area considered in this analysis in 1954 was mainly covered by

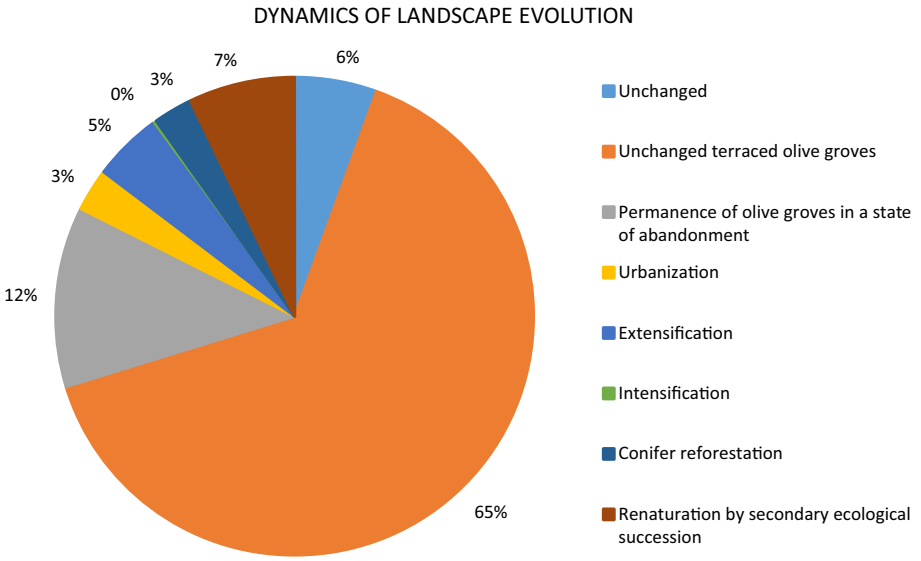

Fig. 10 Dynamics of landscape evolution

terraced olive groves (620 ha), while the remaining 100 ha were mostly uncultivated (50 ha). Forests have a marginal presence and therefore a minor role in the local traditional landscape. The analysis of the dynamics highlighted that most of the olive groves still characterize the slopes, even if some of them are currently classified as abandoned olive groves, as they are no more regularly managed for olive production, no regularly pruned and invaded by shrubs.

The conifer reforestation occupies a single, continuous area in the centre of the site, while secondary succession can be found scattered throughout the site. These new vegetal formations are very different, not only due to the characteristics of their structure or to the species, but also for their origin. Pine forests are artificially planted during the 1960s, while natural reforestation processes are a consequence of the abandonment of cultivated areas and of the secondary successions.

The intensification dynamic is nearly absent in the site, since the soil and the morphology do not allows the development of modern olive plantations with high density and irrigation. The extensification dynamic concerns some small areas scattered throughout the site area. Finally, urbanisation processes have involved areas adjacent to the main road, forming small scattered settlements, even if it is important to underline that the main urbanization processes are found near the medieval town of Vallecorsa.

The graph in Fig. 10 shows important data about the evolution of the terraced landscape. 71% of the area results unchanged (65% unchanged olive groves, 6% other land uses). The second dynamic by coverage is the permanence of olive groves in a state of abandonment (12%), a result that highlights the already mentioned problem of the abandonment phenomenon and the fact that this trend was already started in 1954. The graph shows the presence of conifer reforestation on the 3% of the considered area, corresponding to an artificial plantation of Pinus spp. that have been carried out during the second half of the last century; this dynamic involved mostly surfaces uncultivated in 1954, since those where the most dangerous surfaces for hydrogeological risks and one

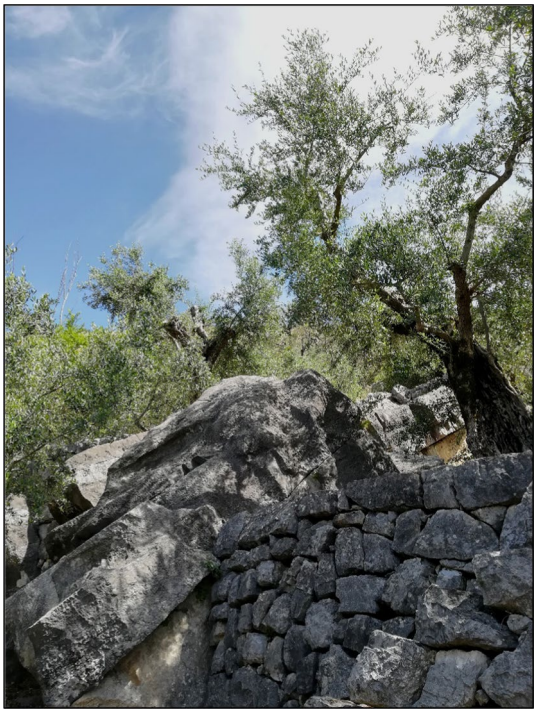

Fig. 11 Dry-stone walls among boulders

of the aims of these afforestation interventions was to stabilize the slopes, along with other important social purposes, including maintaining the employment of local residents (Fig. 11).

Finally, it is relevant to underline the increase of urban areas (3%). This increase appears particularly significant, as it occurred in an area that in the 50 s of the last century was essentially lacking in road infrastructure and the built-up area was represented by very modest rural dwellings, and also because this data underestimate the overall urbanization occurred in the municipality area as it does not consider the area near the historic town.

Biodiversity

The varied mosaic of the landscape that characterizes the territory, generated by the alternation of different microclimates, cultivations, and plant communities, creates the ideal conditions to host a large number of animal species, in many cases of great naturalistic interest as endemic species of the Mediterranean area.

The table (Table 9) indicates the most representative species of the territory, and in particular those concerning terraces and dry-stone walls (Fig. 11), some of which correspond to those included in the Natura 2000 Network of the Lazio Region. The presence of the species listed in the table, which is not exhaustive, derives from a cross comparison between the Flora and fauna biodiversity list in Annex I of the Standard Data Form of the Special Protection Area (SPA) "*Monti Ausoni e Aurunci*", the data

Table 9 List of fauna biodiversity among terraces and dry-stone walls in the municipality of Vallecorsa

Phylum	Class	Description
Mollusca	*Gastropoda*	Dry-stone walls provide an ideal habitat for various species of molluscs. Among these are the land snails that live in the interstices. In particular, it is possible to find the snail *Eobania vermiculata* and the *Leucostigma candidescens*
Chordata	*Amphibia*	Thanks to the widespread diffusion of the wells, the common toad (*Bufo bufo*) and the green frog (*Pelophylaxkl hispanica*) are also present among the terraces
	Reptilia	There are numerous species of reptiles, among the most frequent are the common viper (*Vipera aspis*) and the field lizard (*Podarcis siculus*) which use the macèra, a sunny and dry environment, to hide and defend themselves
		Among the most common ophidians are the Biacco (*Coluber viridiflavus*), the Cervone (*Elaphequatuor lineata*), the Saettone (*Zamenis longissimus*) and the common Gecko (*Tarentola mauritanica*). In fact, these species find an ideal habitat among the dry-stone walls that host them, being warm and dry environments. They also have an important ecological function as they help to contain harmful insects
	Aves	The territory also has a favourable habitat for birds and raptors, as highlighted by the lists of species present in the SPA "Monti Ausoni and Aurunci". Among the most important are the peregrine falcon (*Falco peregrinus*), the short-toed eagle (*Circaetus gallicus*), the kite (*Milvus migransa*), the buzzard (*Buteo buteo*), the barn owl (*Tyto alba*), the owl (*Athene noctua*), the wood pigeon (*Columba palumbus*), the western wild pigeon (*Columba livia*) and rarely the golden eagle (*Aquila chrysatos*) is spotted
		Among the passerines there are: the coral chough (*Pyrrho coraxpyrrhocorax*), the little shrike (*Lanius collurio*), the chaffinch (*Fringilla coelebs*), the blackbird (*Turdu smerula*), the blackcap (*Sylvia atricapilla*), the crow (*Corvus corone*), the hoopoe (*Upupa epops*) and the domestic sparrow (*Passer domesticus*)
	Mammalia	Among the mammals that frequent the terraces are the fox (*Vulpes vulpes*), the marten (*Martes foina*), the weasel (*Mustela nivalis*) and the wild mouse (*Apodemus sylvaticus*)
		It is also possible to encounter insectivores such as the European hedgehog (*Erinaceus europaeus*) and the mole (*Talpa europacea*)
		Among the species of considerable interest as they help maintain the ecosystem balance, there are also the common hare (*Lepus europaeus*) and the bat (*Rhinolophus ferrumequinum*)

collected through precise observations, interviews with the local population and the paragraphs on local fauna of the application dossier for the National Register of Historic Rural Landscapes.

Conclusions

The research presents an investigation about the land use structure of Vallecorsa, with a particular focus on its terraced landscape and its relationship with the state of biodiversity. The study area represents a unique environment where the local community has generated a sustainable agricultural system that respects nature and landscape, maintaining traditional agricultural practices. The land use study has shown that the territory has maintained over time the characteristics of a traditional agricultural landscape strongly characterised by a high diversity of land uses and a high number of landscape patches, especially on the valley floor. The diversified and fragmented landscape, due to the uneven morphology, the highly parcelled land ownership, and the presence of many different crops, has created a diverse environment characterised by a high degree of complexity and landscape biodiversity, especially on the valley floor. On the other hand, ascending along the valley ridges, the biodiversity of the area is mainly characterised by terraced olive groves, i.e., the different olive cultivars, wild fruit trees and the biodiversity of dry-stone walls.

Terraces and "*ciglioni*" cover 17.86% of the study area and they are mainly occupied by olive groves. The construction of terraces and dry-stone walls to make room for crops has been man's way of trying to adapt to hostile environments over time and they represent an expression of the biocultural diversity of the area. Dry-stone walls provide breeding and roosting sites for local fauna and can be a refuge for local plants that bloom between the cavities. They represent an ecological corridor, along with hedges and land cover heterogeneity and, in addition to the environmental benefits they provide, they have also been identified as traditional traits supporting the characterization of cultural landscapes (Agnoletti, 2015). Since the 1980s, the role that dry-stone walls play in the prosperity and proliferation of many species has begun to be explored in greater depth in the literature, but many specific studies still remain to be carried out (Darlington et al. 1981) and a detailed study comparing the biodiversity between Vallecorsa terraced olive groves and not-terraced olive groves could be developed in the future for further study.

The abandonment of rural areas, and in particular of terraced surfaces, represents a threat to the integrity of the traditional agricultural landscape. If not properly maintained, terraces and dry-stone walls risk to collapse thus creating problems in terms of their capacity to retain excessive runoff water and prevent hydrological hazards (Tarolli et al. 2014). In the specific case of Vallecorsa, approximately 16% of the terraces are in a state of abandonment. Among the main reasons, it is possible to enumerate the ageing of the population, youth migration, high maintenance costs and limited accessibility of the fields. Land abandonment interraced land scapes has several multidimensional impacts, among others, the impoverishment of agrobiodiversity and the loss of autochthonous varieties (Varotto et al. 2019). In order to overcome the challenges that traditional agricultural landscapes are experiencing, the inclusion of the study area in the list of the FAO Programme for Globally Important Agricultural Heritage Systems (GIAHS), and the development of a participatory action plan involving all stakeholders, would help the conservation and enhancement of the territory and its biocultural heritage.

Author contributions LS: Conceptualization, LS and GDP: methodology, LS and GDP: investigation, LS: writing, GDP: supervision.

Funding Open access funding provided by Roma Tre University within the CRUI-CARE Agreement.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

Agnoletti M, Conti L, Frezza L, Santoro A (2015) Territorial analysis of the agricultural terraced landscape of tuscany (Italy): preliminary results. Sustainability 7:4564–4581

Agnoletti M, Emanueli F, Corrieri F, Venturi M, Santoro A (2019) Monitoring traditional rural landscapes. Case Italy Sustain 11:6107. https://doi.org/10.3390/su11216107

Antrop M (2004) Landscape change and the urbanization process in Europe. Landsc Urban Plan 67(1/4):9–26

Blasi C, di Pietro R, Fortini P (2000) A phytosociological analysis of abandoned terraced olive grove shrublands in the tyrrhenian district of central Italy. Plant Biosyst 134(3):305–331

Brunori E, Salvati L, Antogiovanni A, Biasi R (2018) Worrying about "vertical landscapes": terraced olive groves and ecosystem services in marginal land in central Italy. Sustainability 2018(10):1164

Carallo S, De Pasquale G (2018) AgriCulture. tutela e valorizzazione del patrimonio rurale nel lazio. Roma Tre-Press, Rome

Collier MJ (2013) Field boundary stone walls as exemplars of novel ecosystems. Landsc Res 38(1):141–150

Darlington A (1981) Ecology of Walls. Heinemann Educational. London, 64p

Deng X, Gibson J, Wang P (2017) Relationship between landscape diversity and crop production: a case study in the Hebei Province of China based on multi-source data integration. J Clean Prod 142:985–992. https://doi.org/10.1016/j.jclepro.2016.03.174

Dover J, Sparks T, Clarke S, Gobbett K, Glossop S (2000) Linear features and butterflies: the importance of green lanes. Agric Ecosyst Environ 80(3):227–242

Gonçalves MM, PérezCanoRosendahlPrates MTSG (2018) When agriculture rules over the teritory: drystone walls. In: Villegas L, Lombillo I, Blanco H, Boffill Y (eds) REHABEND2018—7th Euro-American congress on construction pathology, rehabilitation technology and heritage management. University of Cantabria/University of Extremadura, Cáceres, pp 311–317

Guyot C, Arlettaz R, Korner P, Jacot A (2017) Temporal and spatial scales matter: circannual habitat selection by bird communities in vineyards. PLoS ONE 12(2):e0170176. https://doi.org/10.1371/journal.pone.0170176

ISPRA (2017) Quaderni natura e biodiversità, n.8, frutti dimenticati e biodiversità recuperata. Il germoplasma frutticolo e viticolo dellle agriculture tradizionali italiane. Casi studio: lazio e abruzzo
Laureano P (2001) Atlante d'acqua, conoscenze tradizionali per la lotta alla desertificazione. Bollati Boringhieri, Torino
Meloni et al(2013) I sinkholes di Vallecorsa tra storia e attualità. The Vallecorsa sinkholes between history and news, MemDescr Carta Geol d'It., XCIII (2013), pp 299–320
Napoli R, Paolanti M, Di Ferdinando S (A cura di) (2019) Atlante dei Suoli del Lazio, ARSIAL Regione Lazio, ISBN 978–88–904841–2–4
Naveh Z (1994) From biodiversity to ecodiversity: a landscape-ecology approach to conservation and restoration. Restor Ecol 2(3):180–189
National register of historic rural landscapes,(2017) Oliveti terrazzati di Vallecorsa, Dossier di candidatura
Rivas-Martínez S, Rivas-Sáenz S, Penas A (2018) Worldwide bioclimatic classification system. Glob Geobot 1:1–634
Roose E (2002) Traditional strategies for soil and water conservation in mediterranean areas. In: Rubio et al (eds) Proceedings of the third international congress man and soil at the third millennium. Geoforma Ediciones, Logroño
Socci P, Errico A, Castelli G, Penna D, Preti F (2019) Terracing: from agriculture to multiple ecosystem services. In: Socci P, Errico A, Castelli G, Penna D, Preti F (eds) Oxford research encyclopedia of environmental science. Oxford University Press USA, Oxford
Statute of the Vallecorsa Community prepared in 1327 and updated in 1531 and 1545
Tarolli P, Preti F, Romano N (2014) Terraced landscapes: from an old best practice to a potential hazard for soil degradation due to land abandonment. Anthropocene 6:10–25
UNESCO SCBD, Florence declaration on the links between biological and cultural diversity, UNESCO, Florence, 2014, http://www.landscapeunifi.it/images/pdf/UNESCO-CBD_JP_Florence_Declaration.pdf. Accessed 11 April 2014
Vallés-Planells M, Galiana F, Díez-Torrijos I (2019) Agricultural abandonment and resilience in a Mediterranean periurban traditional agroecosystem: a landscape approach. Ecol Soc 25(1):5
Varotto M, Bonardi L, Tarolli P (2019) World terraced landscapes: history, environment, quality of life, environmental history, vol 9. Springer, Cham
Wei W, Chen D, Wang L, Daryanto S, Chen L, Yu Y, Lu Y, Sun G, Feng T (2016) Global synthesis of the classifications, distributions, benefits and issues of terracing. Earth Sci Rev 159:388–403
Wei W, Chen L, Yang L, Samadani FF, Sun G (2012) (2012) Microtopography recreation benefits ecosystem resotration. Environ Sci Technol 46(20):10875–10876
Winqvist C, Bengtsson J, Aavik T, Berendse F, Clement LW et al (2011) Mixed effects of organic farming and landscape complexity on farmland biodiversity and biological control potential across Europe. J Appl Ecol 48:570–579

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.