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PhD IN
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CYCLE: XXXV

ANALYSIS AND EVALUATION OF HISTORICAL RURAL HERITAGE: INNOVATIVE APPROACHES FOR TERRACED LANDSCAPES IN THE EUROPEAN ALPINE REGION

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Preface

Many rural landscapes in Europe are recognized by the scientific community as important biocultural heritages to be strengthened. Among them, terraced landscapes are anthropic landscapes strongly linked with the rural communities, and characterized by historical agricultural practices and high-quality productions. During the last decades, these landscapes knew moments of crisis, since they were threatened by the abandonment of the cultivations. Furthermore, in the past the agricultural policies have favored the intensive agricultural systems in place of these others, often characterized by lower productions. Nowadays, there is an ever-increasing interest to the recovery of the terraced systems by the new rural generations, and to the added value, represented by the qualitative landscapes were the products came out, by the grooving experiential tourism. For these reasons, many research projects dedicated to these contexts were financed at national and international levels. The challenge for the researchers is the analysis and evaluation of the terraced landscapes, involving the local communities, in order to identify and propose future landscape strategies of development.

This Thesis is the result of three years of research carried out at the Department of Agricultural, Forest and Food Sciences, University of Turin with the supervision of Prof. Federica Larcher. The work took also advantage of a collaboration with the Department of Architecture and Design of the University of Genoa, thanks to the support of Prof. Adriana Ghersi. The knowledge about the terraced landscapes was enriched during the participation to international conferences and scientific exchanges in Switzerland, Portugal, and Spain.

The Thesis is organized as follow:

Chapter I contextualizes in the literature the historical rural landscapes, the methodological approaches from their characterization to their dynamic conservation, and the terraced landscapes. The Chapter also shows the aims of the PhD research, the case studies considered, and the methodological framework developed.

Chapter II reports the preliminary analyses and evaluations made up for the Northwest Italian Alpine Arch Terraced Landscapes characterization (data not yet published).

Chapter III: Pomatto, E., Devecchi, M., Larcher, F., 2022. Coevolution between Terraced Landscapes and Rural Communities: An Integrated Approach Using Expert-Based Assessment and Evaluation of Winegrowers' Perceptions (Northwest Piedmont, Italy). Sustainability 14(14), 8624. DOI: 10.3390/su14148624.

Chapter IV: Pomatto E., Devecchi M., Larcher F., 2022. Assessment of the Terraced Landscapes' Integrity: A GIS-Based Approach in a Potential GIAHS-FAO Site (Northwest Piedmont, Italy). Land 11(12), 2269. DOI: 10.3390/land11122269.

Chapter V: Pomatto E., Gullino P., Novelli S., Devecchi M., Larcher F. Landscape Strategies Making for Terraced Landscapes in the European Alpine Region Using a Mixed-Method Analysis Tool. Submitted to ISI/Scopus Journal.

Chapter VI reports the conclusions with the main findings of the PhD activities, and the future research perspectives.

At the end of the Thesis, all other scientific activities carried out during the PhD are reported.

Chapter I

Introduction

1. The Historical Rural Landscapes

In this Thesis is assumed that the landscape is the result of many transformations across the centuries that have historical values. As further explored in Chapter III, the threshold to consider historic a landscape is debated. As an example, the Italian legislation fix the middle of the last century (1960) to consider historical the previously exiting vineyards cultivated with traditional practices (Decree nr. 6899, 30th June 2020). In the present work, according to Bastian et al. (2013), the elements of the landscape originated in the past under different socio-economic and cultural conditions are considered historical, regardless of their epoch of introduction. Following, are briefly presented the main definitions of these heritage with biocultural values, the methodological approaches from their characterization to the dynamic conservation, and the main characteristics of the terraced landscapes, as reported by the scientific community.

1.1 An Heritage with Biocultural Values

The European Landscape Convention defines the landscape as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (ELC, 2000). Signed in Florence (Italy) on 20th October 2000, the Convention is the first international treaty dedicated to the European landscapes of any types, in order to their promotion, protection, management, and planning (Déjeant-Pons, 2006; De Montis, 2014). Pătru-Stupariu and Nita (2022) observed that the implementation of the European Landscape Convention favored

the development of landscape planning, policies, and interdisciplinary researches. Indeed, the definition reported in the Convention links the natural factors that belong to multiple disciplines (e.g. environmental, ecological) with human disciplines (e.g. social, cultural). Furthermore, Jones (2007) highlighted that the specification "as perceived by people" implies that the participation of all groups of people in decision processes is a priority. Indeed, an important role in the quality of people lives belonging to all areas is recognized to the landscape. In this perspective the diversity of the landscape and the cultural diversity are common values to be preserved (Jones and Stenseke, 2011).

The scientific community recognizes that the landscapes can be classified in different categories (Carlier and Moran, 2019; Simensen et al., 2021; Vizzari et al., 2018; Vizzari and Sigura, 2015). Wandl et al. (2014) reported that one of the possible classifications is based on the land uses. The International Council on Monuments and Sites defines the rural landscapes as "terrestrial and aquatic areas co-produced by human-nature interaction used for the production of food and other renewable natural resources, via agriculture, animal husbandry and pastoralism, fishing and aquaculture, forestry, wild food gathering, hunting, and extraction of other resources, such as salt. Rural landscapes are multifunctional resources. (…) all rural areas have cultural meanings attributed to them by people and communities (…). Rural landscapes are dynamic, living systems encompassing places produced and managed through traditional methods, techniques, accumulated knowledge, and cultural practices, as well as those places where traditional approaches to production have been changed" (ICOMOS-IFLA, 2017). Scazzosi (2018a) underlined that this definition outlines the landscape as copresence of physical features and of meanings attributed to it. This is in line with the European Landscape

Convention perspective. The author reported also the importance of the attribute “dynamic”. Indeed, differently from cultural heritages as buildings, the landscape cannot be considered as a static object to be preserved in a museum, and its conservation is not in contradiction with its innovation. Di Fazio and Modica (2018) reported that the rural landscapes bring multiple benefits: to primary production, to biodiversity conservation, and to spiritual and cultural values.

In this context, the United Nations Educational, Scientific and Cultural Organization (UNESCO) defines the cultural landscape as “cultural properties [that] represent the *combined works of nature and of man* designated in Article 1 of the Convention. They are illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal. (…) Cultural landscapes often reflect specific techniques of sustainable land use, considering the characteristics and limits of the natural environment they are established in, and may reflect a specific spiritual relationship to nature. Protection of cultural landscapes can contribute to current techniques of sustainable land use and can maintain or enhance natural values in the landscape. The continued existence of traditional forms of land use supports biological diversity in many regions of the world. The protection of traditional cultural landscapes is therefore helpful in maintaining biological diversity” (UNESCO, 2021). Cultural landscapes were firstly included in the World Heritage List in 1992. The definition outlines once again as the landscape is the result of the interaction between man and nature, and introduce the need of their protection. For doing that an important parameter to be maintained in the UNESCO cultural landscapes is the integrity. Indeed, it

is an important value that allow to recognize their identity (Gullino and Larcher, 2013). Many authors agreed that cultural landscapes are heritages with biocultural values, that provide ecosystem services, and have a high touristic potential to be enhanced (Della Spina and Giorno, 2021; Pijet-Migoń and Piotr Migoń, 2021; Szepesi et al., 2017; Senes et al., 2023).

The Framework Convention on the Value of Cultural Heritage for Society, also known as Faro Convention, defines the cultural heritage as "a group of resources inherited from the past which people identify, independently of ownership, as a reflection and expression of their constantly evolving values, beliefs, knowledge and traditions. It includes all aspects of the environment resulting from the interaction between people and places through time" (Faro Convention, 2005). This definition, linked with the previous ones, allows to consider the landscape as cultural heritage. Indeed, it is characterized by material and immaterial identity values inherited and is expression of the people-places coevolution. According to the Faro Convention, Zubiaurre et al. (2022) explored the educational dimension of the landscape. They reported that the transferability of the cultural heritages to the future generations is a fundamental future challenge for the conservation of the landscape, adding a sustainability perspective.

The Food and Agriculture Organization of the United Nations (FAO) defines the *Globally Important Agricultural Heritage Systems (GIAHS)* as "living, evolving systems of human communities in an intricate relationship with their territory, cultural or agricultural landscape or biophysical and wider social environment" (FAO, 2002). In chapter IV this definition is deeply explored, but it is useful to introduce the GIAHS-FAO approach. Indeed, it recognizes that the dynamic conservation is the key

goal to strengthening the agricultural landscapes (Koohafkan and Cruz, 2011). In this perspective the coevolution of the landscape with the rural communities, and their mutual benefits, are not seen as something inherited from the past to be statically conserved. By contrast, the GIAHS sites are in continuous evolution, and are characterized by the agricultural multifunctionality (Lu and Qingwen, 2013).

The International Association for Landscape Ecology defines the biocultural landscapes as landscapes that "embed high ecological and cultural values, and reveal the link between nature and culture. This link is essential for understanding the character of these landscapes, providing tools for their conservation and development" (IALE, 2023). Hong (2014) reported that the biocultural landscape concept recognizes the close link between the biodiversity and the cultural diversity, since nature and man are in continuous interrelation. This dynamic interaction in the environment is at the basis of their dynamism (Antrop, 2005). Izakovičová et al. (2022) explored the biocultural landscapes in Slovakia, highlighting that rural and agricultural landscapes are among the most valuable types of biocultural landscapes. To them social-ecological values, and important roles in ecosystem services provision are recognized by many authors (Ciftcioglu et al., 2016; Leksono and Zairina, 2022; Merçon et al., 2019).

The Italian Ministry of Agriculture, Food Sovereignty and Forests defines the *Traditional rural landscape and of historical interest* as "portions of territory classified as rural (…) that while continuing their evolutionary process keep evident evidences of their origin and of their history, maintaining a role in society and in economy" (Decree n. 17070, 19 November 2012). As reported in chapter IV, these landscapes are collected in a National Register of Historical Rural Landscapes, Agricultural

Practices, and Traditional Knowledges with the aim of their monitoring and enhancement (Agnoletti et al., 2019). Recognizing the historical values of the landscape is a challenge for the cultural recognition of their historical elements that need to be preserved. Jelen et al. (2021) reported that the analysis of the cultural and historical elements allows to understand what functions are performed by the landscape. The authors identified seven typologies of historical cultural landscapes. One of them is the agricultural landscape, where the human activity is focused on the primarily production. Furthermore, Špulerová et al. (2011) identified four classes of historical structures of the agricultural landscape in Slovakia, influenced by their land uses: (1) historical structures of agricultural landscape with dispersed settlement, (2) historical structures of vineyards landscape, (3) historical structures of arable-land, grasslands and orchards, and (4) historical structures of arable-land and grasslands. They observed that these historical structures are mainly preserved in mountain areas, not suitable for more modern and intensive agricultural forms. Furthermore, Brown et al. (2023) defined the mountain landscapes as "lifescapes", underlining the important role of the rural communities in their management, that allow to increase their resilience.

Therefore, it is evident that the historical rural landscapes are heritages dedicated to agriculture, and characterized by biocultural values to be preserved. Indeed, regarding the traditional agricultural landscapes, a strong connection between ecological and cultural-historical values is well known in literature (Dobrovodská et al., 2019). Furthermore, they are systems in continuous co-evolution with the rural communities, and are characterized by dynamics of often rapid change. For these reasons, the analysis and evaluation of the historical rural landscape is a priority to develop shared landscape strategies for their future development.

1.2 Methodological Approaches from the Characterization to the Dynamic Conservation

The scientific community recognizes that, since the landscape is a dynamic ever evolving system, the approach to its analysis and evaluation needs to be based on its resilience instead of stability (Wu, 2012). Indeed, Scazzosi (2018b) underlined that the rural landscapes can be considered as systems of tangible and intangible relationships that have their roots in the past and are projected to the future. The author reported also that, in order to read these complex relationships, interdisciplinary approaches have to be applied. According with this, Bastian (2001) highlighted the key role of an holistic view in the process, from the landscape evaluation to the elaboration of development goals. The importance of involving several disciplines in the agricultural landscape assessment is well established in literature. As an example, Van Mansvelt (1997) suggested to consider the environmental and natural sciences (e.g. ecology), the social sciences (e.g. economy, sociology), and the cultural sciences (e.g. aesthetic, ethic, history). Among the other important disciplines recognized, there are: agronomy, anthropology, landscape ecology, landscape architecture and planning, geography, pedology, geology, botany, psychology, and archeology (Benoît et al., 2012; Kullmann, 2016; Pennock and Veldkamp, 2006). All of these disciplines are applied by experts. Subsequently, especially thanks to the perspective introduced by the European Landscape Convention, the need of develop participatory approaches emerged, in order to consider the public perception in landscape planning (Larcher et al., 2013). Rossetti et al. (2022) underlined that the stakeholders participation in decision making is critical to ensure the sustainable development and the heritage conservation.

Therefore, the characterization of an historical rural landscape is composed by the expert-based assessment and the participatory evaluation. Marine (2022) reported three methods for the landscape analysis and evaluation, used in Spain, that consider two steps for decision making: the landscape characterization and the public valuation. Furthermore, according with the literature cited above, as shown in Figure 1, the analyses carried out by experts involve a pool of experts belonging to multiple disciplines. A multiscale approach has to be applied in order to understand the context and to develop site-specific landscape strategies (Van Eetvelde and Antrop, 2009; Willemen et al., 2012). The first step is the reconstruction of the historical landscape, to understand its configuration and functions (Křováková et al., 2015). For this purpose, the historical documents, maps, and iconographies are useful sources (Tesfamariam et al., 2019). Also, the historical aerial images are recognized for the analysis of the landscape dating back from the middle of the last century (Sevara et al., 2018). The Geographic Information Systems (GIS) software are widely used to perform cartographical analyses useful for the spatial planning, thanks to the possibility of consider a very large range of thematic layers (Senes and Toccolini, 1998). As an example, Tassinari et al. (2013) developed a multicriteria analysis model considering firstly the analyses of the land use and of the land-cover changes. Simensen et al. (2018) found that the 83% of 54 different method for the landscape characterization all over the word, that they analyzed, considered the land cover as variable to assess the human influence on the landscape. Similarly, Petrovič et al. (2021) applied a GIS based diachronic analysis to assess the dynamics of the historical cultural landscape in Slovakia. They also identified the historical landscape and agricultural structures, through archival analyses and field inspections.

Secondly, for the involvement of the rural communities, in literature different methodologies involving the stakeholders individually or in groups are recognized. The target groups to be involved in the research need to be firstly defined (Gullino et al., 2018). For example, Santoro et al. (2021) administered an anonymous questionnaire to farmers and tourists, to evaluate their perception regarding the cultural landscape of the Cinque Terre and Porto Venere UNESCO Site (Italy). While, Gullino et al. (2020) involved different categories of local stakeholders in focus groups aimed at considering their perceptions in traditional chestnut landscapes management in Piedmont (Italy).

Finally, the analysis and evaluations of the historical rural landscapes converge to the definition of landscapes strategies useful for their strengthening. The landscape qualities of the territories need to be safeguarded (Senes et al., 2020). According to the literature cited above, the final objective is the dynamic conservation of the landscape, restoring its past traditions, and seeing to their future development.

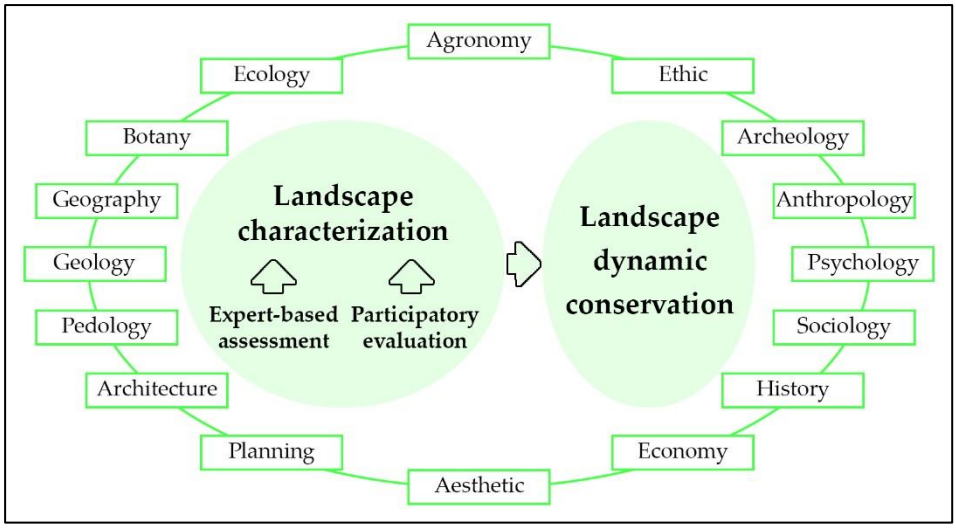

Figure 1. Theoretical framework with the multiple disciplines involved from the characterization to the dynamic conservation of the historical rural landscapes.

1.3 The Terraced Landscapes

The terraced landscapes belong to the historical rural landscapes since they were created across centuries by the human-nature coevolution. They were constructed in ancient times in order to obtain useful surfaces for agricultural purposes in uncultivable conditions due to the high slopes (Ghersi and Ghiglione, 2012). Agnoletti et al. (2015) reported that in Italy there are testimonies of terracing since the Neolithic, and that from the Renaissance (14^{th}–15^{th} century AD) terraces become as widespread to represent together important types of agricultural landscapes: the terraced landscapes. Meeus (1995) highlighted that terraced landscapes are a specific typology of landscape, and observed that they are "completely artificial landscape, where topography, soil and drainage system of the hilly terrain is reshaped by man". Similarly, Zerbe (2022) reported that they belong to the various types of traditional cultural landscapes throughout the world. The author described the terraced landscapes as "slopes terraced, often with dry-stone walls for stabilization, for the cultivation of grapes, fruit and olive trees, rice, potatoes, and other crops", that are possible to find "practically in most of the world's mountainous areas, e.g. in the Mediterranean region, in the Andes, and in Central and Southeast Asia". Varotto et al. (2019) reported that in Europe the terraced landscapes were historically mainly developed for viticulture and olive groves, while in Asia, Africa, and Americas terraces were mainly used for the cereal crops (e.g. corn, rice, sorghum, and millet). Bonardi (2019) reported that the principal European terraced landscapes dedicated to viticulture (with a cultivated surface greater than 50 ha) are located in Italy (seven sites), France (two sites), Switzerland (two sites), Portugal, Spain, Germany, and Austria (one site each). The author also highlighted that these terraced vineyards are located in different geographical

backgrounds: alpine, maritime, fluvial, and lacustrine. Regarding the Italian terraced landscapes, Bonardi and Varotto (2016) estimated an extension of at least 200000 ha, with two Regions (Liguria and Sicily) characterized by very high terracing intensity. They underlined that it is an underestimation due to the lack of mapping, and to the presence of abandoned surfaces with invasion woodlands that makes not possible to identify the terraces analyzing the aerial photographs (i.e. through photointerpretation). This difficulty in terraces mapping was also reported by Romero Martín et al. (2020) in Gran Canaria (Canary Islands, Spain).

Chapters III, IV, and V contain a deep literature review regarding the values and threats of terraced landscapes. However, it is useful to introduce here some aspects that will be further explored below. The international interest is confirmed by the presence of an International Terraced Landscape Alliance (ITLA), constituted in 2010 during the first world conference dedicated to the terraced landscapes (Murtas, 2015). Furthermore, the "art of dry-stone walling, knowledge and techniques" was recognized by the UNESCO as intangible cultural heritage of humanity with the aim of its safeguard (Jiménez de Madariaga, 2021).

As shown in Figure 2a, terraces determine a morphological variation on the slope scale, allowing to obtain horizontal surfaces. Their soils are considered anthropogenic (Van Asperen et al., 2014). To them important functions for the crops, thanks to their fertility, and for the runoff control, is recognized by the scientific community (Stanchi et al., 2012). According to Preti et al. (2018a), the terraced systems are characterized by important hydrologic–hydraulic functions. Indeed, the drainage is guarantee by the construction elements of the terraces. The stones for the filling and the drainage allow the infiltration of the water, and the dry-stone walls

constructed without binder allow its outflow. For these reasons the terraced systems need to a continuous management to guarantee the correct water circulation and hydrogeological functioning (Preti et al., 2018b). In Figure 2a is also possible to observe that the declivity of the slope influences the characteristics of the terraces: to higher declivity correspond higher height of the dry-stone walls, and less extended useful surfaces of the terraces. Figure 2b shows a dry-stone wall in course of recovery, photographed in Cinque Terre (Liguria Region, Italy) during the research stage, that allows to see the construction elements of dry-stone walls cited above.

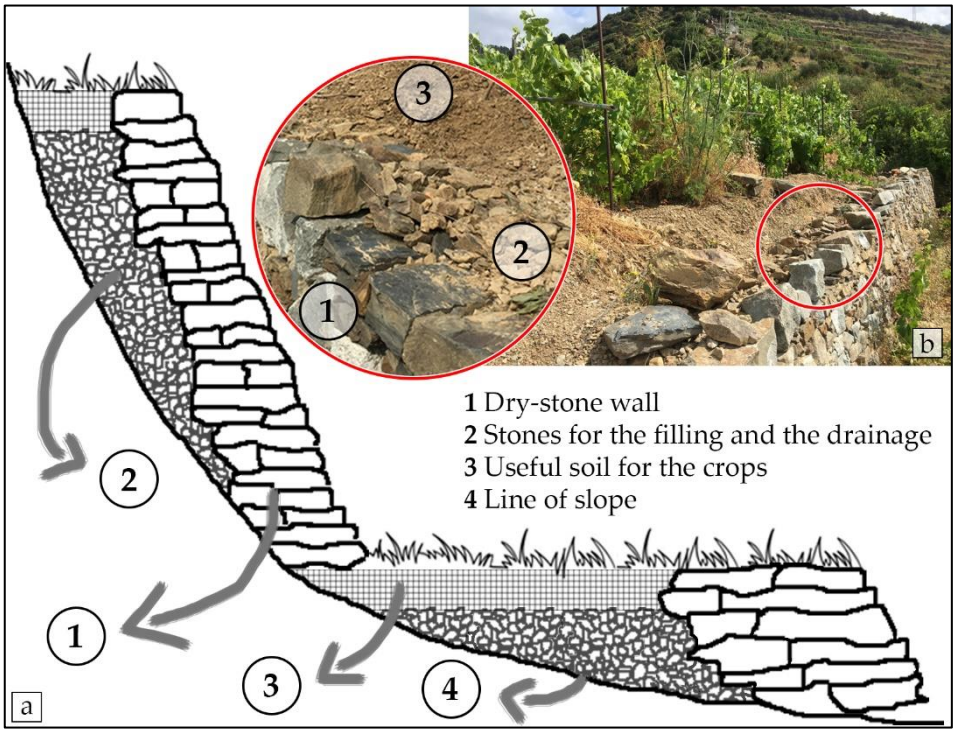

Figure 2. (**a**) Schematic section of a terraced system. (**b**) A dry-stone wall in course of recovery, photographed in Cinque Terre (Liguria Region, Italy) during the research stage. It is possible to observe the construction features of the terrace.

The configuration described above, where terraces are characterized by dry-stone walls, is the most common in the context of the terraced

landscapes. However, other forms of terraces are possible to find where the declivity of the slopes are lower. As an example, Turner et al. (2018) reported that in Catalonia (Spain) the terraced landscapes are characterized by the presence of bot dry-stone walls and earth banks. Instead, De Pasquale and Livia (2022) reported that in Vallecorsa (Lazio Region, Italy) is possible to find particular types of terraces called "lunettes". They are small enclaves with semi-circular walls useful to protect single olive trees. Figure 3 shows these different typologies of terraces that were observed during the PhD in Portugal, Spain, and Switzerland. Specifically, Figure 3a reports the terraced landscapes made up with drystone walls observed during a conference participation in Douro Valley (Portugal). It is a fluvial terraced landscape included in the UNESCO World Heritage List. While, during a cultural exchange in the Spanish Rioja Region, terraced vineyards supported by earth banks were observed (Figure 3b). The context was the Life Project called *MIDMACC – Mid-mountain adaptation to climate change*, aimed at developing landscape adaptation measures in marginal mid-mountain areas in order to improve their environmental and socioeconomic resilience to climate change (MIDMACC Project, 2023). The preliminary observations showed during the period confirmed a better performance of terraces in runoff retention and resilience to the climate change tan the non-terraced slopes. Dastgerdi et al. (2022) recognized these capabilities of the terraces, but underlined the need of their continuous management. Indeed, in literature is well established the dangerous effects of the terraces abandonment, that reduces the water infiltration increasing the runoff and the soil erosion (Arnáez et al., 2015). As further explored in the following Chapters, the abandonment is due to multiple threats of the terraced landscapes. It is a very big problem for the public safety since causes the increase of the risk of erosion and danger of

fires, and brings to the identity and unique landscapes destroy (Romero Martín et al., 2019). Finally, Figure 3c shows traditional lunettes observed in chestnut groves in Grisons Canton (Switzerland). Historically, they were useful to keep the chestnuts near the trees, facilitating their harvest and avoiding their downstream rolling. All of these different forms of terraces contribute to create traditional terraced landscapes strongly linked with the geological contexts and human needs.

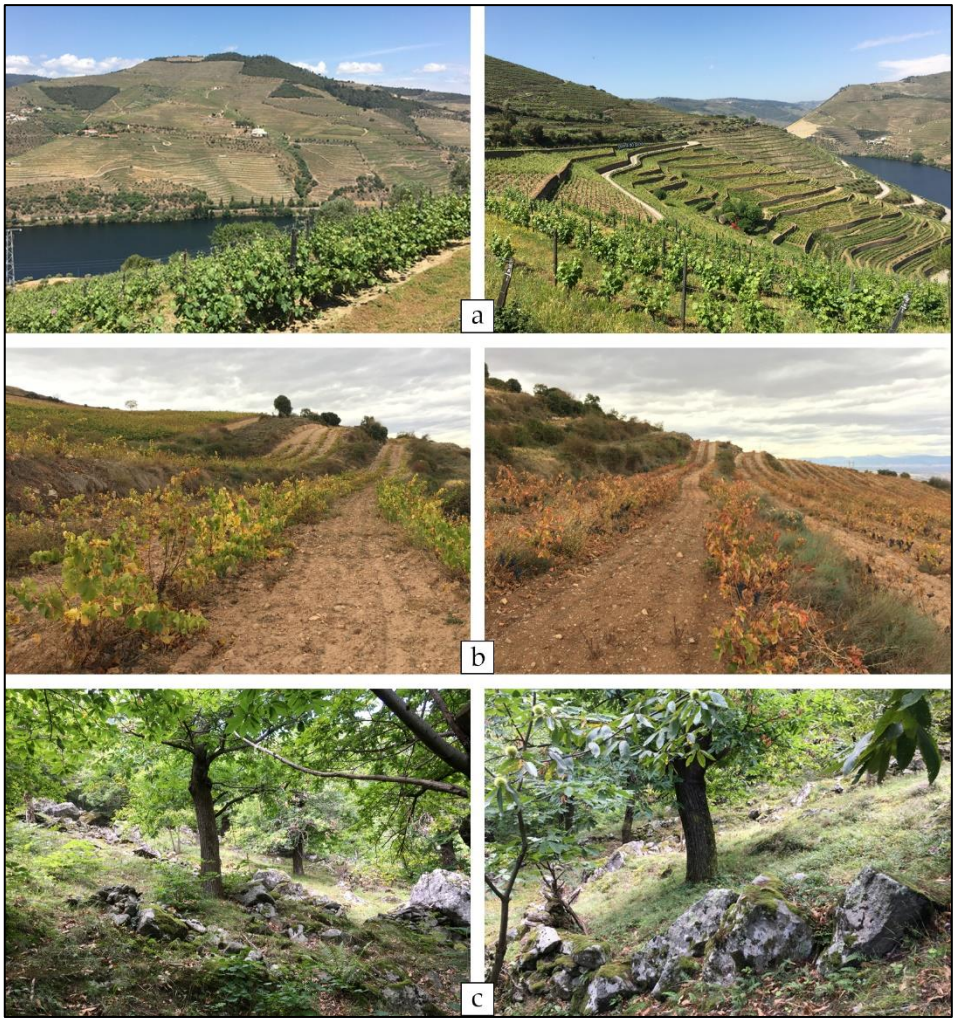

Figure 3. Different typologies of terraces that were observed abroad during the PhD: (**a**) Dry-stone walls in Douro Valley (Portugal). (**b**) Earth banks in Rioja Region (Spain). (**c**) Lunettes in Grisons Canton (Switzerland).

2. The PhD Research

2.1 The Aims of the Research

In the complex context described, the PhD research assumed that: (a) the terraced landscapes are historical rural heritages, in continuous coevolution with man, to dynamically conserve; (b) the analysis of the historical landscape elements and the evaluation of their state of conservation are a priority; (c) the development of landscapes strategies aimed at reconciling the historical biocultural values with the current needs is a challenge; (d) the perspectives of the rural communities have to be considered with participatory approaches.

With the key goal of analyze, evaluate, and increase the knowledge about the historical rural heritage constituted by the terraced landscapes in the European Alpine Region, the aims of the research were:

I. To develop an innovative scientific methodological approach from the characterization to the dynamic conservation of the terraced landscapes, through expert-based assessment and participatory evaluation.
II. To analyze the historical elements of the terraced landscapes.
III. To evaluate the dynamics and their landscape impacts.
IV. To develop future landscapes strategies for recover and strength the terraced landscapes.

2.2 The Case Studies Considered

The research considered, as case studies, the terraced landscapes of the Italian Alpine Arc, and two cross-border terraced landscapes of Switzerland. It is possible to group them in three main case studies, that were analyzed in the context of specific research projects. As shown in

table 1, the first case study was the terraced landscape of the Ivrea Morainic Amphitheatre, in the context of its ongoing candidature to the National Register of the Historical Rural Landscapes. The second case study involved the cross-border Italian and Switzerland terraced landscapes, in the context of the InTERRACED-NET European Project (Interreg). The study areas belonged to the Piedmont, Aosta Valley, Lombardy Regions (Italy), and to the Grisons Canton (Switzerland). Finally, the characterization of the terraced landscapes of the Northwest Italian Alpine Arch was completed through the study of the Ligurian terraced landscapes, in the context of the research stage carried out at the Department of Architecture and Design of the University of Genoa (14th June – 18th July 2021).

Table 1. The case studies considered during the research, the contexts, and the Italian regions and Switzerland cantons involved.

Case studies	Contexts	Italian regions / Switzerland canton involved
1) Ivrea Morainic Amphitheatre terraced landscape	Candidature to the National Register of the Historical Rural Landscapes	Piedmont (IT)
2) Cross-border Italian and Switzerland terraced landscapes	InTERRACED-NET European Project (Interreg)	Piedmont (IT), Aosta Valley (IT), Lombardy (IT), Grisons (SW)
3) Ligurian terraced landscapes	Research stage at the Department of Architecture and Design, University of Genoa	Liguria (IT)

2.3 The Methodological Framework

To achieve the goals, the research developed and applied an integrated approach to analyze and evaluate the historical rural heritage represented by the terraced landscapes. As shown in Figure 4, preliminarily to the

characterization, a deep bibliographic research was performed. In the context of the case studies considered, the study areas were defined and the parameters to be detected were identified.

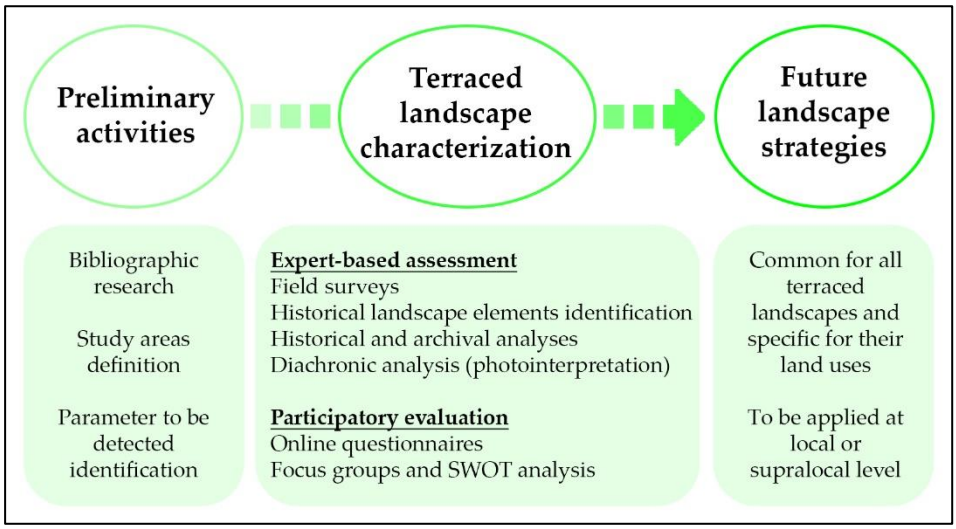

Figure 4. The methodological framework applied in the PhD research.

The terraced landscape characterization was divided in expert-based assessment and participatory evaluation. The first one involved the field surveys, to analyze the current structures of the terraced landscapes and their state of conservation. The historical landscape elements were identified. The study was supported with historical and archival analyses, in order to reconstruct the historical features and the historical land uses organization, as reported in documents, iconographies, and historical maps. The dynamics of the terraced landscape were analyzed with diachronic analyses made up through photointerpretation in GIS environment. For the participatory evaluation, online questionnaires were administered to local farmers, in order to understand their perceptions on the historical landscape elements and future development perspectives. Then, the decision makers and the civil society stakeholders were involved

in the definition of strategies, through the organization of specific focus groups during which the SWOT analyses and the cumulative voting methods were applied.

All of the analyses performed allowed to develop future landscapes strategies for the enhancement of the terraced landscapes. They were divided in common strategies for all terraced landscapes, and other specific strategies, influenced by land uses. Furthermore, they were classified in strategies to be applied at local or supralocal levels.

Table 2 shows in which case studies the various methods, developed for the terraced landscapes characterization, were differently applied.

Table 2. The preliminary activities and the methods developed for the terraced landscape characterization applied in the different case studies considered.

		Case studies		
		1) Ivrea Morainic Amphitheatre terraced landscape	2) Cross-border Italian and Switzerland terraced landscapes	3) Ligurian terraced landscape
Preliminary activities	Study areas definition	X	X	X
	Parameter to be detected identification	X	X	X
Terraced landscape characterization	**Expert-based assessment**			
	Field surveys	X	X	X
	Historical landscape elements identification	X	X	X
	Historical and archival analyses	X		
	Diachronic analysis (photointerpretation)	X		
	Participatory evaluation			
	Online questionnaires	X		
	Focus groups and SWOT analysis		X	

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Chapter II

Characterization of the Northwest Italian Alpine Arch Terraced Landscapes

In this Chapter the preliminary analyses through field inspections for the Northwest Italian Alpine Arch Terraced Landscapes characterization are reported. They were performed in the contexts of the InTERRACED-NET European Project, and of the research stage at the Department of Architecture and Design (University of Genoa). Instead, the characterization of the Ivrea Morainic Amphitheatre terraced landscape through field inspections is deeply explored in Chapter III. The results were useful to analyze and evaluate the main characteristics of the terraced landscapes considered, identifying the constructions types, land uses, historical landscape elements, states of conservation, and the impact on the landscape of the change dynamics. Therefore, the findings of these first phase, based on expert-based assessment, contributed to achieve important knowledges for the development of the future landscape strategies (Chapter V) for recover and strength the terraced landscapes.

1. Methodology

According to the literature cited in the Chapter I, the analysis of the terraced landscapes belonging to the Northwest Italian Alpine Arch aimed at their characterization, was performed through the organization of multiple field inspections in the terraced case studies considered. A survey form was developed and used during the field inspections. It was divided in five sections: general aspects, agronomic aspects, construction types, landscape aspects and state of conservation. Table 1 synthetizes the content of these sections. Some parameters were directedly observed,

while others were asked to farmers owners of the fields analyzed, meet during the inspections. Following, in this Chapter, the results are discussed in aggregate form, reporting the main findings of the analyses.

Table 1. Description of the survey form content used during the field inspections.

Sections	Description
General aspects	• General aspects of the slope where the field is located (e.g. elevation, accessibility, state of conservation); • History of the farm. • Distribution channels of the products.
Agronomic aspects	• Land use; • Cultivated varieties; • Productivity; • Distance among plants; • Inter-rows management; • In case of viticulture: vine breeding technique, and orientation of the rows; • Phytosanitary problems; • Criticalities in the agronomic management.
Construction types	• Typologies of terraces; • Drainage and water regulation system.
Landscape aspects	• Historical landscape elements; • Impact on the landscape of the elements non-historical or for the meccanization of the crops (e.g. monorails); • Change dynamics and their impact on the landscape.
State of conservation	• State of conservation of the terraces, • Spontaneous vegetation of invasion; • Abandoned terraced surfaces near the field analyzed.

2. Study Areas

According to local stakeholders and experts, the fields identified as study areas were selected for their representativeness in the specific contexts (e.g. Aosta Valley, Cinque Terre National Park, etc.). Indeed, in these fields the different representative conditions with both the good preservation of the historical rural heritage, and the introduction of features with non-historical values were observed. Figure 1 shows the localization

of the fields selected as study areas for the field inspections and their elevations.

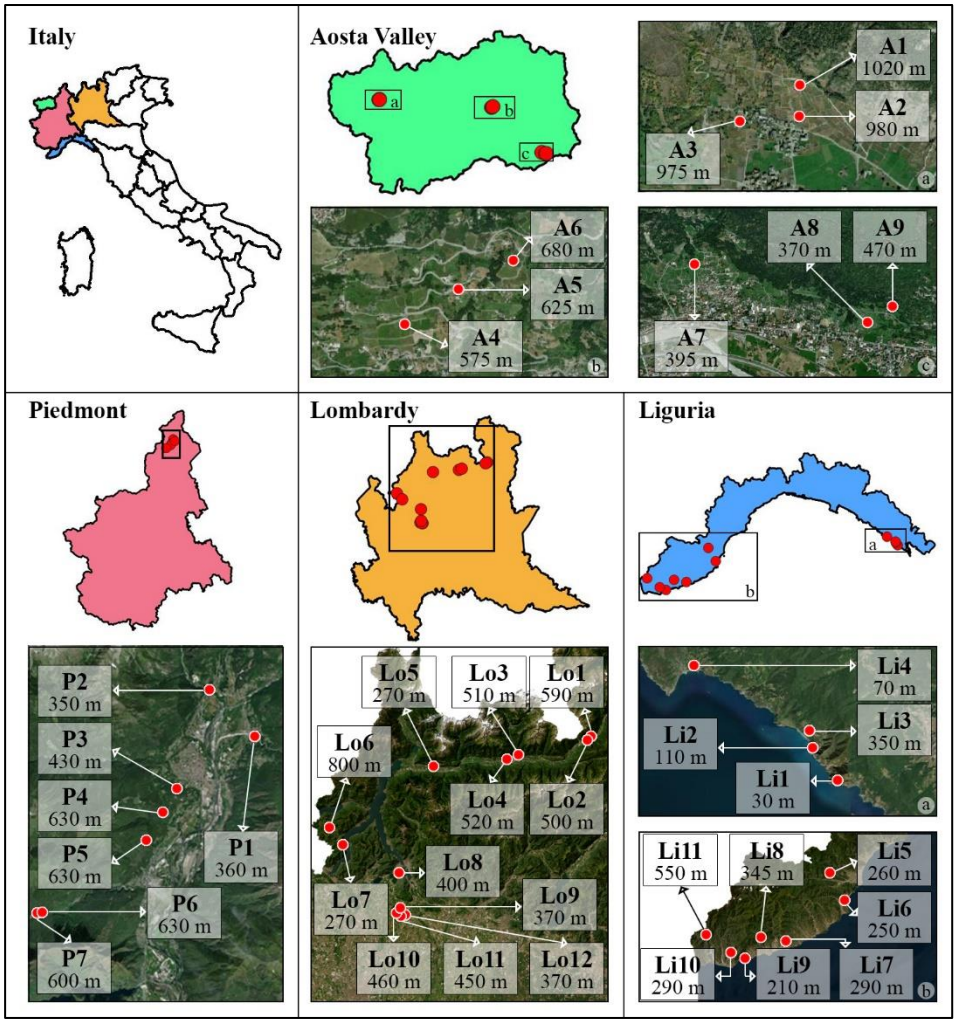

Figure 1. The localization of the fields belonging to the Northwestern Italian Alpine Arch terraced landscapes selected as study areas for the field inspections, and their elevations (m a.s.l.).

In table 2 the municipalities and the contexts of the fields analyzed during the field inspections are reported.

Table 2. Municipalities and contexts of the fields analyzed during the field inspections (Figure 1).

Field code	Municipality	Context	Field code	Municipality	Context
Aosta Valley Region			**Lombardy Region** (cont.)		
A1	Morgex	High valley	Lo4	Sondrio	Valtellina
A2	Morgex	High valley	Lo5	Traona	
A3	Morgex	High valley	Lo6	Centro Valle Intelvi	Lario Intelvese
A4	Chambave	Medium valley	Lo7	Brienno	
A5	Chambave	Medium valley	Lo8	Galbiate	Monte Barro Park
A6	Saint-Denis	Medium valley	Lo9	La Valletta Brianza	Montevecchia and Curone Valley Regional Park
A7	Donnas	Low valley	Lo10	Montevcchia	
A8	Donnas	Low valley	Lo11	Montevecchia	
A9	Perloz	Low valley	Lo12	Montevecchia	
Piedmont Region			**Liguria Region**		
P1	Trontano	Val Grande National Park	Li1	Riomaggiore	Cinque Terre National Park
P2	Crevoladossola	Ossola Valley Protected Areas	Li2	Riomaggiore (Manarola)	
P3	Domodossola		Li3	Riomaggiore (Volastra)	
P4	Domodossola		Li4	Monterosso al Mare	
P5	Villadossola		Li5	Arnasco	Western Liguria
P6	Borgomezzavalle		Li6	Laigueglia	
P7	Borgomezzavalle		Li7	Terzorio	
Lombardy Region			Li8	Ceriana	
Lo1	Sernio	Valtellina	Li9	Sanremo (Coldirodi)	
Lo2	Tirano		Li10	Vallebona	
Lo3	Sondrio		Li11	Airole	

3. Results

Table 3 shows the main aspects detected during the field inspections for the analysis and evaluation of the Northwest Italian terraced landscapes aimed at their characterization.

Table 3. Main aspects detected during the field inspections for the analysis and evaluation of the Northwest Italian terraced landscapes aimed at their characterization.

Field code	Land use	Vine breeding technique	Typology of terraces [1]	Historical landscape elements	Non-historical / meccanization elements and impact on the landscape [2]	State of conservation [2]	
						Field	**Slope**
A1	Vineyard	Low pergola	D	Vine, low pergola (larch poles) supported by stone elements; stone accumulations	-	1	1
A2	Vineyard	Pergola	D	Vine, stone accumulations	Modified pergola "Y" (concrete poles and iron tubes) 2	1	1
A3	Vineyard	Low pergola	D	Vine, low pergola (larch poles) supported by stone elements; consociation with horticulture	-	1	1
A4	Vineyard	Espalier	D	Vine	Rows orientation (maximum slope) - 1	1	1
A5	Vineyard	Sapling	D	Vine, sapling (high value, residual)	-	1	1
A6	Vineyard	Espalier	E	Vine, rows orientation (parallel to the slope)	-	1	1
A7	Vineyard	Pergola	D	Vine, high pergola (chestnut poles), stone elements for water harvest	-	1	1

Table 3. *Cont.*

Field code	Land use	Vine breeding technique	Typology of terraces [1]	Historical landscape elements	Non-historical / meccanization elements and impact on the landscape [2]	State of conservation [2]	
						Field	**Slope**
A8	Vineyard	Pergola	D	Vine, high pergola (chestnut poles), stone elements for water harvest	Monorail (3), presence of concrete poles (3)	1	1
A9	Vineyard	Pergola	D	Vine, high pergola (chestnut poles), stone elements for water harvest	-	2	3
P1	Vineyard	Pergola	D	Vine, high pergola (wood and stone poles)	Presence of concrete and iron poles (3)	1	3
P2	Vineyard	Espalier	E	Vine	-		3
P3	Vineyard	Espalier	D, E	New vineyard just planted after abandonment	-	2	3
P4	Vineyard	Espalier	D, E	Vine, chestnut poles	-	1	3
P5	Vineyard	Espalier, pergola	D	Vine, residual permanence of pergolas	-	1	3
P6	Vineyard	Espalier	D	Vine	-	2	3
P7	Vineyard	Espalier	D	Vine	-	2	3
Lo1	Olive grove	-	D	Stone accumulations, stone elements for water harvest	Olive groves after vineyards abandonment (1)	2	3
Lo2	Vineyard	Espalier	D	Stone elements for water harvest	Guyot pruning (3)	1	1
Lo3	Vineyard	Espalier	D	Stone accumulations	Guyot pruning and “archetto valtellinese” modified (3), monorail (3)	1	1

Table 3. *Cont.*

Field code	Land use	Vine breeding technique	Typology of terraces [1]	Historical landscape elements	Non-historical / meccanization elements and impact on the landscape [2]	State of conservation [2]	
						Field	**Slope**
Lo4	Vineyard	Espalier	D	Vine	Guyot pruning (3)	1	1
Lo5	Vineyard	Espalier	D	Grapevine pruning (*Archetto valtellinese*)	Introduction of Guyot pruning (3), presence of concrete walls (1)	1	1
Lo6	Meadow	-	E	Meadow and agroforestry system	-	1	2
Lo7	Olive grove	-	D	Olive groves	-	1	3
Lo8	Vineyard	Espalier	E	New vineyard just planted after abandonment	-	2	3
Lo9	Vineyard	Espalier	E, D	Vine	-	1	1
Lo10	Vineyard	Espalier	E	Vine, chestnut poles, consociations with aromatics and fruit trees	-	1	1
Lo11	Vineyard	Espalier	D	Vine, chestnut poles, consociations with aromatics and fruit trees	-	2	1
Lo12	Vineyard	Espalier	D	Vine	-	3	1
Li1	Vineyard	Pergola, espalier	D	Vine, low pergola	Espaliers (1), Monorail (3)	1	1
Li2	Vineyard	Pergola	D	Vine, low pergola	Espaliers (1), Monorail (3)	1	1
Li3	Vineyard	Pergola	D, E	Vine, low pergola, bundles of heather for wind shelter	Espaliers (1), photovoltaic panels (1)	1	1

Table 3. *Cont.*

Field code	Land use	Vine breeding technique	Typology of terraces [1]	Historical landscape elements	Non-historical / meccanization elements and impact on the landscape [2]	State of conservation [2]	
						Field	**Slope**
Li4	Vineyard olive and citrus grove	Espalier	D, E	Historical mosaic of crops, water regulation system, stone elements for water harvest, high stone wall for wind shelter	-	1	1
Li5	Olive grove	-	D	Olive trees	Presence of not local stones in dry-stone walls (1)	2	2
Li6	Flower, olive grove	-	D	Ornamental cut fronds production (in particular *Helichrysum italicum*), olive trees, water regulation system	-	1	3
Li7	Vineyard	Espalier	D	Vine	-	3	3
Li8	Vineyard	Espalier	D	Vine, stone elements for water harvest	Presence of not local stones and cement binder in the walls (1)	1	2
Li9	Chili pepper	-	D	Diversified productions on terraces, greenhouses	Concrete tanks for water harvest (1), presence of concrete walls (1)	2	2
Li10	Citrus grove, vine	Espalier	D	Mosaic of crops, water regulation system	Concrete tanks for water harvest (1)	1	1

Table 3. *Cont.*

Field code	Land use	Vine breeding technique	Typology of terraces [1]	Historical landscape elements	Non-historical / meccanization elements and impact on the landscape [2]	State of conservation [2]	
						Field	Slope
Li11	Vineyard and olive grove	Espalier	D	-	Recent vine planting (2000) on a surface never planted with vine before (1)	1	3

[1] D = dry-stone walls, E = earth banks. [2] 1 = high, 2 = medium, 3 = low.

As shown in Table 3, the Northwest Italian Alpine Arch terraced landscapes characterization highlighted an high variability in terms of terraces typologies, land uses, historical landscape elements, and states of conservation. It is due to the different geographical, environmental, historical, and social conditions. According with this, Stanchi et al. (2013) observed that the suitable areas for the mountain viticulture in Aosta Valley are influenced by slope, aspect, altitude and soil. In the Italian Alpine Arch were identified terraced landscapes from beyond 1000 m a.s.l in high Aosta Valley, to almost the sea level in Cinque Terre (Figure 2).

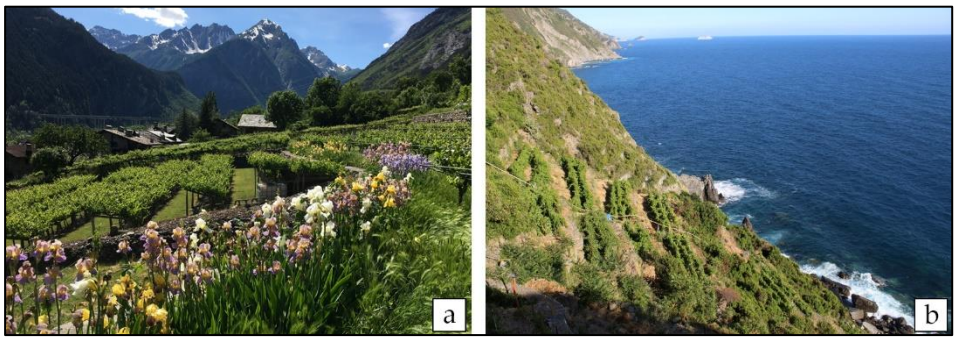

Figure 2. (**a**) The highest field analyzed in Aosta Valley (A1 - image took in the slope near the field), (**b**) The lowest field analyzed in Cinque Terre (Li1).

3.1 Typologies of terraces and land uses

According with the literature cited in the Chapter I, in the Northwest Italian Alpine Arch terraced landscapes different typologies of terraces were identified: dry-stone walls and earth banks (Figure 3). By contrast, the lunettes were not observed. As cited above, the geomorphological contexts influence the terraces characteristics, since they are strictly connected with the slopes. Therefore, to higher slopes (e.g. low Aosta Valley) correspond higher heights of the dry-stone walls. While, to lower slopes the terraced landscapes are characterized by low dry-stone walls (e.g. high Aosta Valley) or earth banks (e.g. Montevecchia and Curone Valley Regional Park). The farmers met during the field inspections reported that the management of the terraces is influenced by their types. Dry-stone walls need to periodic attentions in order to avoid the obstructions of the drainage systems and the walls collapse. On the other hand, the earth banks require a continuous management to recover the fall down of earth caused by the erosion processes, and to the mow of the grass that cover them. The stones used for the dry-stone walls are usually local. In some contexts, they contribute to create optimal microclimate conditions for the crops supported by terraces, reducing the temperature range.

Furthermore, it was evidenced that the Northwest Italian Alpine Arch terraced landscapes are dedicated to many land uses, depending by the different environmental conditions (Figure 3). The vineyards are the main land use observed, present in all of the Italian regions considered, with some common and many specific features. Indeed, according to Brancucci et al. (2017) the geodiversity determines a high variety of landscapes with specific *terroir* in which different high-quality wines are produced. Indeed, to many of them are recognized different certifications, as Controlled

Designation of Origin (e.g. Valle d'Aosta DOC, Moscatello di Taggia DOC, Cinque Terre Sciacchetrà DOC) and Controlled and Guaranteed Designation of Origin (e.g. Valtellina Superiore DOCG). Among the land uses identified, meadows were observed in the agroforestry system of the Lario Intelvese (Lo6) on earth banks. While, terraced dedicated to horticulture were observed in Western Liguria (Li9). Instead, some land uses observed are characteristic of warmer Mediterranean climates, possible to find only in Liguria. It is the case of the citrus groves and the flowers cultivations. The first ones were particularly detected in the Cinque Terre National Park (Li4) and in Western Liguria (Li10). In both cases they are considered traditional cultivations with high historical values. In Cinque Terre, and in particular in Monterosso al Mare, many citrus groves are dedicated to lemons, while in Vallebona in ancient times the cultivation of the bitter orange was very important to produce the bitter orange flower water. To this product nowadays is dedicated a Slow Food Presidium. It continues to be produced in the field analyzed, even though it is a residual case in the slope. Instead, the flowers and cut fronds production are strictly connected with the Western Liguria traditions famous all over the world for the floriculture sector. Also olive groves are typical of the Liguria region and other specific contexts (Lario Intelvese), however nowadays it is possible to find them also in place of vineyards in Aosta Valley and Valtellina. It is a dynamic of change, further explored in Chapter (III), probably possible also thanks to the climate change.

Finally, it was observed that if some terraced landscapes are strictly connected with one land use (e.g. vineyards in Aosta Valley), in other contexts, as in Liguria, is possible to find very complex mosaic of crops. Figure 4 shows a mosaic of cultivations in which vineyards, olive, and citrus groves draw an unique historical rural heritage.

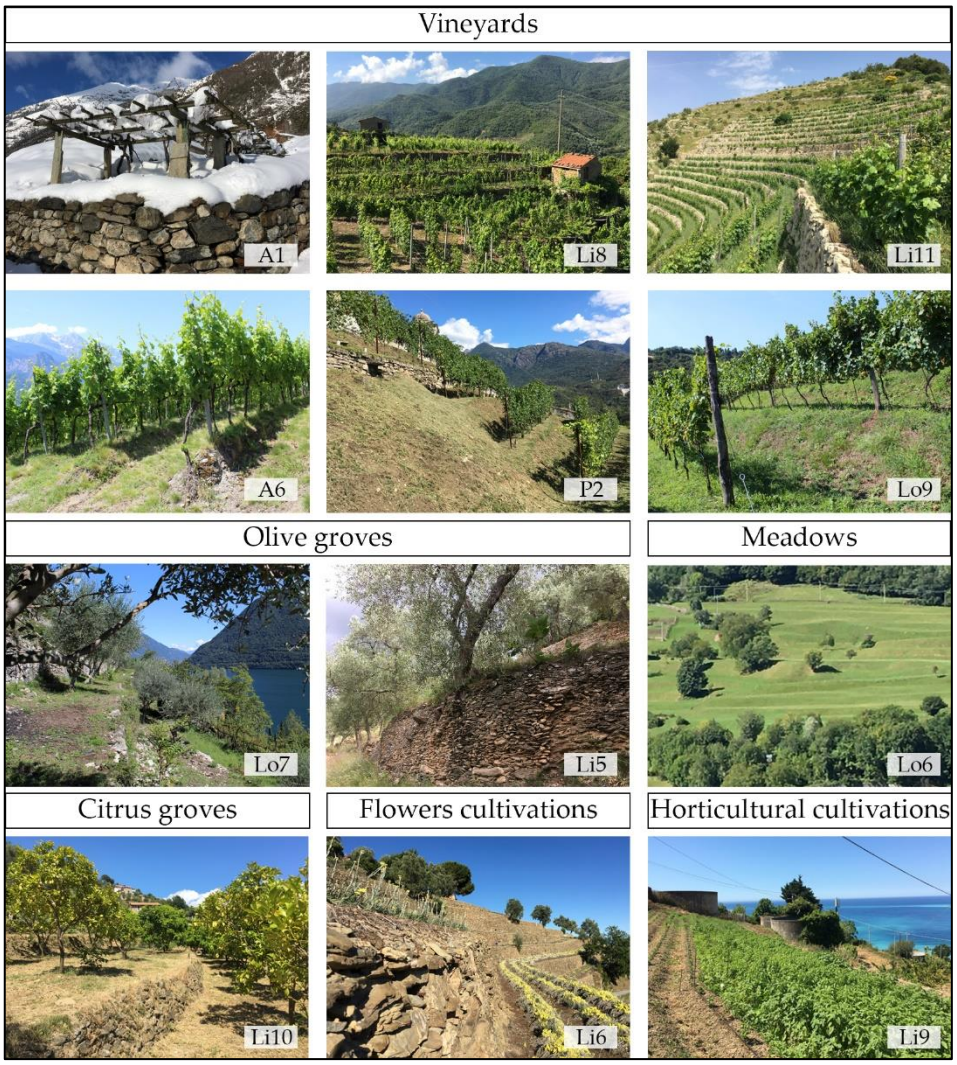

Figure 3. The different typologies of terraces and land uses identified.

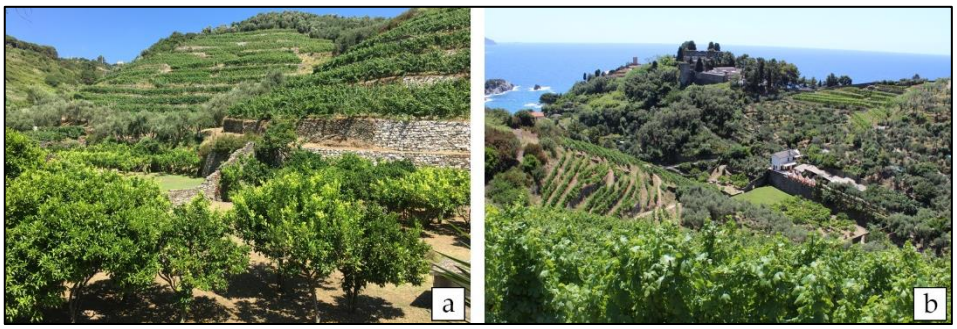

Figure 4. The mosaic of cultivations with vineyards, olive, and citrus groves observed in Cinque Terre (Li4). (**a**) View of the slope, (**b**) view from the slope.

3.2 Historical vine breeding techniques

Many historical vine breeding techniques were identified (Figure 5). Pergola is the most represented. Its configuration is strictly connected with the environmental characteristics. Indeed, in the higher part of Aosta Valley there are low pergolas supported by stone elements. Cultivating in this condition is very complex because all of the agricultural activities (e.g. pruning or harvest) have to be conducted on the knees. However, this type of vine breeding technique in a context located about at 1000 m a.s.l. allows to maintain the heat near the soil. Similarly, the low pergola is an important historical element in vineyards of Cinque Terre, where is useful to protect the vines from the wind that comes from the sea. With the same purpose were observed many bundles of heather. Instead, in the lower part of the Aosta Valley, pergolas are high in order to increase the vineyard aeration. While, in the central part of the valley the sapling vine breeding technique has high historical values but is residual. Finally, the *archetto valtellinese* is a famous vine pruning technique in Valtellina.

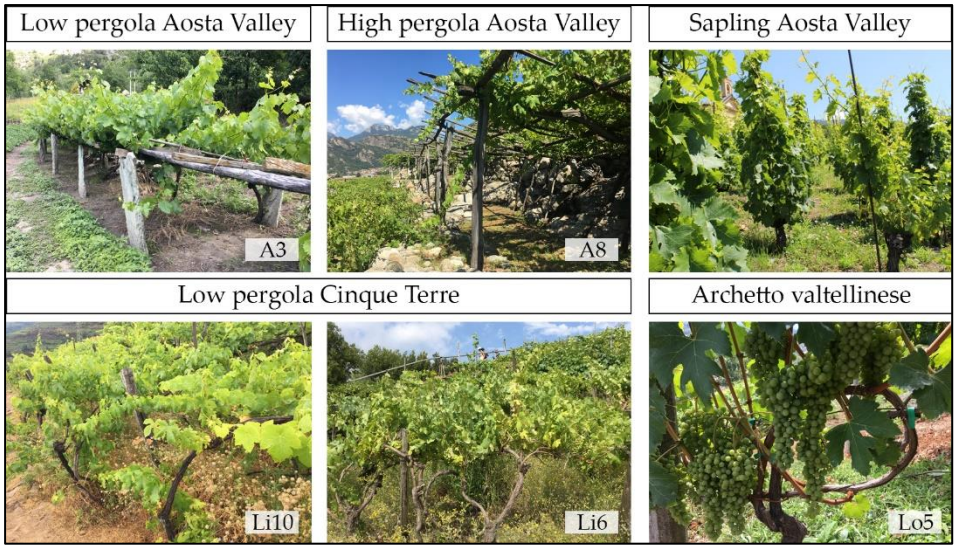

Figure 5. The historical vine breeding technique and pruning identified.

3.3 Other historical landscape elements

During the field inspections many other historical landscape elements were identified (Figure 6). The multifunctionality of the terraced landscapes was evident in some contexts characterized by interesting consociations. As an example, in Aosta Valley the central part of the fields enclosed to the vine pergolas was historically dedicated to the horticulture (A3). Similarly, in Montevecchia and Curone Valley Regional Park vines are consociated with aromatics and fruits trees (Lo10). Furthermore, characteristic stone accumulations, derived from an high availability of stones in the slopes, delimit many fields in Aosta Valley and Valtellina. In many cases the stone elements for the water harvest and the water regulation systems are good preserved and recognizable.

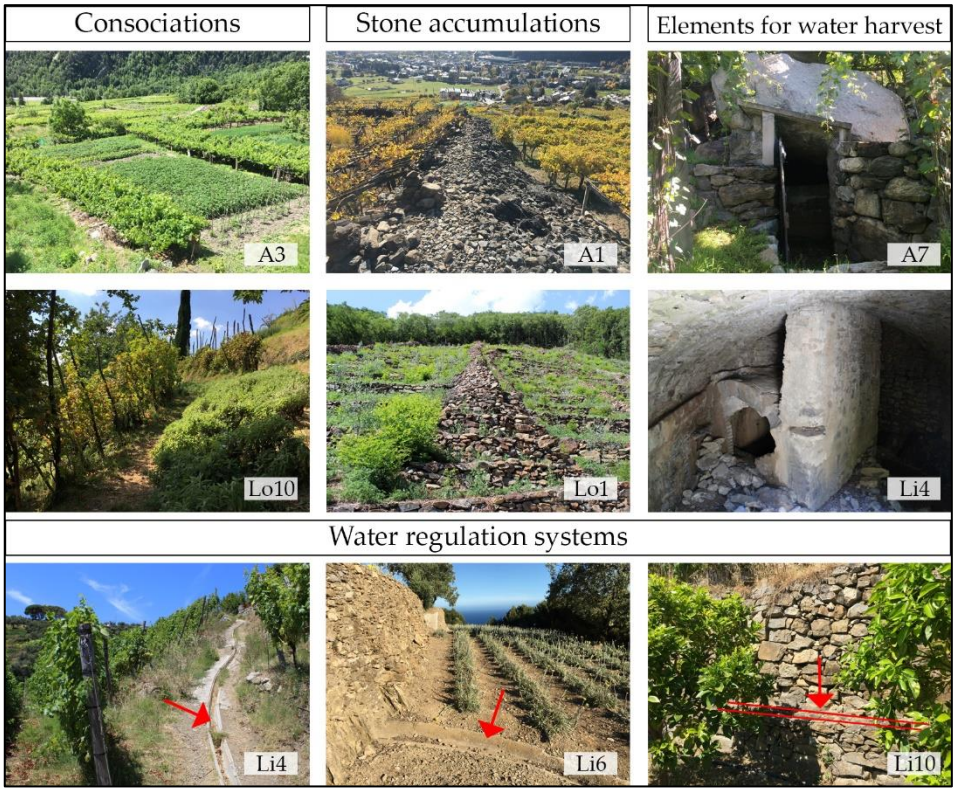

Figure 6. The other historical landscape elements identified.

3.4 Non-historical landscape elements and criticalities

During the field inspections, the introduction of non-historical landscapes elements and some criticalities were detected, and their impact on the landscape was evaluated. Figure 7 shows them.

Regarding the vine breeding techniques some changes more or less impacting on the terraced landscapes were observed. This topic is further explored in Chapter III. As an example, the modified pergolas "Y" in place of the low pergolas made up with larch poles and supported by stone elements in high Aosta Valley (A2) determine a lower impact that the introduction of the espaliers in Cinque Terre (Li2). However, the nets used to protect the grapes dedicated to the ice vine production in autumn and winter make them more impacting. According to Mazzarino (2006), the introduction of more modern vine breeding techniques (e.g. espaliers) is due to their minor request of management efforts. With the same aim, sporadically the farmers introduced some meccanization elements, as the monorails in Cinque Terre and low Aosta Valley. As shown in Figure 7, they bring a low impact on the landscape, limited to its transit (Li2).

About the state of conservation of the Northwest Italian Alpine Arch terraced landscapes, some criticalities were identified. Firstly, the difficulty in local stones finding for the recovery of terraces was observed in Western Liguria, where the use of non-local stones impacts on the perception of the landscape (Li5). Furthermore, even worse situations were detected where the walls of the terraces are not made with the dry technique or are made with cement (Li9). In these cases, the important drainage functions of terraces, explored in Chapter I, is completely loss. The fall down of the dry-stone wall shown in Figure 7 is referred to one of the fields analyzed in Ossola Valley (P6). It is a common threat for all the

terraced landscapes considered. Some of them (e.g. Monte Barro Park, Val Grande National Park, and Ossola Valley) are nowadays in more advanced state of abandonment. While others (e.g. Aosta Valley and Valtellina) show better states of conservations. However, abandoned terraced surfaces were observed in all of the contexts, threating the landscapes integrity and their multiple functions. For these reasons, develop analysis tools for recover the abandoned terraces, in order to avoid the hydrogeological risk increase, is a priority evidenced by many authors (Agnoletti et al., 2019; Cignetti et al., 2019; Godone et al., 2018).

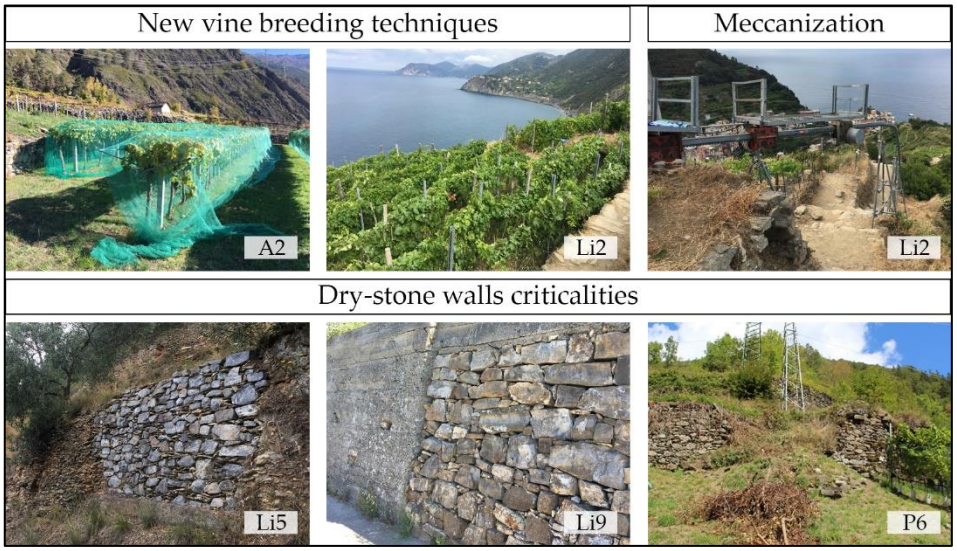

Figure 7. The non-historical landscape elements and the criticalities detected.

In conclusion, the characterization of the Northwest Italian Alpine Arch terraced landscapes evidenced the need of strength the values and avoid the criticalities that affect them. Therefore, the firsts analyses and evaluations reported in this Chapter laid the basis to be further explored in the following Chapters, and were useful for the development of the future and alternative landscapes strategies.

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Chapter III

Coevolution between Terraced Landscapes and Rural Communities: An Integrated Approach Using Expert-Based Assessment and Evaluation of Winegrowers' Perceptions (Northwest Piedmont, Italy)

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Abstract: Terraced landscapes are characterized by many features but are also threatened by abandonment, with the loss of the historical landscape and increased hydrogeological risk. In this research, we developed an innovative integrated approach using expert-based assessment and evaluation of winegrowers' perceptions to investigate the coevolution between terraced landscapes and rural communities. The aims were as follows: (i) to identify the historical landscape elements, (ii) to identify the landscape dynamics, and (iii) to analyze winegrowers' perceptions about the historical landscape elements and future development prospects. The methodology was applied to a terraced vineyard landscape (545 ha) located in Piedmont (Italy). The expert-based assessment included historical analyses and field surveys. To evaluate winegrowers' perceptions, an online questionnaire was used to understand their perceptions about the landscape's historical elements and dynamics. The results suggest that unique historical landscape elements and traditional practices (vine pergolas supported by stone columns) are conserved in the area, but also highlight some dynamics, including new vine-breeding techniques (espaliers) and new land uses (olive groves, meadows, and woodland). Winegrowers (n = 49) recognized as identity elements the same identified as historical by experts. Regarding future prospects, almost all winegrowers preferred the conservation of vineyards and pergolas. The research methodology was able to show the mutual link between terraced landscapes and rural communities in coevolutionary terms and could be replicated in similar contexts. According to the winegrowers' awareness, future planning strategies will have to support dynamic conservation of the landscape.

Keywords: historical rural landscapes; agricultural heritage systems; landscape identity; agroforestry systems; traditional agricultural practices; dry stone walls; GIAHS; landscape dynamic conservation.

1. Introduction

1.1. Terraced Landscapes and Rural Communities

The scientific community recognizes that terraced landscapes have a high degree of multifunctionality and provide ecosystem services [1,2]. According to Ghersi and Ghiglione [3], they represent important biocultural heritage and can preserve biodiversity. Indeed, dry stone walls create ecological niches where small animals and plants can live. Moreover, terraced landscapes often safeguard ancient and highly valued vine cultivars that in more mechanized agriculture practices have disappeared. Furthermore, this particular type of historical landscape preserves the know-how of rural communities; in 2018, the "art of dry stone walling, knowledge and techniques" was added to the United Nations Educational, Scientific and Cultural Organization (UNESCO) Representative List of Intangible Cultural Heritage of Humanity for Croatia, Cyprus, France, Greece, Italy, Slovenia, Spain, and Switzerland. Recent research highlighted the importance of rediscovering this knowledge and raising public awareness in order to enhance the identity and social and cultural values of terraced landscapes and prevent abandonment by reconverting it into "useful heritage" [4].

Terraced landscapes belong to the category of historical rural landscapes and have multiple values. They are strongly anthropic landscapes, made arable only after great effort to modify the steep slopes and create the optimal conditions for growing crops. Indeed, soils of terraces are characterized by better water availability and nutrient conservation [5]. These anthropogenic soils were classified by Freppaz et al. [6] as Technic Cambisols (Escalic). Pijl et al. [7] observed the responses of different practices on steep slopes in Italy to extreme rainfall events and found that

terracing practices were characterized by better mitigation of sediment flux than nonterracing practices. Along the same lines, recent research conducted in Morocco showed the important capability of agricultural terraces of increasing water infiltration and their important role in flood protection and runoff mitigation [8]. Chen et al. [9] showed that, in China, terraces have a strategic role in water erosion control, mainly where they are covered by tree crops. In order to take advantage of these important functions, a terraced system has to be continually managed [10].

Abandonment is the main factor that threatens terraced landscapes, due to a series of causes related to the difficulty of managing terraces and the social, economic, and cultural conditions of rural communities. In recent times, the viticulture practiced on terraced systems has been increasingly associated with the attribute “heroic”, underlining the great efforts that this cultivation requires in these particular conditions where mechanization is quite impossible [11]. In Italy, the term was recognized for the first time at the regulatory level with an Inter-Ministerial Decree (no. 6899, 30 June 2020) that fixed four parameters, at least one of which must be satisfied to define a vineyard as “heroic”: an altitude higher than 500 m above sea level, a slope greater than 30%, cultivation on terraces, and cultivation on small islands [12]. This was a positive step, because recognition at the national policy level indicates the importance of dedicating specific funds to this type of vineyard, preventing their abandonment. This phenomenon determines not only the loss of historical landscape but also increased hydrogeological risk.

Indeed, the lack of management of terraced systems causes spontaneous plant colonization and results in damage to water regulation, with consequent soil erosion and dry stone walls falling down [13,14].

Agnoletti et al. [15] showed that at Cinque Terre National Park (Italy), a terraced vineyard landscape designated as a UNESCO world heritage site, dramatic landslides during an extremely intense rainfall event occurred in 2011 caused by the presence of extensive abandoned terraces. Modica et al. [16] observed a drastic reduction (-85.4%) in cultivated terraces between 1955 and 2014 in Costa Viola (Calabria, Italy), confirming the negative trend and highlighting the importance of maintaining sustainable agriculture and enhancing terraced systems. In effect, enhancing terraced landscapes using an innovative regeneration approach from a past-to-future perspective is an important challenge to developing sustainable agriculture and reactivating a local circular economy [17]. Indeed, this particular type of rural landscape needs sustainable practices that highlight historical value and mitigate threats [18].

For this purpose, at the international level, since 2002 the Food and Agriculture Organization of the United Nations (FAO) has promoted the Globally Important Agricultural Heritage Systems (GIAHS) program, which is aimed at recognizing the universal value of traditional agriculture systems that are in continuous coevolution with rural communities [19]. Nowadays, 62 sites in 22 countries are included in GIAHS, and two of them are Italian terraced landscapes [20].

The interaction between humans and nature, which is the basis of coevolution and the key point of the FAO approach, has been studied by many authors [21–23]. Nan et al. [24] explored the interrelationship between agricultural biodiversity and traditional culture at GIAHS sites, underlining that there is mutual benefit in the ability to maintain food cultures and traditions and social relations. Zhang et al. [25] showed that rural communities conserve ancient culture strictly connected to the sense

of belonging and traditional agricultural practices, which allows terraced landscapes to remain productive and managed. Terraced landscapes cannot exist without management, and rural communities need to cultivate the agricultural landscape in which they live to produce food and wine. Fusco Girard et al. [26] showed that when there is a gap in this relationship due to socioeconomic changes, the multifunctionality of terraced landscapes is threatened. The authors highlighted that terraced landscapes represent a circular model that can increase human well-being and are important driving forces for territorial development. In this direction, recent research on terraced landscape in Cyprus recognized the involvement of rural communities and farmers' cooperation as being key in the rehabilitation of abandoned terraces and collapsed dry stone walls [27].

In coevolutionary terms, a historical landscape, such as a terraced landscape, is characterized by elements that date back to different periods, with recognizable stratification of different epochs due to continuous agricultural activity [28]. This concept is the basis for the significance (the possibility to reconstruct different landscape elements to match a specific epoch) that is one of the parameters to assess, with integrity and vulnerability, for another important recognition strictly related to the GIAHS program in Italy [29]. Indeed, at the national level, the Italian Ministry of Agricultural, Food, and Forestry Policies instituted the National Register of Historical Rural Landscapes, Agricultural Practices, and Traditional Knowledge in 2012 with the aim of collecting rural landscapes managed with traditional agricultural practices. Today, 27 landscapes and four agricultural practices are included [30].

The threshold by which to define the historical value of landscape elements has been debated in the literature. Bastian et al. [31] recognized such

elements as all of those that did not originate under present conditions, without defining a precise date, and considered historical landscapes as the result of coevolution between nature and man at different times characterized by different social and economic conditions. Other studies assumed the middle of the last century as the dividing line to consider previous elements (e.g., land uses) as historical [32,33]. Heider et al. [34] defined "traditional agricultural areas" as rural areas established over decades to centuries where the landscape's historical elements are integrated with cultural values. The UNESCO World Heritage List considers the permanence of historical landscape elements as the most important integrity indicator that should be preserved [35].

Furthermore, the importance of different stakeholders' involvement in the assessment, management, and policy planning of terraced landscapes has been recognized by many authors [36–38]. However, recent research showed a lack of studies on local farmers' involvement in decision making regarding the conservation of terraced landscapes [39]. The close link that has always existed, specifically between terraced vineyard landscapes and winegrowers, using an approach from expert-based assessment of historical landscape elements and dynamics to perceptive studies, is unexplored.

In this complex context, in this research, we developed and applied an innovative integrated approach using an expert-based assessment and evaluation of winegrowers' perceptions to investigate the close link between terraced landscapes and rural communities in coevolutionary terms. In particular, the aims of the research were as follows: (i) to identify the historical landscape elements, (ii) to identify the landscape dynamics,

and (iii) to analyze winegrowers' perceptions about the historical landscape elements and future development prospects.

1.2. Case Study Area

The research was applied at a terraced vineyard landscape located in Northwest Piedmont (Italy), in the northern part of the Ivrea Morainic Amphitheatre, an important geological formation known worldwide. Located at the outlet of the Dora Baltea Valley (505 km2), it is the third largest Italian amphitheater [40]. It characterizes the eastern part of the Canavese area and its boundaries are defined by the Piedmont Regional Landscape Plan [41].

As shown in Figure 1, the Ivrea Morainic Amphitheatre consists of a flat center dedicated to the plain's agriculture (e.g., cereals) enclosed by glacial moraines in which there are tree crops and woods. In particular, on the slope to the hydrographical left of the Dora Baltea River, thanks to better sun exposure, there are many vineyards. Terraces are principally concentrated in the northern part because it has the greatest slopes. Ivrea city is the most extensive urban center within the amphitheater.

The case study area extends over 545 ha into four municipalities of the Metropolitan City of Turin: Borgofranco di Ivrea, Carema, Nomaglio, and Settimo Vittone. It is a candidate for the National Register of Historical Rural Landscapes for its terraced vineyard landscape, in which vineyards cover about 70 ha. Its relevance from an international point of view is demonstrated by the presence of unique elements, which will be discussed. Furthermore, it is an important area that preserves the art of dry stone walling, knowledge, and techniques, since the municipality of Carema is included on the list of community organizations or representatives

concerned about safeguarding UNESCO's intangible cultural heritage [42].

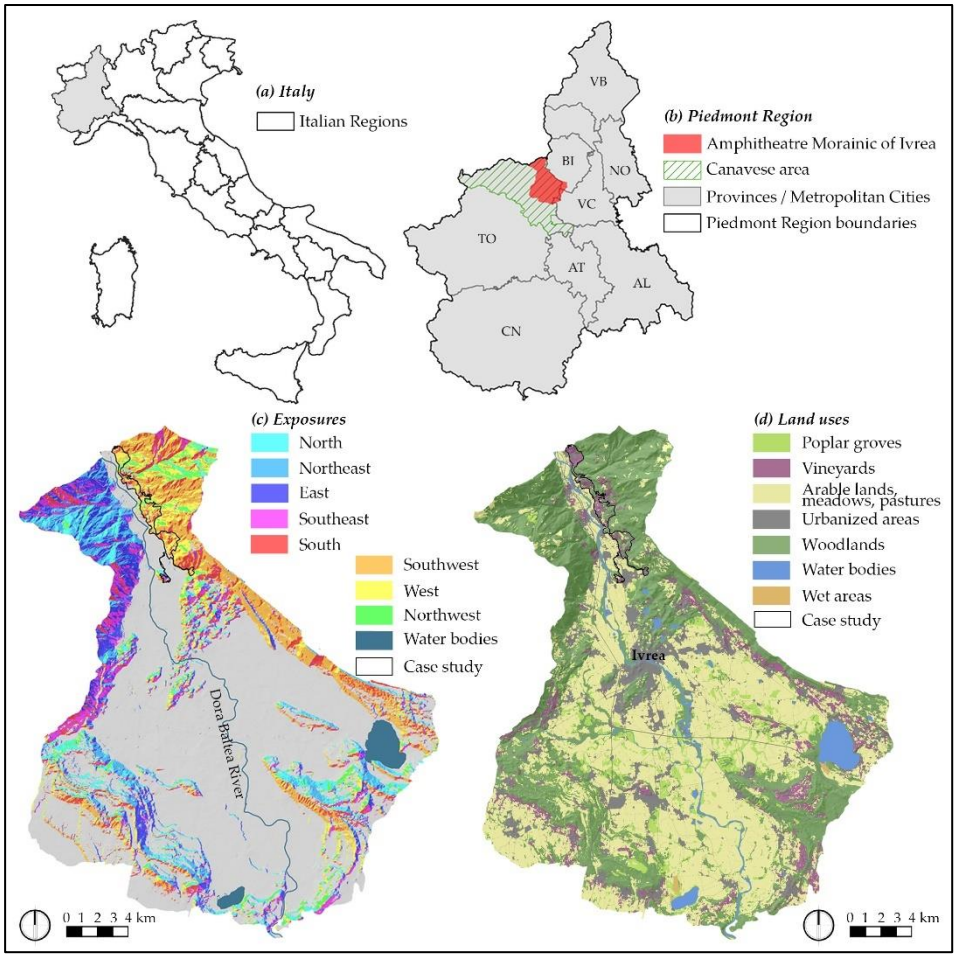

Figure 1. (a) Location of Piedmont region in Italy; (b) location of Ivrea Morainic Amphitheatre within Piedmont region; (c) exposure map of amphitheater; (d) land use map of amphitheater.

About 6100 inhabitants live in the four municipalities. Table 1 reports the aging index and housing density. Considering the data of the Piedmont region, it is evident that in the case study area, located in the rural part of the region, the aging index is higher. In all four municipalities, the most represented age range is 46–60 years, while the least represented is 18–30

years. This is a consequence of the aging of the rural community, which is one of the threats to historical landscape conservation. Carema, Nomaglio, and Settimo Vittone have lower housing density than the Piedmont region, while Borgofranco di Ivrea has higher housing density. The latter is the municipality nearest to Ivrea city and outside the case study area is characterized by recent urbanization. The case study area is located in a strategic point of connection between Turin and Aosta, the capital cities of the Piedmont and Aosta Valley regions, respectively. It is near state road SS26 (Strada Statale 26 della Valle d'Aosta), the A5 Torino-Aosta highway, which runs parallel to it in the north–south direction, and the historic Chivasso–Ivrea–Aosta railway (1870). The communication system and internet connectivity are good.

Table 1. Demographic characteristics of municipalities and Italian region of case study area (elaborations from ISTAT data [43]).

	Inhabitants (no.)	**Aging Index (no. of Inhabitants >64 Years Old Per 100 Inhabitants <15 Years Old)**	**Housing Density (Inhabitants/km^2)**
Borgofranco di Ivrea	3590	234	267
Carema	739	233	72
Nomaglio	291	273	95
Settimo Vittone	1513	245	65
Piedmont region	4,274,945	215	168

During 2019, the production of denomination of controlled origin (DOC) wines in the Piedmont region was worth EUR 980 million (6.4% more than 2018) and the Piedmont region was ranked third nationally after Veneto and Tuscany for the value of wine [44]. In the case study area, the primary source of income is agriculture, and vineyards are the most representative on terraces: 133 vine farms totaling 42.3 ha are recorded by the Piedmont

region [45]. Most of these farms are run by nonprofessionals. It is important to highlight that in the case study area, there are many vineyards dedicated to self-consumption that are not included in the statistics, but they are an important part of the viticulture system of the area.

In addition to the elements unique in the world, the case study area is characterized by historical landscape elements to be preserved and dynamics that are the result of coevolution between the landscape and rural communities. Similar to other terraced systems, the abandonment of terraces and the introduction of invading woods are the main concerns. However, nowadays, there is increasing interest in local quality production, as evidenced by two DOC wines and one slow food presidium. In this context, experiential tourism and requests for wine from other countries are expanding. For these reasons, the terraced vineyard landscape of the case study area has to be studied and enhanced in order to preserve the historical landscape, recover abandoned terraces, and increase quality production. Winegrowers' perceptions need to be explored and considered for future planning strategies.

2. Materials and Methods

2.1. Methodological Framework

In the literature, it is recognized that assessing and enhancing the historical landscape elements are critical to maintain the social identity [46]. The European Landscape Convention defined the landscape as *an area perceived by people whose character is the result of the action and interaction of natural and/or human factors* [47], so studies and planning for rural landscapes have to consider bottom-up approaches. Antrop et al.

[48] showed the importance of applying integrated and transdisciplinary approaches in landscape studies.

For these reasons, in order to investigate the close link between terraced landscapes and rural communities in coevolutionary terms, the research was conducted from two perspectives: expert-based assessment and evaluation of winegrowers' perceptions. The first allowed identification of historical elements and dynamics of the landscape, while the second allowed investigation of the perceptions of winegrowers about these elements and dynamics and about future development prospects. Figure 2 shows the methodological framework of the research.

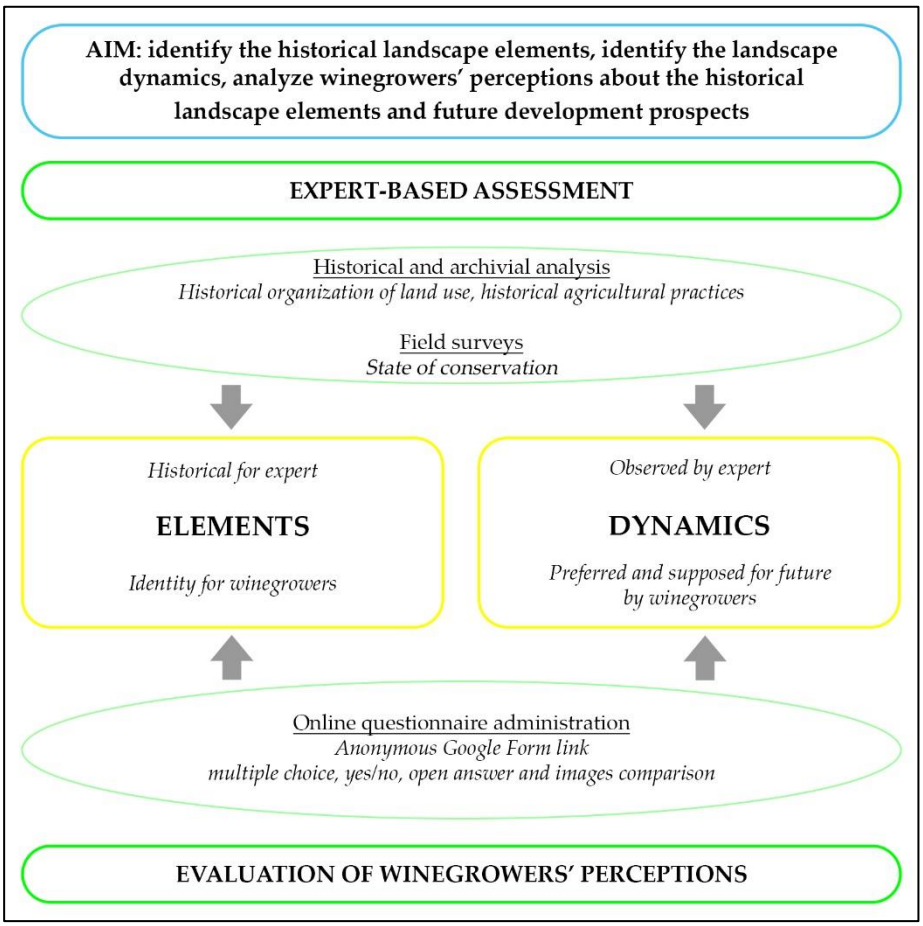

Figure 2. Methodological framework.

2.2 Expert-Based Assessment

The analysis of landscape elements based on expert assessment requires an integrated approach with preliminary desk studies and map analysis followed by field surveys [49]. Slámová et al. [50] highlighted the importance of archive and field research for identifying and assessing the characteristics of historical landscape as a tool for landscape planning in Slovakia. Historical cadastral maps are widely used to assess the structure of historical landscapes in terms of the organization of land use [51,52]. The literature also recognizes photographs as important sources of information for assessing historical landscapes and monitoring changes [53]. Other reliable sources that are useful to understand the elements of historical landscapes are art, iconography, and religious paintings, about which Tesfamariam et al. [54] indicated a need for more research in the future.

The expert-based assessment was performed by the authors, who, according to Arnés García et al. [55], are researchers with experience related to analyzing the historical landscape. The assessment was performed in two steps as suggested by the literature cited above. The first step was to conduct historical and archival analyses in order to identify elements of the historical landscape in terms of the organization of land use and agricultural practices. The GIAHS-FAO approach was assumed to define the time range for considering landscape elements as historic. According to Fuller et al. [56], GIAHS sites are very complex, characterized by elements with historical roots from different epochs. These various layers of history are more or less evident on the landscape, considering different periods of human evolution. Stabbetorp et al. [57] focused their research on the agricultural period, since farming societies

modified the landscape more than the previous hunting/gathering societies. For these reasons, the time period considered in the present research started in the epoch during which the steep slopes were terraced and dedicated to viticulture. All of the agricultural elements that were defined as historical originated in the past and are still recognizable in their original configuration. Table 2 lists the documents found in local historical archives and libraries that were analyzed. These historical documents date from the middle of the 1600s to the beginning of the 1900s and include accurate references to the origin of historical landscape elements.

Table 2. List of historical documents found in local archives and libraries.

Archive Name and Location	Year	Original Name	Documentation
Historical archive of Carema municipality	1651	Lettere per Inibizione delle Vendemmie Istanti li Agenti della Comunità di Carema	Written letter
Historical archive of Carema municipality	1749	Cattastro della Molto Magnifica Comunità di Carema Provincia di Ivrea	Cadastral map
Historical archive of Settimo Vittone municipality	1789	Catastro della Molto Magnifica Comunità di Settovittone	Cadastral map of Savoy family
Historical archive of Carema municipality	1802	Libro Campagnolo Figurato di Tutto il Territorio di Carema	Cadastral map
Historical archive of Carema municipality	1802	Catasto del Commune di Carema	Cadastral map
Costantino Nigra Civic Library of Ivrea	1833	Saggio intorno alle viti ed ai vini della Provincia d'Ivrea e della Valle d'Aosta del Medico Lorenzo Francesco Gatta	Monograph
Costantino Nigra Civic Library of Ivrea	1910	I Vigneti ed il Vino di Carema. Indagini e Considerazioni del Direttore Prof. Dott. G. Chiej-Gamacchio	Monograph
Costantino Nigra Civic Library of Ivrea	1986	I Balmetti di Borgofranco di Ivrea	Monograph

In order to identify the historical organization of land use, cadastral maps were analyzed. Particularly, the Savoy family cadastral map (1789) was deeply studied. The map was found in the historical archive of Settimo Vittone municipality and was in an excellent state of conservation. Land uses were color-coded and all cadastral parcels included a number. All of the numbers corresponded to an accurate description of land use reported in the summary book. The map was reproduced through orthophotography and subsequently digitalized in Adobe Photoshop CC 2017. A representative area was selected, and land uses were reconstructed through digitalization. Figure 3 shows an image of the original Savoy family cadastral map, the orthophotographic reproduction process, and the sample area used for in-depth analysis of historical land use organization.

Other documents that were found included manuscripts, books, and letters. They were useful to identify the historical agricultural practices, traditional vine varieties, and characteristics of the historical landscape elements.

The second step of expert-based assessment involved organizing several field surveys aimed at assessing the state of conservation of terraced landscapes. The historical landscape elements identified during the historical and archival analyses were verified. Other signs of historical significance of the landscape were also found. During field inspections, different landscape dynamics were observed.

All of the analyses conducted for the expert-based assessment allowed us to list the historical landscape elements, the state of conservation, and dynamics of change. Regarding the historical landscape elements, the research identified both agricultural and architecture elements, but only the agricultural elements will be discussed below.

Figure 3. (a) Savoy family cadastral map (1789) found in historical archive of Settimo Vittone municipality. (b) Orthophotographic reproduction process. (c) Sample area used for in-depth analysis of historical land uses' organization. (d) Detail of sample area.

2.3. Evaluation of Winegrowers' Perceptions

To evaluate winegrowers' perceptions, an online questionnaire was administered to winegrowers operating in the case study area. This particular type of stakeholder was chosen according to Cicinelli et al. [39], who highlighted the strategic role of local farmers in maintaining terraced landscapes. The use of a questionnaire administered via the Internet is well established in the literature [58]. Different studies have used Google Forms, a very easy platform that allows researchers to reach respondents by sending a link without any contact between them or any type of influence on the answers [59]. The first paragraph of the questionnaire described the aims of the research. Respondents were not identifiable by their answers and consented to the use of their anonymous answers. According to many authors who showed the efficacy of using images in questionnaires focusing on landscape perception, a series of images were presented to the respondents [60,61].

The questionnaire underwent a pretest phase (8 completed questionnaires) to verify the content and wording of the questions. It was written in Italian and posed 34 questions of different types: multiple choice, yes/no, open answer, and image comparison. The questionnaire was divided into five sections:

I. General information (questions 1–7).
II. Farm characteristics (questions 8–20).
III. Product characteristics (questions 21–23).
IV. Landscape perception (questions 24–31).
V. Future development prospects (questions 32–34).

The questions and their answer choices are reported in Table 3.

Table 3. Questions and answers used in questionnaire.

Questions	Answer Choices
I. General Information	
1. Do you manage terraced vineyards?	Yes, professional activity; yes, non-professional activity; no
2. Age	(Years)
3. Sex (not mandatory)	Male, female
4. Education	Primary school, secondary school, high school, university degree
5. Among your family, is there anyone who wants to continue the viticultural activity?	Yes, no, do not know
6. Do you think you have a role in maintaining the terraced landscape?	Yes, no
7. What are the identity elements in the landscape?	(Open)
II. Farm's characteristics	
8. How many family members besides you work on the farm?	(Number)
9. Do you have permanent and/or seasonal employees?	(Number)
10. Are all the vineyards merged?	Yes, no
11. Age of oldest vineyards	(Number of years)
12. Age of youngest vineyards	(Number of years)
13. Total surface area of terraced vineyards	(m^2)
14. Which vine varieties are present?	Nebbiolo Picotendro, Nebbiolo Prugnet, other Nebbiolo, Barbera, Freisa, Bonarda, Neretto, Croatina, Erbaluce, Chardonnay, other
15. What is the main vine-breeding system?	Traditional high pergola (warp with wooden poles), modified high pergola; espalier, other
16. Are stone columns (*pilun*) present?	Yes, no
17. In addition to terraced vineyards, do you have any of the following categories?	Meadow/pasture, arable land and cereals, olive groves, chestnut groves, sheep and goats, bovines, no, other
18. What is the state of conservation of dry stone walls?	Intact, partially damaged, completely damaged
19. What type of agriculture do you practice?	Conventional, integrated, biological, other
20. Do you have problems managing terraced vineyards? If so, which ones?	(Open)

Table 3. *Cont.*

Questions	Answer Choices
III. Product characteristics	
21. Do you produce DOC wines?	(List of DOC wines produced in the area), do not produce DOC wines, give grapes to other cellars
22. What are the distribution channels for produced wine?	Direct sale on the farm, hotels/restaurants/cafes, big organized distribution (supermarkets), solidarity buying groups, online, give grapes to other cellars, not sold (family use), other
23. In which geographical area is the wine produced sold?	Piedmont/Aosta Valley, Northern Italy, Central and/or Southern Italy, Europe, non-EU countries, give grapes to other cellars, not sold (family use)
IV. Landscape perception	
24. Do you think the terraced landscape should be considered an added value to the wine produced there?	Yes, no
25. Do you think the terraced landscape could also be of interest from a tourist point of view?	Yes, no
26. Do you think dry stone walls are identity elements of the landscape?	Yes, no
27. Do you think stone columns (*pilun*) are identity elements of the landscape?	Yes, no
28. Do you think the pergola vine-breeding technique is an identity element of the landscape?	Yes, no
29. Do you think espalier vine-breeding technique is an identity element of the landscape?	Yes, no
30. Do you think vines are an identity element of the landscape?	Yes, no
31. Do you think olive groves are an identity element of the landscape?	Yes, no

Table 3. *Cont.*

Questions	Answer Choices
V. Future development prospects	
32. Which future do you think is more possible for your terraced vineyards?	They will continue to be managed in the traditional way (pergola), the traditional vine-breeding technique will be modified (espalier), they will be converted to other crops (olive groves), they will no longer be cultivated but will be managed (mowed), they will be completely abandoned and invaded by woods
33. Between the two future prospects proposed in the following pairs of images, which do you like more? (indicate an answer for each pair)	A-B; 1-2; 1-3; 1-4; 2-3; 2-4; 3-4 *
34. Between the two future prospects proposed in the following pairs of images, which do you think is more likely in the future? (indicate an answer for each pair)	A-B; 1-2; 1-3; 1-4; 2-3; 2-4; 3-4 *

* Pictures are shown in Figure 4.

In agreement with Nederhof [62], the questionnaire was submitted anonymously. It was sent to winegrowers as a Google Forms link with the support of the municipalities and the only social cellar in the case study area. The winegrowers were invited to share the link with local colleagues. For this reason, it was not possible to know the actual number of winegrowers who saw the questionnaire, and the evaluation of their perceptions was based on the answers received.

A basic descriptive analysis was carried out in the form of percentages, in line with Santoro et al. [60]. The first part of the questionnaire was used to frame the sample and collect general information. This part included an open question about the identity elements in the landscape (#7) in order to collect the first thoughts that came to respondents' minds without being

influenced by the specific questions that emerged from the expert assessments (parts IV and V). The second part was used to frame the farm characteristics and state of conservation. This part included an open question about problems with managing terraced vineyards (#20), which are a sign of vulnerability. The third part was used to highlight product characteristics in terms of DOC wine production, distribution channels, and basins. The fourth part presented specific elements detected on terraces during the expert-based assessment in relation to terraces' construction features, vine-breeding techniques, and land use (#26–31). In the last part, one image for each dynamic on terraces observed during the expert-based assessment was selected in terms of different vine-breeding techniques and land uses. Images were restricted to the specific element proposed (type of vine-breeding technique or land use), without other elements present (e.g., mountains, sky, etc.), in order to not influence the respondents. These images were presented in pairs, and respondents were asked to choose which one they liked more and which was more likely in the future (#33–34). The pictures are shown in Figure 4. Pictures A and B show two vine-breeding techniques, historical pergolas and espaliers, respectively. Pictures 1–4 show land uses observed on terraces: picture 1 is related to the historical land use, vineyards, and 2–4 are related to observed dynamics: olive groves, meadows, and invading woods, respectively.

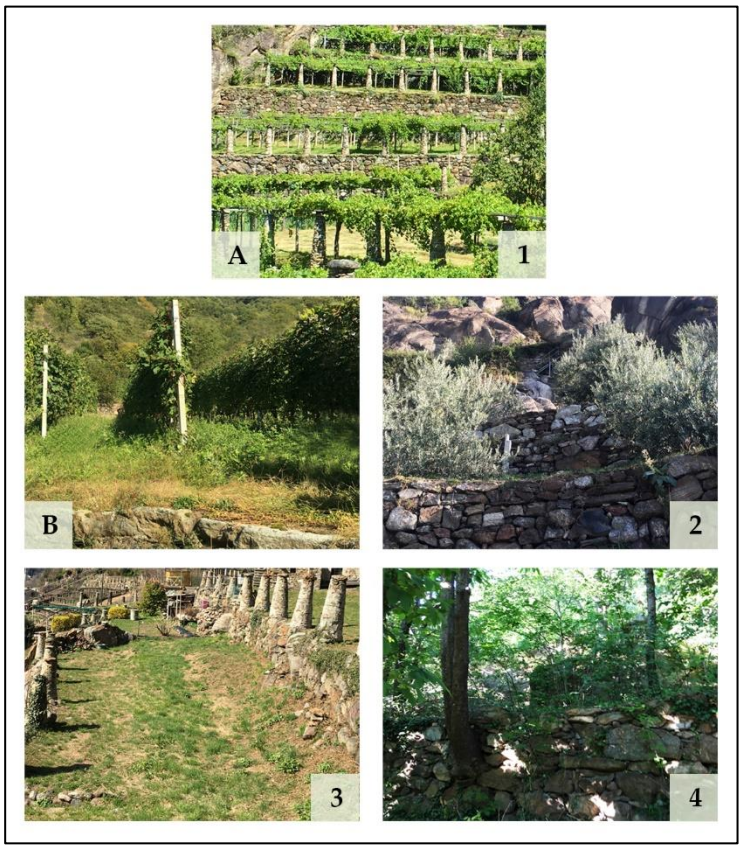

Figure 4. Images in the questionnaire presented in pairs (A-B; 1-2; 1-3; 1-4; 2-3; 2-4; 3-4) (questions 33 and 34).

3. Results

3.1. Expert-Based Assessment

The first phase of the expert-based assessment was historical and archival analyses. Regarding the historical organization of land use, the Savoy family cadastral map and the overlap of level curves suggested that historically, vineyards were located at an altitude range between 280 and 500 m above sea level. In the sample area selected for in-depth analysis, the historical land uses (1789) were reconstructed. As shown in Figure 5, historically, vineyards occupied the center of the system, on the lower part of the slope. The flat land was dedicated to meadows and arable land.

Above the vineyards were woodlands, mainly chestnut trees. Many chestnut groves were described in the cadastral map's summary book as pasture chestnut, where trees were planted in a regular pattern and used for fruit production. Animals grazed under the plants. Woodland comprising chestnut also had an important role in the production of poles used for the pergola vine-breeding system. Above the woodlands, the slope was very steep and there were rocks and pastures.

Figure 5. Land uses in sample area in 1789 (reconstructed from Savoy family cadastral map found in Settimo Vittone municipality's historical archive).

The other documents found in local historical archives and libraries allowed us to identify the historical agricultural practice, which is unique in the world. Historically, the technique for breeding vines used pergolas made with chestnut poles and supported by stone columns. Locally, this vine-breeding technique is called *tupiun*, and the stone columns are called *pilun*. These columns have two important roles. The first is to support the pergolas. The second is related to their ability to heat up during the day and release heat overnight, which reduces the temperature range between day and night. For this reason, they are also called stove columns. The historical vine-breeding technique is strongly linked to the case study area because it only exists there; it can also be called *pergola caremiese*. The main vine variety cultivated in the area is Nebbiolo, also known by its synonymous *Picotendro*. It is characterized by vigorous plants whose branches are prone to break in the wind. The pergola vine-breeding technique reduces this problem and allows better passage of light through the vegetative mass, especially where the terrace is very narrow. The historical monograph from 1833 described the characteristics of Nebbiolo and confirmed that it was historically the main cultivated vine variety in the case study area. Nowadays, the two main wines with denomination of controlled origin designation produced in the area (DOC Carema and DOC Canavese Nebbiolo) are composed of at least 85% Nebbiolo. Indeed, statistical data of the Piedmont region show that in the four municipalities in the area, 85.29% of the total vine area is dedicated to Nebbiolo cultivation [45].

The historical documents highlighted that *pergola caremiese* originated during Roman times, while vines were introduced in the area during pre-Roman times. Barsimi [63] reported that the introduction of vines from the Middle East in the Dora Baltea Valley dates back to 3000 BC, with the

presence of Neolithic settlements that were among the oldest in Italy. The main impulse for the development of viticulture in the area is attributed to the Salassi. They were a population of Celtic–Ligurian origin with Greek–Etruscan influences that inhabited the Canavese area before the arrival of the Romans. Since then, viticulture has seen moments of expansion and contraction in relation to different human social needs and phytosanitary problems (e.g., Phylloxera). The historical document from 1910 shows that in those years, viticulture was expanding, which also affected the part of the slope less suitable for vine cultivation or more difficult to cultivate. It is probable that these vineyards were the first to be abandoned in subsequent times of contraction in the last century, when industrialization deprived the countryside of manpower. A letter dated 1651 was found in the Carema historical archive. It talks of the grape harvest and attests to the historical presence of vines in the case study area.

The historical document from 1986 found in the Costantino Nigra Civic Library in Ivrea allowed us to identify another historical landscape element unique in the world: the Balmetti of Borgofranco di Ivrea, which comprises 213 cellars historically used for wine and cheese storage. They lean against the mountain, where natural faults from morainal rocks of the Mombarone massif, due to ancient glacier action, allow the passage of air currents called ore. These currents allow the dampness and temperature (7–8 °C) in the cellars to be maintained at constant levels throughout the year. The cellars are linked together; therefore, air currents flow between them. The first written attestation of the presence of these Balmetti dates back to the mid-1600s. They are important historical landscape elements strictly connected to viticultural activity in the case study area, but since they are elements of rural architecture, they will not be discussed further.

The second phase of the expert-based assessment was field surveys, which allowed us to verify the historical landscape elements found during archival analysis, and identify the state of conservation and dynamics. Regarding the historical landscape elements, a good state of conservation of terraces, dry stone walls, and pergolas was observed. As shown in Figure 6, the historical organization of land use described above was perfectly recognizable, with vertical landscapes where vineyards occupied the lowest part of the slope and the middle of the agricultural system (Figure 6a,c). Terraced vineyard landscapes showed an interesting dynamic throughout the seasons: green vegetative mass during spring and summer (Figure 6a), yellow/orange chromatic variations during autumn (Figure 6b), and the absence of vegetation in winter when the snow highlighted the presence of the terraces (Figure 6c). Winter was the best season to identify the structural characteristics of the historical landscape elements (Figure 6d). The historical presence and importance of vines in the case study area was evidenced by many elements identified during field surveys (e.g., art, iconography, and religious paintings). Representations of grapes were considered a sign of the historical presence of vines and rural communities' recognition of their importance.

Figure 6. Good state of conservation of terraced landscape observed during field inspections, with (a,c) perfectly recognizable historical organization of land use, (a–c) landscape dynamism during seasons, and (d) good identifiability of historical landscape structure during winter.

As shown in Figure 7, a very rigorous structure of pergolas was observed, with four orders of chestnut poles perpendicularly overlapped (Figure 7a,d). Vines were planted along the terracing walls and grass between the rows. Stone columns were historically built on the top of the terrace walls. The pergolas' chestnut poles were supported by stone columns at the front and embedded in the wall of the terrace behind. Many columns show the date of construction (e.g., 1821 in the stone column shown in Figure 7c). This is further evidence of their historical presence in the case study area. Vineyards and pergolas supported by columns were integrated with other historically important elements of rural architecture; for example, the

vineyard shown in Figure 7b evidently has a close relationship with a wash house, which historically had an important social and aggregation role.

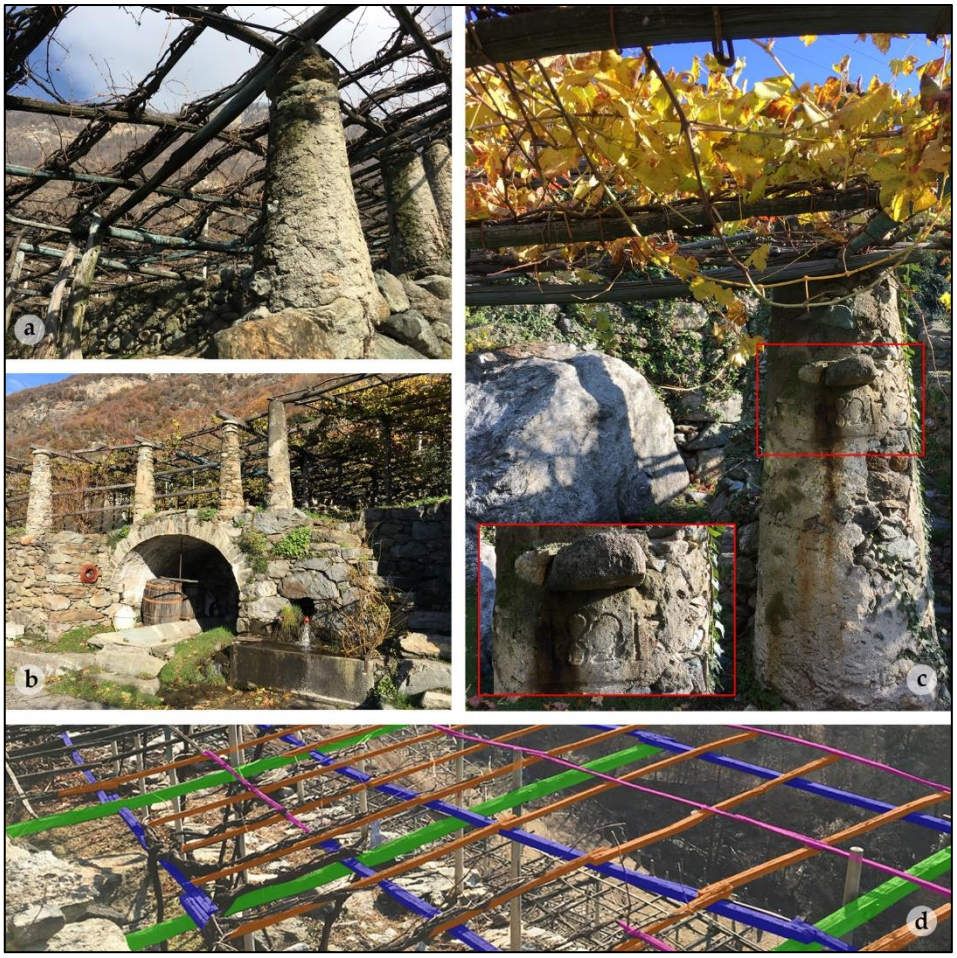

Figure 7. (a) Historical vine-breeding technique: pergola made of chestnut poles supported by stone columns. (b) Pergolas integrated with other important historical landscape elements of rural architecture. (c) Dated stone columns for pergola support (1821). (d) Detail of four orders of chestnut poles perpendicularly overlapped that make up pergolas (shown in green, blue, orange, and pink).

During field inspections, the historical presence of chestnut trees in the main woodland above vineyards in terms of composition and pasture chestnuts was verified. The presence of secular plants and an ecomuseum dedicated to chestnuts was noted. Figure 8 shows secular plants of chestnut

designated as the oldest in Nomaglio municipality (Figure 8a) and a permanent chestnut grove that was already reported as pasture chestnut in the sample area according to the Savoy family cadastral map (Figure 8b). Today the historical structure is still recognizable, with chestnut trees intended for fruit production planted in a regular scheme, where, historically, animals grazed.

Figure 8. (a) Secular chestnut trees designated as the oldest in Nomaglio municipality. (b) Chestnut grove reported as pasture chestnut in sample area according to Savoy family cadastral map.

During field inspections, another historical landscape element emerged: the historical presence of olive trees in the case study area. Indeed, they were not present as cultivation, but many plants were present principally at an important religious Romanic complex of Settimo Vittone, Battistero di San Giovanni e Pieve di San Lorenzo. The historical presence of these trees is also evidenced by a fresco from the late 1700s found in a church in Tavagnasco, a municipality bordering Settimo Vittone. Figure 9 shows the fresco and the secular olive trees.

Figure 9. (a) Secular olive trees historically present at Battistero di San Giovanni e Pieve di San Lorenzo, a religious Romanic complex. (b) Evidence of historical presence of olive trees in case study area: a fresco dated late 1700s illustrating this religious complex and its olive trees.

Another result of field surveys was the identification of dynamics. As discussed above, a good state of conservation and maintenance of vines and the historical breeding system were observed. However, dynamics related to vine-breeding techniques and land uses were also identified, which were directly affected by the coevolution between man and the landscape and social changes (e.g., aging of rural communities).

Regarding the vine-breeding system, the introduction of some differences affecting more or less the landscape was observed. The first one was the permanence of pergolas supported by stone columns but constructed with less use of chestnut poles. The result is modified pergolas with only two orders of chestnut poles perpendicularly overlapped and one order of metal wires. Winegrowers explained that this type of modified pergola allows for reduced management costs, since metal wires are more durable than chestnut poles and do not intercept phytosanitary treatments. As shown in Figure 10, this change leads to low impact on the landscape and is evident only in winter when there is no vegetative mass. In some cases, it was observed that vines were planted in the middle of terraces and not along

the dry stone walls. Winegrowers highlighted that based on their experience, this nonhistorical handling of plants allows better aeration of the fields.

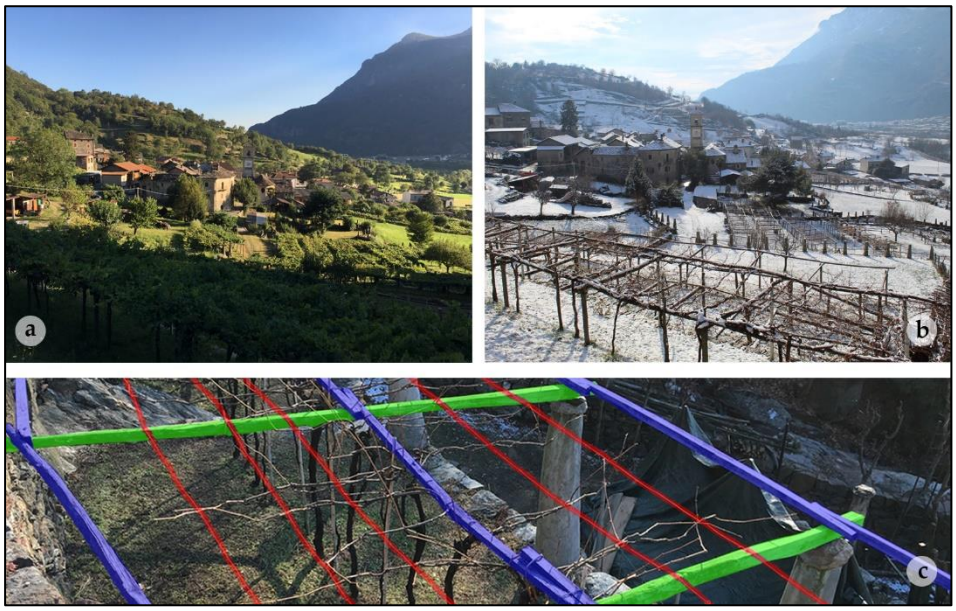

Figure 10. Modified pergolas in (a) summer and (b) winter, where (c) some orders of chestnut poles were replaced with metal wires and vines were planted in the middle of terraces.

The second change to the vine-breeding system that was observed during field inspections was the introduction of espaliers (Figure 11). This has more impact on the landscape than the modified pergola and has no historical value, since it was developed in recent times. Nowadays, the use of espaliers is limited to particular conditions where the slopes are reduced and the terrace area is more extensive, and there is no problem of one espalier shading the others. Stone columns remained in the field but lost their historical role of pergola support.

Figure 11. (a) Use of espalier vine-breeding technique on lower part of slope and its impact on landscape. (b) Detail of espalier technique.

Regarding land uses, the consequences of abandoning vineyards were observed. Figure 12 shows the main dynamics that brought landscape change. The first one is the introduction of olive groves (Figure 12a). This dynamic is limited to a few contexts and is related to self-consumption, but is in the process of expanding. This cultivation was taken from the observation of olive trees at the Battistero di San Giovanni e Pieve di San Lorenzo complex, which were present for centuries thanks to the optimal climate of the case study area. Another dynamic that was related to the abandonment of cultivation was the continuous management of terraces that were mowed (Figure 12b). These dynamics brought landscape change but allowed continuous management of terraces against the hydrogeological risk. The worst dynamic from a hydrogeological point of view that was observed during field surveys was related to the more or less recent total abandonment of terraces, with the presence of invasive shrubs or woodland (Figure 12c,d). In all of these cases, the stone columns historically used to support vine pergolas lost their role but remain as witnesses of the viticultural past.

Figure 12. Consequences of vineyard abandonment: (a) introduction of olive groves; (b) abandonment of cultivation but continuous terrace management (mowed); (c) recent terrace abandonment with the presence of invasive shrubs; (d) total terrace abandonment with the presence of invasive woodland.

3.2. Evaluation of Winegrowers' Perceptions

We obtained 49 completed questionnaires from winegrowers. Among the respondents, 77.6% manage their terraced vineyards at a nonprofessional level (question 1). Table 4 frames the sample in terms of age range, sex, and education (questions 2–4).

Table 4. Answers to questions 2–4.

Age Range (2) (%)				Sex (3) (%)		Education (4) (%)			
18–30	**31–45**	**46–60**	**>60**	**M**	**F**	**Primary School**	**Secondary School**	**High School**	**University Degree**
6	31	22	41	85.7	14.3	4	33	43	20

As shown in Table 4, most of the respondents were older than 60 years (41%), while the minority (6%) were young (18–30 years old); 31 and 22% of the respondents were 31–45 and 46–60 years old, respectively. Among them, 85.7% were male and 14.3% were female. Regarding education, 20% obtained a university degree, 43% graduated from high school, 33% from secondary school, and only 4% from primary school.

Just under half of the respondents (46.9%) reported that there was someone in their family who wanted to continue the viticultural activity, while 18.4% reported that there was not (question 5). Almost all respondents (98%) indicated that they were aware of their role in maintaining the terraced landscape (question 6).

Regarding the farm characteristics, the questionnaire allowed us to identify the respondents' farm workforce in terms of family members and employees (questions 8–9). Table 5 lists them.

Table 5. Answers to questions 8 and 9.

	How Many Family Members Besides You Work on the Farm? (8) (%)	**Do you Have Permanent and/or Seasonal Employees? (9) (%)**
0	49	89.8
1	26.53	8.16
2	12.24	-
3	10.2	2.04
4	2.04	-

As shown in Table 5, on just over half of the farms (51%), one or more family members worked besides the interviewed winegrower. In most cases, only one family member besides the respondent worked (26.53%). The greatest number of family members reported was four (2.04%). Among the farms, 89.8% were run only by the family, and the remainder

had one (8.16%) or three (2.04%) permanent and/or seasonal employees.

Among the vineyards, 67.3% were not merged (question 10). The average age of the oldest vineyards was 57 years, and the youngest was 8 years (questions 11–12). The average vineyard area was 0.54 ha (question 13). The principal cultivated vine variety was Nebbiolo Picotendro, which was cultivated on 89.8% of farms (question 14).

The traditional high pergola (warp with wooden poles) was the main vine-breeding systemon 77.6%of the farms (question 15). Other vine-breeding systemswere less represented: modified high pergola (12.2%) and espalier (8.2%). On 79.6% of the farms, there were stone columns (question 16). Among the winegrowers, 65.3% had other agricultural categories in addition to terraced vineyards (question 17). In particular, just under half of the respondents (49%) also had meadows/pastures, followed by chestnut groves (34.7%), olive groves (24.5%), arable land and cereals (8.2), sheep and goats (8.2%), and bovines (2%).

Regarding the state of conservation of dry stone walls (question 18), in 59.2% of the cases they were intact, while 40.8% were partially damaged. No winegrower reported that their dry stone walls were completely damaged. Conventional agricultural was practiced by 61.2% of respondents, followed by integrated (30.6%) and biological (8.2%) (question 19). Most of the respondents (79.6%) reported problems with management of terraced vineyards (question 20). Table 6 lists them.

As shown in Table 6, the main problems in the management of terraced vineyards reported by winegrowers were terraces management and accessibility (cited 12 and 11 times, respectively), followed by poor mechanization (7), difficulty with management (5), and water availability (5). Problems cited less frequently were proximity to uncultivated lands

(2), too much time for cultivation (2), land pulverization (2), management costs (2), too much time for pergola vine-breeding technique management (1), and *pilun* management (1).

Table 6. Answers to question 20.

Do you Have Problems Managing Terraced Vineyards? If So, Which Ones?	
Reported Problem	**Number of Citations**
Terraces management	12
Accessibility	11
Poor mechanization	7
Difficulty with management	5
Water availability	5
Proximity to uncultivated lands	2
Too much time	2
Land pulverization	2
Management costs	2
Too much time for pergola management	1
Pilun management	1

Regarding product characteristics, among possible DOC wines produced in the area, those most produced were DOC Carema, DOC Carema reserve, and DOC Canavese Nebbiolo, by 49%, 24.5%, and 24.5% of respondents, respectively (question 21).

The main distribution channels for the wine (question 22) were giving grapes to other cellars (44.9%), followed by selling directly on the farm (28.6%) and selling to hotels/restaurants/cafes (26.5%). About a quarter of respondents (24.5%) produced wine only for family use.

The wines produced were sold principally in the Piedmont and Aosta Valley regions (30.6%) and across all Italy (question 23). Moreover, many winegrowers reported that they also sold wine in Europe (24.5%) and in non-EU countries (20.4%).

Regarding the landscape, respondents reported many identity elements (question 7). They are listed in Table 7.

Table 7. Answers to question 7.

What Are the Identity Elements in the Landscape?			
Reported Element	**Number of Citations**	**Reported Element**	**Number of Citations**
Terraces	31	Pastures	1
Vineyards/viticulture	19	Woodlands	1
Pilun	14	Mixed agriculture	1
Pergolas	13	Uniqueness	1
Dry stone walls	7	Rocks	1
Chestnut groves	6	Fragility of terraces	1
Olive groves	6	Cows	1
Nebbiolo	2	Restaurants	1
Mule tracks	2	Cheeses	1
Architecture	2	Mountains	1
Meadows	1	People	1

Table 7 shows all of the identity elements in the landscape reported by winegrowers. The most cited elements were terraces (31) followed by vineyards/viticulture (19), *pilun* (14), and pergola vine-breeding technique (13). Dry stone walls were cited by seven respondents, while chestnut and olive groves were both cited six times. Other elements were Nebbiolo, mule tracks, and architecture (two each) and meadows, pastures, woodlands, mixed agriculture, uniqueness, rocks, fragility of terraces, cows, restaurants, cheeses, mountains, and people (one each).

All of the interviewed winegrowers (100%) thought that the terraced landscape should be considered an added value for the wine produced there (question 24). Almost all of them (98%) thought that it may also be of interest from a tourist point of view (question 25). Table 8 reports the answers to questions 26–31 about winegrowers' perceptions of specific elements.

Table 8. Answers to questions 26–31.

Do You Think These Are Identity Elements of the Landscape?		
Proposed Element	**Yes (%)**	**No (%)**
Dry stone walls (26)	100	0
Stone columns (*pilun*) (27)	98	2
Pergola vine-breeding technique (28)	100	0
Espalier vine-breeding technique (29)	14.3	85.7
Vines (30)	98	2
Olive groves (31)	32.7	67.3

As shown in Table 8, most of the respondents perceived dry stone walls (100%), stone columns (98%), pergola vine-breeding technique (100%), and vines (98%) as identity elements of the landscape. On the contrary, they did not consider the espalier vine-breeding technique (85.7%) or olive groves (67.3%) as such.

Regarding future development prospects, most of the respondents (74.5%) reported that their terraced vineyards will continue to be managed in the traditional way (pergola), while 4.3% reported that they will modify the traditional vine-breeding technique (espalier) (question 32). Others thought that terraced vineyards will be completely abandoned and invaded by woods (12.8%), 6.4% thought that they will no longer be cultivated but managed (mowed), and 2% thought that they will be converted to other crops (olive groves).

Table 9 reports winegrowers' preferences for future prospects based on presented pictures of vine-breeding techniques and land uses (question 33).

As shown in Table 9, the future prospect the winegrowers most preferred was maintaining the historical landscape elements. Indeed, almost all of them (95.9%) preferred the pergola vine-breeding technique (A) to

espaliers (B). Regarding land uses, 93.9% of respondents preferred vineyards (1) over olive groves (2) and 98% preferred them over meadows (3) and woodlands (4). Between olive groves and meadows, 63.3% preferred the former, and 89.8% preferred olive groves and meadows over woodlands.

Table 9. Answers to question 33.

Between the Two Future Prospects Proposed in the Following Pairs of images, Which Do You Like More? (Indicate an Answer for Each Pair) (%)					
A	**B**	**1**	**2**	**3**	**4**
95.9	4.1	-	-	-	-
-	-	93.9	6.1	-	-
-	-	98	-	2	-
-	-	98	-	-	2
-	-	-	63.3	36.7	-
-	-	-	89.8	-	10.2
-	-	-	-	89.8	10.2

Table 10 reports winegrowers' perceptions of future prospects based on pictures of vine-breeding techniques and land uses in terms of which ones they thought were more likely to occur in the future (question 34).

Table 10. Answers to question 34.

Between the Two Future Prospects Proposed in the Following Pairs of Images, Which Do You Think Is More Likely in the Future? (Indicate an Answer for Each Pair) (%)					
A	**B**	**1**	**2**	**3**	**4**
57.1	42.9	-	-	-	-
-	-	75.5	24.5	-	-
-	-	69.4	-	30.6	-
-	-	75.5	-	-	24.5
-	-	-	55.1	44.9	-
-	-	-	63.3	-	36.7
-	-	-	-	75.5	24.5

As shown in Table 10, winegrowers supposed the maintenance of historical landscape elements in the future, but the percentages of answers were less defined than the previous question. Indeed, just over half of them (57.1%) supposed that the pergola vine-breeding technique (A) would be more likely than espaliers (B). About three-quarters of the respondents (75.5%) thought vineyards (1) would be more likely than olive groves (2) and woodlands (4), while 69.4% thought vineyards would be more likely than meadows (3). Just over half of the respondents (55.1%) supposed that olive groves would be more likely in the future than meadows, while 63.3% thought they would be more likely than woodlands. Finally, 75.5% of winegrowers supposed that meadows would be more likely in the future than woodlands.

4. Discussion

The first part of the research allowed us to understand the rural history of the case study area, where a terraced vineyard landscape appeared as the result of the coevolution between rural communities and natural resources. Indeed, according to Bonardi et al. [64], terraces were developed together with man since prehistory. The analysis of the Savoy family cadastral map showed the historical organization of land use, highlighting a mutual link between different types: vineyards and chestnut groves were functionally linked because the latter provided wooden poles to sustain the former.

We described the historical vine-breeding technique, finding its origin in Roman times. It appeared as a unique element in the world in which vine pergolas were supported by stone columns. These columns, in addition to having a double role of vine pergolas' support and temperature range reduction, strongly characterized the landscape.

Field surveys allowed us to observe the good state of conservation of the terraced system and verify the maintenance of many historical landscape elements. The importance of vines to rural communities over the centuries was evidenced by their representation in art and iconography dating back to different epochs. Similarly, Aimar et al. [65] highlighted the strategic role of studying historical sources in order to assess historical landscapes. The presence of ancient chestnut groves and olive trees was also observed.

Signs of the coevolution between terraced landscapes and rural communities were assessed. Indeed, some dynamics of change in terms of new vine-breeding techniques or land uses were observed. The former were introduced by winegrowers in order to reduce management effort and cost. In similar conditions (pergola vine-breeding technique in Aosta Valley), Mazzarino [66] estimated 1200–1300 h of work/ha per year. The espalier technique requires a lower investment in terms of time and allows much more mechanization of the agricultural process. The same can be said about the introduction of olive groves. In the Piedmont region, olives were introduced by the Etruscans and spread by the Romans, and the Christian tradition allowed many secular trees to be maintained in religious complexes [67]. In the case study area, the oldest olive trees were in the religious Romanic complex of Settimo Vittone municipality. Therefore, the recent development of olive groves is linked with the past and allows productive terraces to be maintained.

Sakellariou [68] highlighted the importance of recultivating terraced landscapes on the Aegean Island of Andros (Greece), taking into account future environmental and social challenges and preventing abandonment. In the case study area, other consequences of abandonment were mowed meadows and invasive shrubs and woodlands. The different states of

conservation, with vegetative sequences from shrubs to woodlands, are similar to other terraced landscapes at the international level threated by abandonment [69]. Figure 13 shows the different dynamics observed by experts (introduction of new vine-breeding techniques and new land uses) and their impact on the landscape. The dynamism of the landscapes that was assessed is in line with Tortora et al. [70], who analyzed rural landscape dynamics, understood as land use changes, based on historical maps. As evident in the figure, the dynamics observed in the case study area brought changes to the historical terraced landscape but, at the same time, allowed for abandonment to be prevented. For these reasons, in coevolutive terms, they can be accepted.

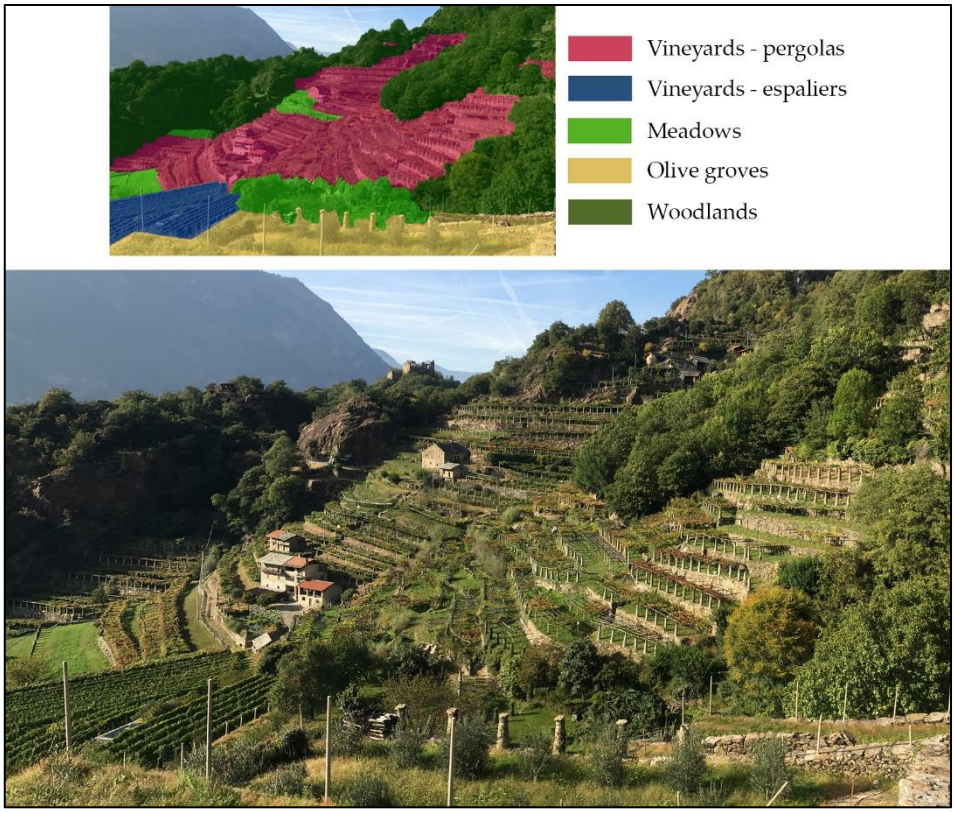

Figure 13. Presence of different dynamics: vineyards with historical vine-breeding technique (pergolas), vineyards with new breeding technique with new breeding technique (espaliers), olive groves, meadows, and invasive woodlands.

The second part of the research allowed us to evaluate the winegrowers' perceptions about the landscape's historical elements and dynamics. The respondents' characteristics were representative of the case study area reality, with a majority of old, nonprofessional winegrowers. Farms were characterized by small size and mainly involved few family members. The presence of the historical vine-breeding technique (*pergola caremiese*) and stone columns on most of the farms confirmed the permanence of the historical landscape elements observed during field inspections, with a still-limited presence of espaliers. The presence of multifunctional agriculture characterized by different land uses was also confirmed. The relevance of the case study in an international context was confirmed by the production of DOC wines sold both in Europe and in non-EU countries.

The main problems with managing terraced vineyards, according to the winegrowers, were related to their intrinsic issues in terms of management, accessibility, and mechanization. Management difficulties are among the causes of terrace abandonment and human exodus from the countryside. For example, the number of residents in Carema municipality decreased by 46.8% from 1921 to 2022 (elaboration of ISTAT data [43]). Petanidou et al. [71] observed a similar occurrence on terraced Nisyros Island (Greece), where the abandonment of cultivation was accompanied by a population reduction since the beginning of the last century.

The evaluation of winegrowers' perceptions also suggests that they perceive as identity elements the historical landscape elements mainly related to terraces and traditional agricultural practices, while the answers to yes/no questions showed that most of them do not consider espaliers and olive groves part of this identity. Winegrowers recognized that the landscape adds value to the wine produced there. It is very important to

transfer this awareness to consumers by emphasizing that the bottle contains not only wine but also the historical landscape in which it was produced. With this purpose, the important role of certifying the historical landscape's quality is recognized [72].

Some differences were observed in winegrowers' preferences and suppositions about future development prospects. Regarding vine-breeding techniques, the permanence of pergolas was both the preferred and supposed future scenario. However, 42.9% of winegrowers considered that pergolas would be less likely in the future than espaliers. The same trend could be observed for land use, with a preference for vineyards. Regarding other land uses, winegrowers preferred the ones that would allow them to maintain terraces' production and management: olive groves, and meadows. Olive groves may be preferred to meadows since they allow the production of olive oil for families and keep the terraces more productive. The least preference was for the scenario with total terrace abandonment (invasive woodlands), in accordance with Gao et al. [73]. They showed the risk awareness and perception of farmers of Honghe Hani rice terraces (China) regarding the hydrogeological risk of abandoning terraces. Regarding future prospects, the winegrowers thought the permanence of viticulture was the most likely and total terrace abandonment the least likely, but in a less convinced way. They are aware of issues that threaten terraces, but at the same time, they seem to be quite optimistic about their future enhancement. These results also agree with Santoro et al. [60], who reported that farmers in Cinque Terre recognized terraced vineyards as the most important land use.

5. Conclusions

This research proposes an innovative and integrated approach to evaluating the coevolution between terraced vineyard landscapes and rural communities. Terraces cannot be maintained without continuous management by man. In the context of historical rural landscapes, terraced landscapes are the most threatened by abandonment and invasive woodland, which increase the hydrogeological risk. Rural communities must manage terraced landscapes in order to reduce their vulnerability and preserve public health. At the same time, they need to cultivate terraces for production purposes and benefit from their high-quality products. The close mutual link between terraced landscapes and rural communities is demonstrated by their coevolution, in which each adapts to the needs of the other. For these reasons, terraced systems, like all rural landscapes, are dynamic systems that evolve with rural communities.

In the case study area, this dynamism is very clear, since the presence of historical landscape elements was mainly observed, but also the introduction of new vine-breeding techniques and land uses. More cartographic and quantitative studies about these dynamics are needed. Hara et al. [74] showed the importance of assessing landscape dynamics starting from the elaboration of past and present land use maps for the development of conservation measures. For these reasons, the research will be further developed in the future, focusing on land use mapping and dynamics assessment in quantitative terms.

The integrated approach including expert-based assessment and evaluation of winegrowers' perceptions allowed us to assess the historical landscape elements and dynamics and evaluate perceptions. Since almost all winegrowers prefer maintaining the historical vine-breeding technique and

land use (vine pergolas and vineyards), but not all consider them more likely to remain in the future, more enhancement actions are need. Future planning policies and resources will have to make maintaining historical landscape elements attractive for winegrowers by recognizing their added value. Greater efforts to continue traditional cultivation require higher remuneration.

In this context, including terraced vineyard landscapes in the National Register of Historical Rural Landscapes and the GIAHS-FAO program could be a strategic move. Indeed, such recognition of the landscape's value could bring its importance and uniqueness to a national and international level. New experiential tourism could be developed, and new consumer awareness about added value could be encouraged. Rediscovering locally produced food and reducing the gap between food producers and consumers could also encourage more sustainable consumption patterns and achievement of the second sustainable development goal (SDG) of the United Nations Agenda 2030 [75], aimed at ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture [76]. Finally, the action plan for the dynamic conservation of the landscape encouraged by GIAHS could support the coevolution between terraced landscapes and rural communities from the past into the future.

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Chapter IV

Assessment of the Terraced Landscapes' Integrity: A GIS-Based Approach in a Potential GIAHS-FAO Site (Northwest Piedmont, Italy)

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Abstract: The GIAHS-FAO program enhances the agricultural systems coevolved with humans through their dynamic conservation to guarantee the livelihood of future generations. The aim of this research was to assess, with a dynamic perspective, the terraced landscape's integrity in a potential GIAHS-FAO site (Northwest Piedmont, Italy, 545 ha) characterized by a pergola caremiese vine-breeding technique. We developed a GIS-based approach to explore the main features that can affect the landscape's integrity, starting from the changes of the land use. The aerial IGMI images (1954–1968) and the AGEA (2018) orthophoto were photo-interpreted using QGIS 3.16.2 "Hannover" (minimum mappable unit 100 m^2). The results showed that 70.16% of the historical landscape was preserved, while the surface of vineyards decreased because of their abandonment. We observed that vineyards are the land use that requires more attention in future planning strategies, and that the landscape's integrity is affected by the limited introduction of non-traditional vine-breeding techniques (espaliers) and new crops (olives groves). The methodology was able to assess the terraced landscape's integrity in a dynamic perspective. The good integrity makes the study area a potential GIAHS-FAO site. Future planning strategies will have to lead the changing processes and preserve the landscape's integrity.

Keywords: historical rural landscapes; land use; dynamics; landscape change; biocultural heritage; photointerpretation; diachronic analyses; mapping; monitoring.

1. Introduction

In Europe, many rural landscapes are characterized by high historical value as the result of the interaction between humans and nature in past conditions [1]. Agnoletti et al. [2] highlighted that these landscapes have an important role in preserving bio-cultural heritage. Indeed, the historical landscapes preserve traditional agricultural practices, which are the expression of ancient knowledge. However, they are affected by the introduction of more modern and mechanizable practices that change the landscape [3]. Patel et al. [4] reported that the traditional practices are more sustainable than modern ones and ensure a higher resilience of the agricultural system to climate change. In Italy during the COVID-19 pandemic, a lower incidence of COVID-19 cases in rural areas characterized by the presence of traditional agriculture was observed compared with plain areas characterized by intensive systems [5]. Furthermore, historical rural landscapes safeguard ancient cultivars that constitute an important reserve of biodiversity and represent a genetic heritage that should be preserved [6]. Bhaskar et al. highlighted that traditional agricultural landscapes in Western India are mosaics of natural features and agricultural land uses [7]. In slope conditions, many rural landscapes were made arable by humans through land terracing using dry-stone walls [8]. Terraced landscapes are anthropic landscapes characterized by multiple values, such as, for example, the reduction of the slopes' erosion, the provision of ecosystem services, and the storage of soil carbon [9]. However, they are nowadays threatened by the abandonment of traditional cultivations with the consequent uncontrolled re-vegetation of the terraces that causes the dry-stone walls to collapse and the hydrogeological risk to increase [10]. Gullino et al. [11] showed that different Italian terraced landscapes considered as world heritage sites are

affected by the deterioration of dry-stone walls and land fragmentation, with many problems of hydrogeological instability. For these reasons, many authors recommended the development of future planning strategies and policies for the conservation and enhancement of terraced landscapes [12–14].

At the national and international levels, some projects are aimed at enhancing historical rural landscapes through the recognition of their quality. The Italian Ministry of Agricultural, Food and Forestry Policies instituted, exactly ten years ago, the National Observatory of the Historical Rural Landscapes and the National Register of the Historical Rural Landscapes, Agricultural Practices, and Traditional Knowledges [15]. The necessity of their institution followed over half a century of agricultural intensification and the necessity to have an inventory of the Italian historical rural landscapes in order to facilitate their enhancement, to highlight their cultural values, and to increase the awareness of citizens [16]. To be admitted into the register, the proponents of a landscape must pass two steps: the presentation of a synthetic form with the main characteristics of the landscape proposed and—if positively evaluated by the National Observatory—the presentation of the extended application dossier. The importance of this recognition and the presence of numerous heterogeneous historical rural landscapes in Italy are demonstrated by the high number of sites that started the procedure (more than 120 demands in ten years). Nowadays, 27 have been inscribed in the register, though none of them are located in the Piedmont region [17]. Three parameters have to be assessed to propose a site for inscription to the register: the significance, the integrity, and the vulnerability [18]. The parameters of significance and vulnerability require qualitative analyses comprised of archival analyses, field inspections, and the involvement of rural communities with bottom–

up approaches. The evaluation of the parameter of the integrity needs a series of quantitative analyses through cartographic elaborations. To be admitted, at least the 50% of the historical rural landscape in the proposed area has to be preserved.

At the international level, the Globally Important Agricultural Heritage Systems (GIAHS) program of the Food and Agriculture Organization of the United Nations (FAO), since 2002, collects the agricultural heritage systems of the world in order to promote and to enhance them [19]. It is an important instrument for territorial development based on traditional agriculture [20]. Bixia et al. [21] highlighted its strategic role in attracting rural tourism, which contributes to territorial enhancement. To be admitted, a site has to satisfy five inscription criteria and present an action plan for the sustainability of the system. These criteria are as follows: 1. food and livelihood security, 2. agro-biodiversity, 3. local and traditional knowledge systems, 4. cultures, value systems, and social organizations, and 5. landscape and seascape features [22]. The FAO approach recognizes the landscape as not a static museum but as a dynamic agroforestry system, and the result of coevolution with humans [23]. Indeed, dynamic conservation is the strategic key point of the GIAHS program [24]. Concerning the fifth criterion, Jiao et al. [25] highlighted that the land use can be assumed as indicator for the ecological conservation of the agricultural landscapes. Fuller et al. [26] showed that the landscape of a GIAHS site is the result of the interaction between human and physical systems and that the study of the land-use changes is a challenge since they can have an impact on the entire system. The guidelines for a GIAHS proposal report the importance of the historic background and of the contemporary relevance of the sites without establishing a threshold of integrity as the National Register does.

However, they recommend assessing the integrity of the structure of the landscape through the creation of past and present land-use maps [27]. In Europe seven sites are inscribed to the GIAHS program, two of which are terraced landscapes of Italy already enrolled in the National Register [28]. Indeed, in Italy the GIAHS program and the National Register of the Historical Rural Landscapes are strictly connected since the sites proposed for the former are mainly selected among the sites inscribed in the second.

Figure 1 synthetizes the parameters and criteria to be assessed for the enrollment to the National Register of the Historical Rural Landscapes and to the GIAHS Program. It shows also the distribution of the already inscribed sites in Italy.

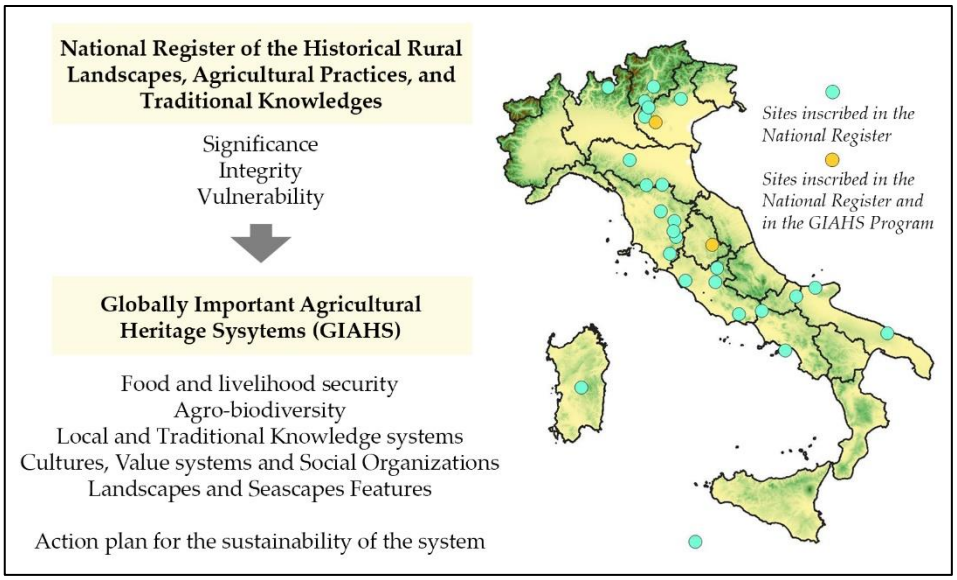

Figure 1. The parameters and criteria to be assessed for the enrollment to the National Register of the Historical Rural Landscapes and to the GIAHS Program, and the distribution of the already inscribed sites in Italy.

An important recognition of the landscape quality based on the parameter of the integrity is represented by the World Heritage List of the United Nations Organization for Education, Science, and Culture (UNESCO). In

Italy different sites inscribed in this are characterized by the presence of traditional agriculture supported by terraces [29]. Gullino et al. [30] highlighted that, since the integrity is the combination between the level of cultural value continuity and the level of natural value conservation, the historical analyses aimed at its definition have to consider the study of the land use. For doing that, the use of aerial images and orthophotos and their photointerpretation are recognized in the literature [31].

While the parameter of the integrity in UNESCO sites was explored by many authors [32], we observed a lack of studies about the assessment of the integrity of GIAHSFAO sites. Indeed, the concept of the integrity is assumed by UNESCO as the critical parameter to be maintained for the conservation of a world heritage site with a static approach [33]. Instead, as we discussed above, the purpose of the FAO program is the dynamic conservation of a GIAHS site. The attribute "dynamic" changes completely the approach for the conservation of the historical rural landscapes. Indeed, according to Wenjun et al. [34], a GIAHS-FAO site is a living agricultural system that maintains the historical features but it is also in continuum coevolution with the rural communities to which guarantees the continuous livelihood. The authors highlighted the need of the development of dynamic monitoring systems for the GIAHS conservation and management. Since the GIAHS sites are characterized by traditional agricultural practices and historical landscape's features, the assessment of the parameter of the integrity in a dynamic perspective is a challenge. In this context, the aim of the research was to assess with a dynamic perspective the terraced landscape's integrity in a potential GIAHS-FAO site characterized by the presence of terraced vineyards, located in Northwest Piedmont (Italy). We developed a GIS-based approach in order to explore the main features that can affect the

landscape's integrity starting from the changes of the land use occurred between the middle of the last century to nowadays. The methodology is internationally replicable in other sites characterized by terraced landscapes with high historical values, dynamically coevolved with the rural communities. In these contexts, the assessment of the landscapes' integrity is the first step to develop future planning strategies for their not static but dynamic conservation.

2. Materials and Methods

2.1. Study Area

Vine terraced landscape located in Northwest Piedmont (Italy) was selected for the methodology application (Figure 2a). It is currently in course of application to the National Register of the Historical Rural Landscapes. The first step was successfully passed, and the application dossier is nowadays in course of evaluation by the National Observatory. Pomatto et al. [35] showed that it is characterized by landscape's historical elements of world uniqueness and traditional agricultural practices. They highlighted the necessity of more studies about its landscape's dynamics in quantitative terms and change monitoring. Four municipalities are included in the study area: Borgofranco di Ivrea, Carema, Nomaglio and Settimo Vittone (Metropolitan City of Turin). One of them was included among the organizations actively involved in the safeguard of the "art of dry stone walling, knowledge, and techniques", which is included in the UNESCO's Representative List of Intangible Cultural Heritage of Humanity [36].

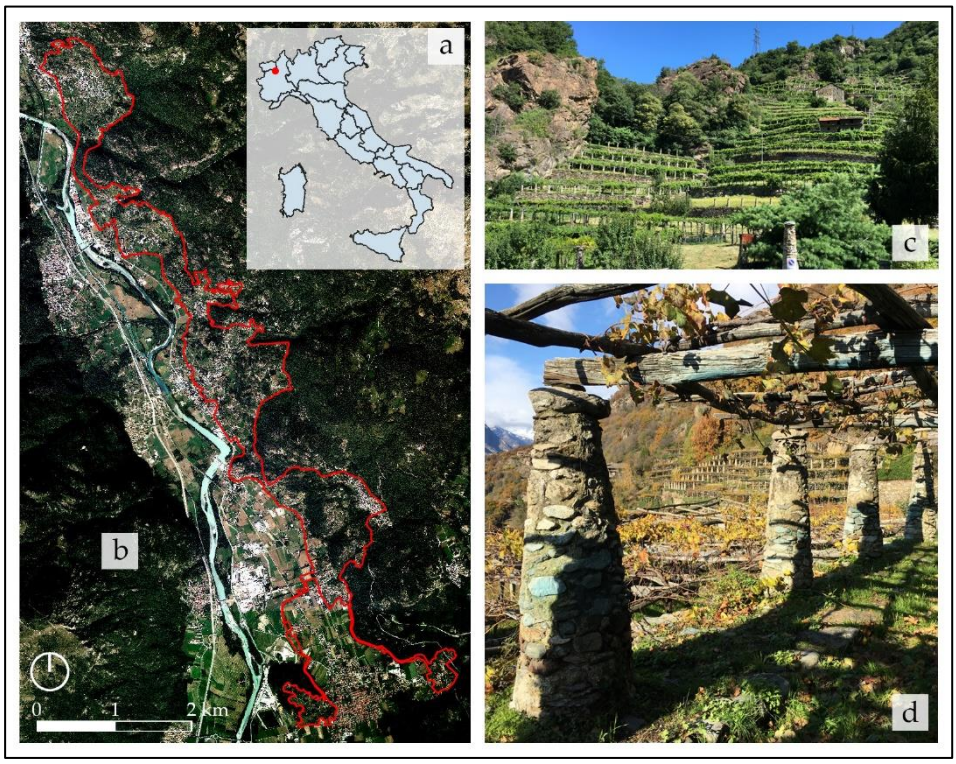

Figure 2. (**a**) The localization of the study area in the context of the Italian regions. (**b**) The boundaries of the study area. (**c**) The vine terraced landscape with the traditional vine-breeding technique that characterizes the study area. (**d**) Detail of the stone columns that support the pergola caremiese which is an important landmark of the unique historical landscape of the study area.

The study area (545 ha) was defined according to the parameters established by the National Observatory for the admission in the National Register: unitary and homogeneous area in which the historical landscape covers at least the 50% of the total surface, without modern urbanized areas historically not connected with the agricultural system (Figure 2b). The traditional vine-breeding technique is the pergola caremiese which is a high pergola made with chestnut poles and supported by stone columns (Figure 2c,d). These columns are a fundamental landmark of the landscape that bring it unique in the world. To them an important role in reducing the temperature range between day and night is recognized. For this reason

they are also known as “stove columns”. The main vine variety cultivated is the Nebbiolo. The quality of the wine produced is demonstrated by two Denomination of Controlled Origin, one of them is also a Slow Food Presidium.

2.2. Methodological Framework for the Assessment of the Integrity

Since the study of the land-use changes is the first step for the assessment of the integrity of a historical landscape in quantitative terms, we focused on the cartographical studies in the Geographic Information System using QGIS software, version 3.16.2, code name: “Hannover” (open access software of the Open Source Geospatial Foundation-OSGeo). The historical and cultural evaluation approach was assumed [37]. It considers the elaboration of past and present land-use maps in order to study the changes of the historical landscape and evaluate the strategies for its planning, management and conservation. Jaworek-Jakubska et al. [38] proposed a spatial-temporal analysis in order to assess the dynamics of the Polish traditional landscape, using aerial images and cartographical elaborations. Furthermore, the use of the photointerpretation for the assessment of the landscape’s dynamics and for the change monitoring is widely recognized by the scientific community [39–42].

In this context, in order to assess the integrity of the vineyard terraced landscape with a dynamic perspective, we acquired the historical aerial images and the most recent orthophotograph available covering the study area. We obtained through photointerpretation the historical land-use (HLU) map, the current land-use (CLU) map, and the maps of the stone elements characterizing the landscape. We assessed the dynamics of the landscape and we applied some landscape indicators. Finally, we identified

the land use that requires more attention in future planning strategies in order to maintain the landscape's integrity. Figure 3 shows the methodological framework for the assessment of the integrity with a dynamic perspective applied in the research.

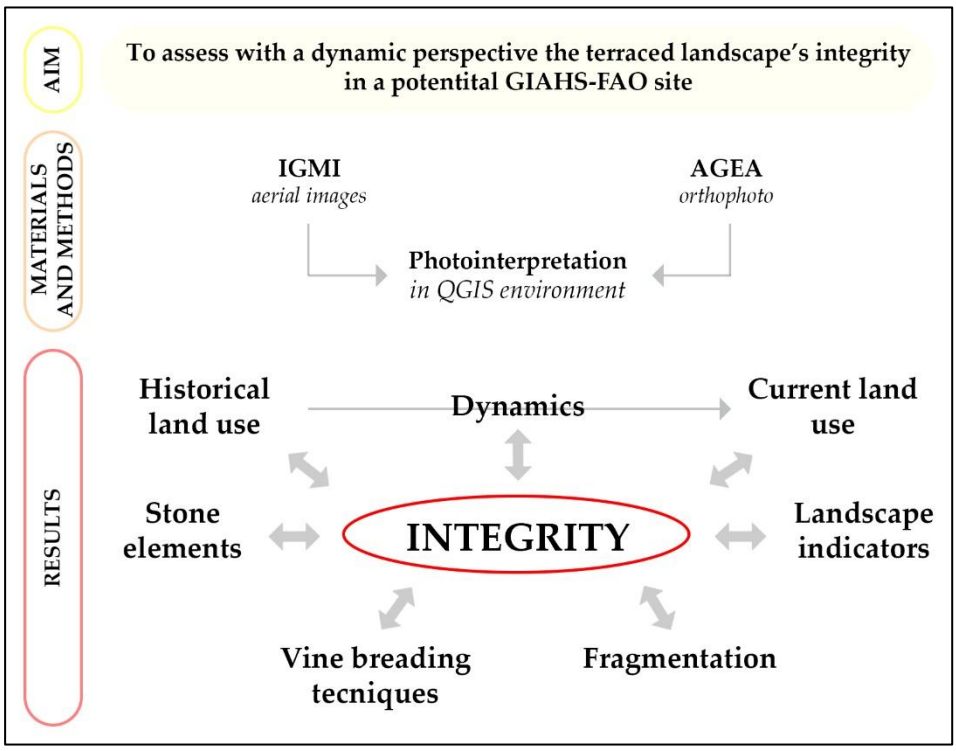

Figure 3. The methodological framework for the assessment of the integrity with a dynamic perspective applied in the research.

2.3. The Selection of the Sources and the Process of Photointerpretation

Regarding the historical land-use map, we assumed the middle of the last century as reference period to define as historic the land use. Indeed, in literature is well established that the abandonment of terraced landscapes and the process of dry-stone walls damage started at the end of the 1800s and accelerated after the 1950s [43]. For this reason, also the National Register of the Historical Rural Landscapes' approach requires the

evaluation of the dynamics occurred from the middle of the last century to nowadays. The Italian law recognizes as historical a vineyard dating back to before the 1960 and cultivated with the traditional practices [44].

In Italy the only available aerial images of that period were acquired by the Italian Military Geographical Institute (IGMI) [45]. Unfortunately, only one aerial image covering all of the study area was available. It was referred to 1954 but with a very low resolution (acquired at quote 10,000 m and scale 1:50,000) and unusable for the photointerpretation. An aerial image referred to 1954 characterized by higher resolution (acquired at quote 5000 m and scale 1:29,000) was present only for the southern part of the study area. For the northern was available the IGMI's aerial image referred to 1968 (acquired at quote 4900 m and scale 1:25,000). Instead, a small central part of the study area was not covered by any historical aerial image. For these reasons, we used for the elaboration of the historical land-use map the aerial image IGMI 1954 more defined covering the southern part of the study area, and the aerial image IGMI 1968 covering the northern. The elaboration of the HLU map (referred to the 1954 to the southern part of the study area and to the 1968 for the northern) allowed us to obtain the land use of the middle of the last century.

Regarding the current land-use map, we used the most recent orthophoto available. It was the orthophoto of the Italian Agricultural Payments Agency (AGEA) referred to 2018 (medium resolution 30 x 30 cm^2). We obtained it through the cartographic geoportal of the Piedmont Region [46]. In this case it was possible to produce the map covering all of the study area. The elaboration of the CLU map (referred to the 2018) allowed us to obtain the land use characterizing nowadays the landscape.

We georeferenced the white/black historical aerial images, while the colored orthophoto of the AGEA was already georeferenced. Figure 4 schematizes the sources used for the elaboration of the historical and current land-use maps in function of the availability of photo-interpretable historical aerial images and current orthophotos. The production of the HLU map and of the CLU map was the first step of the research, all of the following analyses in which there is a comparison from the middle of the last century to nowadays are based on them.

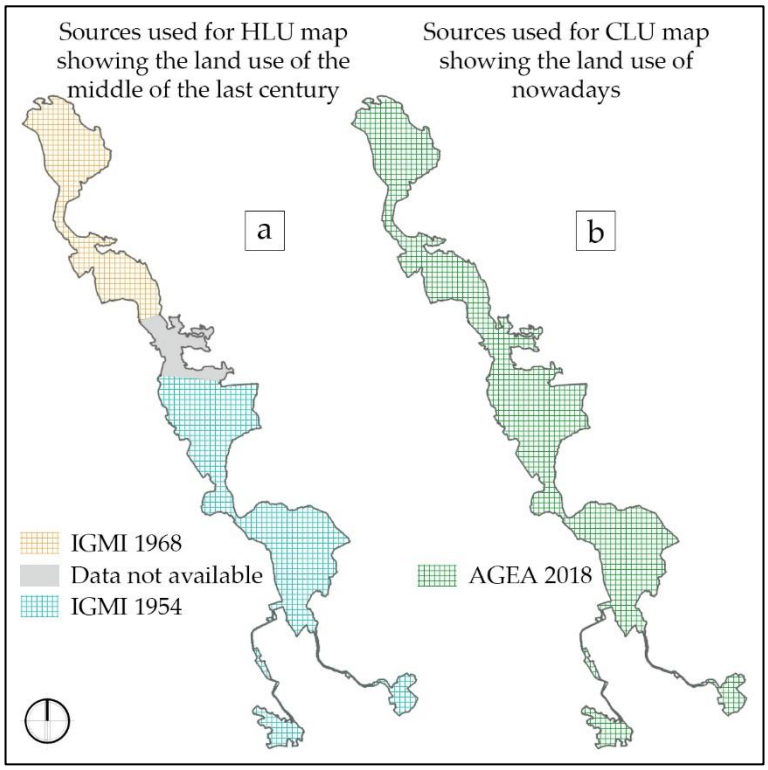

Figure 4. (**a**) The aerial images of the Italian Military Geographical Institute (IGMI) referred to the 1968 for the northern part of the study area and referred to the 1954 for the southern used for the elaboration of the historical land-use map showing the land use of the middle of the last century. (**b**) The orthophoto of the Italian Agricultural Payments Agency (AGEA) referred to the 2018 and covering all the surface of the study area used for the elaboration of the current land-use map showing the land use of nowadays.

According to Rizzo et al. [47], before starting the photointerpretation we proceeded with a general observation of the structure of the different elements of the landscape's mosaic and their arrangement in the space, and we defined the land use classes to consider. For doing that several studies proposed to use the classification of the Corinne Land Cover [48–51]. We decided to classify the land use adopting a higher level of detail for the agricultural classes then the others classes (e.g., urbanized areas). Table 1 reports the classes of the land use identified for the photointerpretation and their description.

Table 1. Classes of the land use identified for the photointerpretation.

Land uses	Description
Vineyards	Vineyards distinguished for the different vine breeding techniques identified: pergolas (historical) and espaliers (non-historical).
Olive groves	Olive groves characterized by trees planted with a regular scheme.
Arable crops	Cereals.
Woody arboriculture	Poplars groves used for wood.
Meadows	Meadows in which grass is mowed and harvest fresh or dry.
Meadows with trees	Meadows with the presence of trees scattered or in small groups.
Chestnut groves	Chestnut trees, often secular, planted with a regular scheme. Historically they were used for the harvest of fruits and for grazing the animals.
Vegetable gardens and orchards	Vegetable gardens and orchards dedicated to self-consumption.
Woodlands	Lands covered by arboreous vegetation as defined by Piedmont Region's forest law: minimum surface 2000 m^2, minimum width 20 m, minimum covered surface 20% [52]. Chestnut trees are the most represented.
Shrublands	Arboreous or shrubby vegetation usually as consequence of the abandonment processes in recent times. They cannot be included in woodlands because they do not respond to the Piedmont Region law's parameters.

Table 1. *Cont.*

Land uses	Description
Conifers	Conifers planted with a regular scheme after the vineyards' abandonment and reforestation by humans.
Rocks	Outcropping rocks typical of the geomorphology of the site where the study area is located.
Water bodies	Main streams that run down to the mountain, cross the terraced landscape, and reach the Dora Baltea.
Riparian vegetation	Riparian vegetation typical of the water bodies' borders.
Urbanized areas	Urban agglomerations: continuous or scattered built-up areas and residential green.
Roads	Main driveway roads that connect inhabited centers.

During the photointerpretation we decided to adopt a high level of detail, fixing to 100 m^2 the minimum mappable unit and to 1:1500 the scale of acquisition of the HLU and CLU maps. We digitalized all the features of the historical and the current land-use maps making sure that there were no contiguous patches characterized by the same land use. We divided the vineyards characterized by the persistence of traditional pergolas and the vineyards characterized by non-traditional vine-breeding techniques (espalier).

Completing the process of photointerpretation, we also digitalized the stone elements that characterize the landscape: the dry-stone walls and the stone columns historically used for the support of the vine pergolas. It was possible to identify them only in relation to the AGEA orthophoto because of the lack of quality of the IGMI aerial images. We digitalized the dry-stone walls not covered by woodlands. The stone columns identified were those who lost their role of supporting pergolas in the abandoned lands not yet covered by woodlands. We fixed the scale of acquisition of the maps of the stone elements to 1:500.

2.4. The Analyses of the Dynamics of Landscape Change

According to the historical and cultural evaluation approach, we identified the dynamics occurring from the middle of the last century to nowadays through the overlapping of the historical and current land-use maps [53]. The process of overlay on QGIS allowed us to obtain a new layer with a new database in which all of the features were characterized by an HLU and a CLU. We created a new field in which for each feature we reported the dynamic of change. Table 2 reports the description of the dynamics occurring from the middle of the last century to nowadays.

Table 2. Dynamics occurring from HLU to CLU.

Dynamics	Description
Unchanged	This is the dynamic indicating that, nowadays, the main typology of land use is the same as that of the past. The transitions from one land use to another belonging to the same macro-category (e.g., meadows and meadows with trees) were included in this dynamic.
Intensification	This is the transition from land uses characterized by lower energy consumption to land uses that require more energy consumption (in terms of work, mechanization, and supply of fertilizers and pesticides).
Extensification	This is the opposite process to that of intensification, mainly a consequence of the abandonment of the cultivations.
Forestation	Forestation consists of the recolonization of shrublands and trees in lands once cultivated. It is strictly related to the total abandonment of the cultivations and of any kind of land management.
Conifer reforestation	This is related to reforestation by man with conifer trees.
Deforestation	Deforestation is related to the loss of woodlands in favor of agricultural lands.
Urbanization	This is related to the expansion of urbanized areas on lands once dedicated to agriculture or woodlands.

In order to assess the landscape's integrity, we analyzed the surface of the study area in which the historical landscape was preserved. For doing that

we selected all of the features of the new layer obtained for which HLU = CLU and we calculated the percentage of historical land use preserved. We used the selected features to thematize a map.

2.5. The Application of Landscape Indicators

In the last part of the research we applied some landscape indicators and calculated them through the analyses of the features of the two land-use maps produced. Indeed, the analysis of the landscape's integrity also has to consider its fragmentation [54]. The scientific community recognizes that the number and the structure of the patches can be evaluated as spatial-temporal metrics [55–57]. For these reasons we calculated the variation of the number and average areas of the patches and the variation of the medium agricultural surface from the middle of the last century to nowadays. We also calculated the variation of the number of the land uses. According to Tang et al. [58], we calculated the Edge Density (ED), since it is an indicator of the fragmentation of the landscape through the segmentation of the edge of the patches that compose it. We calculated it using the following formula:

$$ED = p_i/a_i \quad (1)$$

where p*i* is the total perimeter of the *i* land use class expressed in m, and a*i* is the total area of the *i* land use class expressed in ha.

Finally, we identified the land use that requires more attention in the future planning strategies in order to maintain the integrity of the landscape. For this purpose, we calculated the historical index (HI) for each class of historical land use nowadays preserved [53]. Then, we used it to thematize a map, reporting only the features in which the land use was not changed

from the HLU to the CLU. We calculated the HI using the following formula:

$$HI = Hp\ (Hgd/Pgd) \quad (2)$$

where:

- Hp is the historical persistence of the land use class, that is, the ratio between the observed number of years of its existence and the number of years of the temporal scale considered. The value of Hp varies from 0 to 1. Since in our case the comparison was made up considering two periods—(1) the middle of the last century (HLU referred to the 1954 for the southern part of the study area and to the 1968 for the northern), and (2) nowadays (CLU referred to 2018)—the number of observed existence years and the number of years considered are the same. For this reason, its value is 1.
- Hgd is the historical geographical distribution of the land use class, that is, its extension expressed in ha in relation to HLU.
- Pgd is the present geographical distribution of the land use class, that is, its extension expressed in ha in relation to CLU.

In other words, for each land-use class, we calculated the HI as the ratio between its surface of the HLU (ha) and its surface of the CLU (ha).

3. Results

All of the results of the GIS-based approach, which was developed to assess the terraced landscape's integrity with a dynamic perspective in a potential GIAHS-FAO site characterized by the presence of terraced vineyards, are reported below in the form of maps, graphs, and tables.

3.1. The Land Use and the Stone Elements

The first part of the research allowed us to reconstruct through photointerpretation the land use that characterized the study area during the middle of the last century (HLU referred to the 1954 for the southern part of the study area and to the 1968 for the northern) and nowadays (CLU referred to 2018). Figure 5 shows the historical land-use map and the current land-use map obtained. Their comparison suggests that in the vineyard terraced landscape of the study area some changes occurred during the considered time period and in general that the total surface of the vineyards decreased while the area of the woodlands increased.

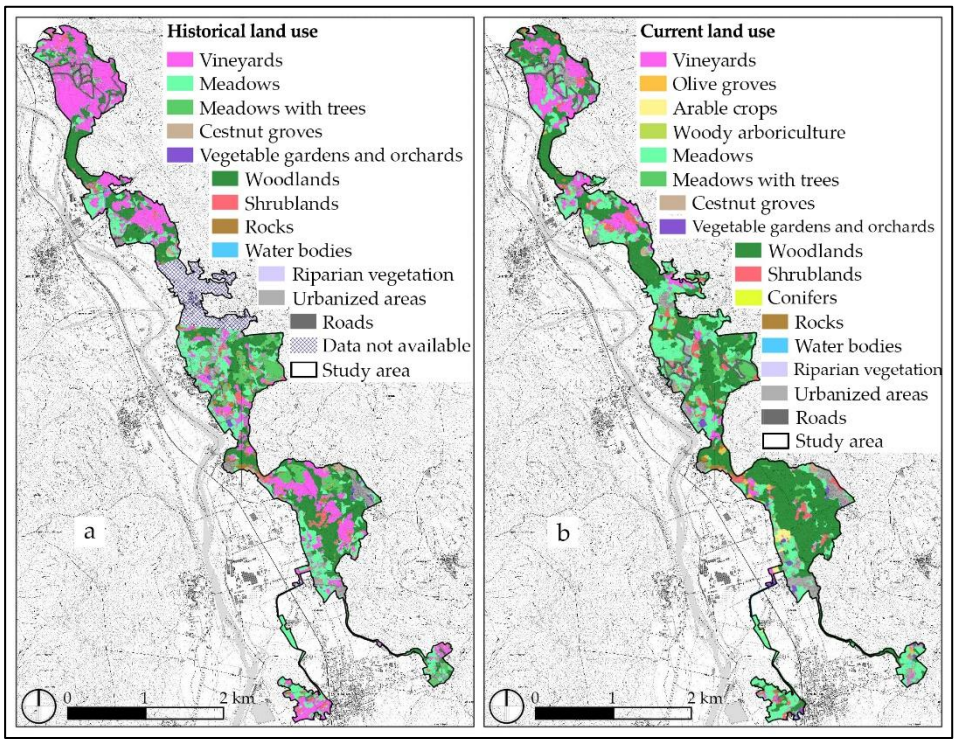

Figure 5. Land-use maps obtained through photointerpretation: (**a**) historical land-use map (HLU); (**b**) current land-use map (CLU).

Indeed, as reported in Table 3, in the area in which the photointerpretation of HLU was possible, the historical vineyards represented the most

extended land use (146.6 ha) and all of them were characterized by the traditional vine-breeding technique. They were followed by woodlands (138.5 ha), meadows (92.77 ha), and meadows with trees (31 ha). Urbanized areas occupied 46.2 ha. Some signs of the abandonment processes were also present but contained since shrublands covered only 12.03 ha. The other land uses were less represented.

Table 3. Areas and percentages of the study area covered by the different historical land use (HLU) and current land use (CLU).

Land uses	Areas HLU (ha)	Percentages HLU (%)	Areas CLU [1] (ha)	Percentages CLU [1] (%)	Areas CLU [2] (ha)	Percentages CLU [2] (%)
Vineyards	146.6	29.53	69.55	14.01	75.77	13.91
Olive groves	0	0	7.45	1.5	7.94	1.46
Arable crops	0	0	5.04	1.02	5.04	0.93
Woody arboriculture	0	0	0.25	0.05	0.25	0.05
Meadows	92.77	18.69	109.92	22.14	123.03	22.58
Meadows with trees	31	6.28	18.14	3.65	20.62	3.79
Chestnut groves	3.24	0.65	3.24	0.65	3.24	0.06
Vegetable gardens and orchards	3.08	0.62	5.52	1.11	5.75	1.05
Woodlands	138.5	27.9	166.23	33.49	182.92	33.58
Shrublands	12.03	2.42	20.41	4.11	22.25	4.08
Conifers	0	0	0.16	0.03	0.16	0.03
Rocks	14.93	3.01	14.93	3.01	17.54	3.22
Water bodies	2.55	0.51	2.54	0.51	2.8	0.51
Riparian vegetation	0.72	0.15	0.72	0.15	0.72	0.13
Urbanized areas	46.2	9.3	64.7	13.03	68.88	12.64
Roads	4.69	0.94	7.64	1.54	7.87	1.44
Total	496	100	496	100	544.78	100

[1] Referred to the area in which the comparison with HLU was possible. [2] Referred to the total area of study area.

In recent times, considering the area in which the comparison with HLU was possible, the surface of vineyards decreased to 69.55 ha, while that of the woodlands increased (166.23 ha). Additionally, the area of the

meadows increased (109.92 ha), while meadows with trees are nowadays less extended than in the past (18.14 ha). Strictly connected with the abandonment processes, the area of shrublands also increased (20.41 ha). During the considered period, we did not verify a great urban expansion, and the surface of urbanized areas covers nowadays 64.7 ha. Some new land uses were observed. The most extended was represented by the olive groves (7.45 ha) followed by the arable crops (5.04 ha). Woody arboriculture and conifers were introduced in only one field each, covering 0.25 ha and 0.16 ha, respectively. The area of chestnut groves was unchanged (3.24 ha).

Considering the total study area, nowadays woodlands represent the first land use for extension (182.92 ha), followed by meadows (123.03 ha) and vineyards (75.77 ha). Even though the vineyards' areas decreased by about half, they remain the main arboreous crop that characterizes the terraced landscape of the study area. Shrublands cover 22.25 ha. The total surface covered by olive groves is 7.94 ha. Urbanized areas account for 68.88 ha. Regarding the vine-breeding technique, the persistence of the traditional pergolas account for the 94.7% of the vineyard surface; however, in the 5.3% of the total current vineyard surface the introduction of the espalier vine-breeding technique, which has no historical values, was observed.

Regarding the stone elements, we identified 98.34 km of dry-stone walls not covered by woodlands. At the same time, we identified 6138 stone columns once used for the support of the vine pergolas on lands not yet covered by woodlands. Figure 6 shows the maps of the stone elements obtained through photointerpretation in 2018.

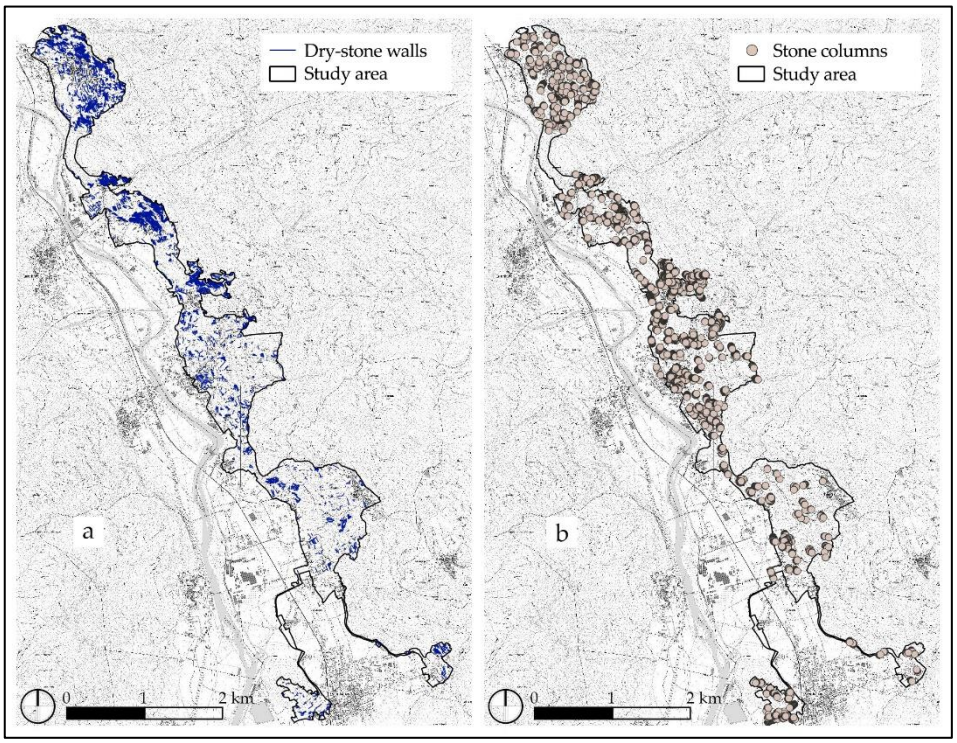

Figure 6. Maps of the stone elements in 2018: (**a**) dry-stone walls not covered by woodlands; (**b**) stone columns once used for the support of the vine pergolas on lands not yet covered by woodlands.

3.2. The Dynamics of Landscape Change

The process of overlapping of the historical land-use map and the current land-use map allowed us to analyze the dynamics occurring from the middle of the last century to nowadays (from 1954 for the southern part of the study area and 1968 for the northern to 2018, Figure 4). Figure 7 reports the cross tabulation that allows to understand all of the transformations for each land-use class. We found that the 146.6 hectares of the historical vineyards were unchanged for 67.34 ha, while the others evolved principally in meadows (33.98 ha), woodlands (21.23 ha), and shrublands (10.92 ha). Of the vineyards, 5.78 ha changed into olive groves. This new land use appeared almost exclusively in place of vineyards. Additionally,

the only field currently occupied by conifers (0.16 ha) historically was dedicated to viticulture. Meadows were unchanged for 62.92 ha. The difference evolved mainly in urbanized areas (8.81 ha), woodlands (7.69 ha), arable crops (4.18), and shrublands (2.67 ha). Only about the half of the historical meadows with trees remained unchanged (15.34 ha), while 8.53 ha evolved in woodlands and 4.01 ha evolved in meadows. Most of the woodlands did not undergo transformations (122.59 ha); only 8.47 ha evolved in meadows and 4.24 ha in urbanized areas. Most of the shrublands evolved in woodlands (6.19 ha), while 4.99 ha remained shrublands. The other land uses did not undergo relevant changes.

		CURRENT LAND USE (ha)																
		Vineyards	Olive groves	Arable crops	Woody arboriculture	Meadows	Meadows with trees	Chestnut groves	Vegetable gardens and orchards	Woodlands	Shrublands	Conifers	Rocks	Water bodies	Riparian vegetation	Urbanized areas	Roads	TOTAL HLU
HISTORICAL LAND USE (ha)	Vineyards	67.34	5.78	0.86	0.19	33.98	0.86		1.35	21.23	10.92	0.16				3.60	0.35	146.6
	Meadows	1.69	1.26	4.18	0.07	62.92	1.76		0.92	7.69	2.67					8.81	0.80	92.77
	Meadows with trees	0.48	0.04			4.01	15.34		0.03	8.53	0.67					1.68	0.36	31
	Chestnut groves							3.24										3.24
	Vegetable gardens and orchards								2.90							0.19		3.08
	Woodlands	0.04	0.38			8.47	0.18		0.32	122.59	1.16					4.24	1.12	138.5
	Shrublands					0.54				6.19	4.99					0.24	0.07	12.03
	Rocks												14.93					14.93
	Water bodies													2.54			0.01	2.55
	Riparian vegetation														0.72			0.72
	Urbanized areas															45.93	0.24	46.2
	Roads																4.69	4.69
	TOTAL CLU	69.55	7.45	5.04	0.25	109.92	18.14	3.24	5.52	166.23	20.41	0.16	14.93	2.54	0.72	64.7	7.64	**496**

Figure 7. Cross tabulation that shows the transformations occurring from the middle of the last century to nowadays (from 1954 for the southern part of the study area and 1968 for the northern to 2018, Figure 4). The colors of the cells are linked with the dynamics reported in the following figure.

All of these transformations generated some dynamics shown in Figure 8a. The principal of these is the unchanged areas which covered 74.82% of the study area. As we explained above, this dynamic also includes the transition from one land use to another belonging to the same macro-category (e.g., meadows and meadows with trees). Forestation is the second dynamic for extension (10.42%), followed by extensification

(8.49%). As reported by cross-tabulation, both of them were mainly related to the abandonment of vineyards. The other dynamics were less represented: urbanization (4.32%), intensification (1.92%), deforestation (2%), and conifer reforestation (0.03%).

The map reported in Figure 8b shows the historical landscape preserved, for which HLU = CLU. The 70.16% of the study area in which the comparison with HLU was possible is nowadays characterized by the same land use of the 1950s. This indicates a high level of historical landscape preserved.

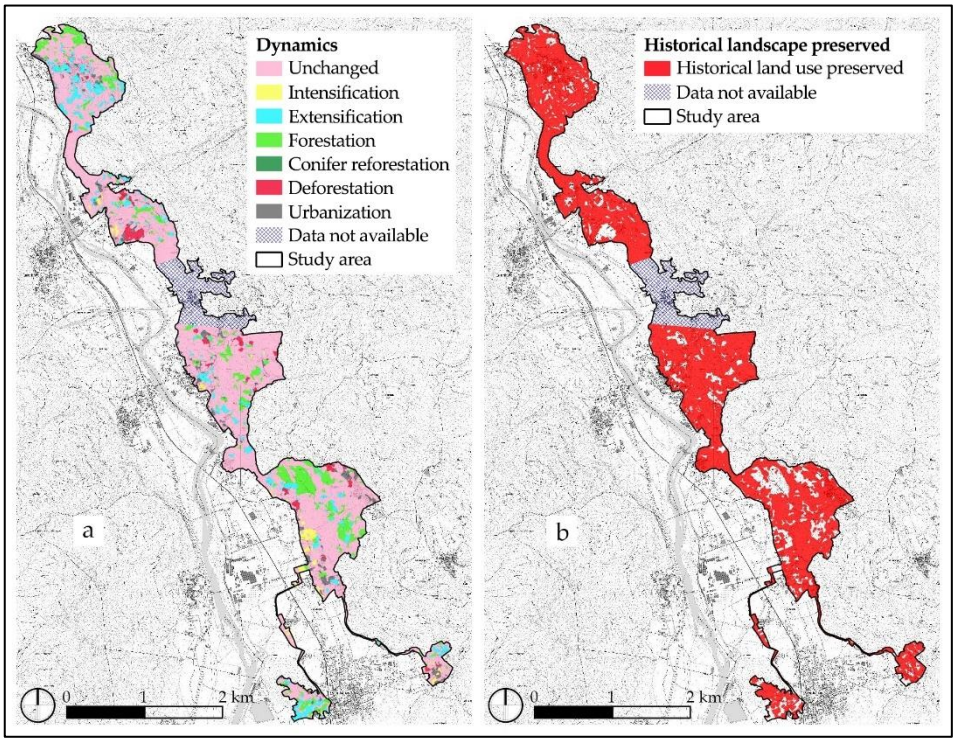

Figure 8. (**a**) Map of the dynamics occurring from the middle of the last century to nowadays (from 1954 for the southern part of the study area and 1968 for the northern to 2018, Figure 4); (**b**) map of the historical landscape preserved.

3.3. The Landscape Indicators

The elaboration process of the HLU and CLU maps allowed us to observe a criticality that affected the study area in recent times: the land fragmentation. Particularly, referring to the area in which the comparison with HLU was possible, the number of patches increased from 1187 to 1848 and their average areas decreased from 0.42 ha to 0.27 ha. The medium agricultural surface decreased from 0.56 ha to 0.23 ha. Instead, the number of land uses increased from 12 to 16.

The fragmentation of the landscape mosaic also emerged from the edge density calculation. As shown in Table 4, at landscape level it increased from 781 m/ha to 997 m/ha. Vineyards represent the land-use class for which the ED increased more (from 603 m/ha to 1207 m/ha). Instead, for woodlands the ED decreased from 540 m/ha to 506 m/ha. These data confirmed the observed dynamics. Indeed, the forestation consequent to the abandonment processes rendered patches of woodlands bigger and homogeneous at the expense of the patches of vineyards, which are presently smaller and more fragmented than in the past.

Table 4. The edge density for each land-use class and at the landscape level from the middle of the last century to nowadays (from 1954 for the southern part of the study area and 1968 for the northern to 2018, Figure 4).

Land Uses	HLU (m/ha)	CLU [1] (m/ha)
Vineyards	603	1207
Olive groves	-	1302
Arable crops	-	756
Woody arboriculture	-	874
Meadows	857	1110
Meadows with trees	596	798
Chestnut groves	623	623
Vegetable gardens and orchards	1300	1522
Woodlands	540	506
Shrublands	1214	1569

Table 4. *Cont.*

Land Uses	HLU (m/ha)	CLU [1] (m/ha)
Conifers	-	1228
Rocks	1540	1540
Water bodies	2948	2962
Riparian vegetation	2627	2627
Urbanized areas	1167	1087
Roads	4191	4130
Landscape	781	997

[1] Referred to the area in which the comparison with HLU was possible.

The map and the graph of the historical index shown in Figure 9 categorize the historical land uses preserved for their risk of disappearance. Vineyards presented the highest historical index (2.11). Indeed, as seen above, it was the land use for which the surface decreased most during the time period considered. Meadows with trees constituted the second land use for the HI (1.72). Some land uses—water bodies, chestnut groves, rocks, and riparian vegetation—were not characterized by any area variations (HI = 1). The other land uses showed historical indexes <1 since they increased their areas from the middle of the last century to nowadays (from 1954 for the southern part of the study area and 1968 for the northern to 2018). Indeed, their increase is mainly due to the dynamics of forestation and urbanization.

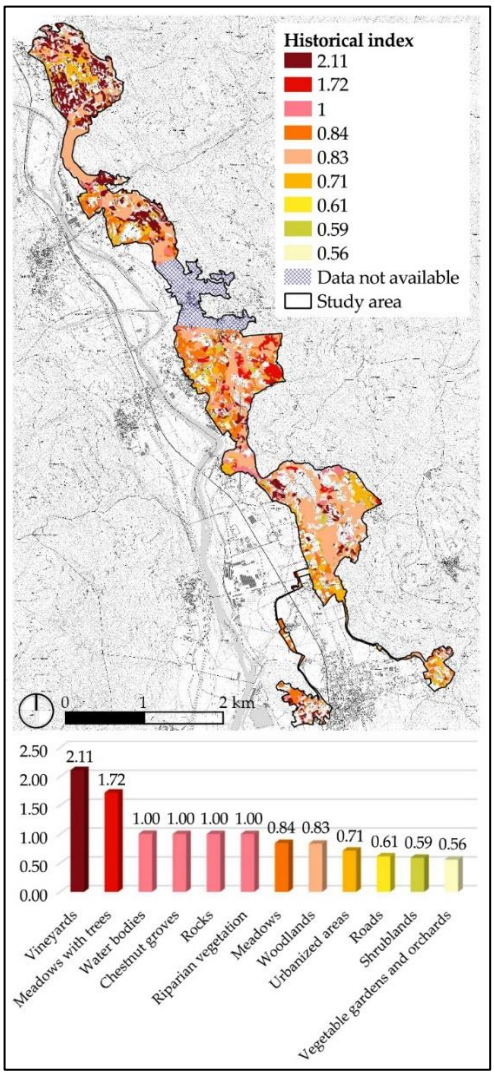

Figure 9. Map and graph of the historical index.

4. Discussions

The assessment of the terraced landscape's integrity in a dynamic perspective requires us to carry out multidimensional analysis, starting with diachronic analyses. The dynamics of the landscape must be analyzed and comprised without adopting a static, conservative approach. Indeed, as we explained above, the GIAHS-FAO approach recognizes the coevolution between humans and rural landscapes as the starting point for

the livelihood of the former and the dynamic conservation of the latter. Since the landscape and seascape features constitute one of the criteria for a GIAHS proposal, the identification of the permanence of the stone elements in a terraced landscape is critical to assess its integrity. Additionally, the fragmentation of the landscape could affect its integrity because it exposes it to further abandonment processes. For these reasons, we analyzed the different elements able to influence the landscape's integrity in a unique vineyard terraced landscape.

The first phase of our research was the photointerpretation of the IGMI aerial images and of the AGEA orthophoto. It allowed us to obtain a historical land-use map and a current land-use map with a high level of detail. The former showed that in the middle of the last century (1954 for the southern part of the study area and 1968 for the northern), vineyards were the first land-use class for extension, while the latter highlighted that, nowadays (2018), woodlands are the land use most represented in absolute values. However, vineyards remain the most extended arboreous crop. These data are consistent with other studies, which highlighted at the international level a reduction of the cultivated terraces consequent of the abandonment processes, occurred from the second half of the 1900s. For example, the areas of terraced vineyards in Costa Viola (Italy) showed a dramatic decrease (-88.79%) from 1955 to 2014 caused by the abandonment of the agriculture with the consequent forestation of the terraces [59]. Poyatos et al. [60] observed that during the second half of the 1900s (1957–1996), in the catchment of Cal Rodò (Catalonia, Spain), the surface of the cultivated terraced landscape decreased, while that of the spontaneous woodlands increased (+24%).

According to the literature cited above, the study of the historical and of the current land uses was the first step that allowed us to assess the integrity with a dynamic perspective of the terraced landscape of the study area. The process of overlapping of the two produced maps highlighted the dynamics occurring during the considered time period. Through cross-tabulation, we determined all of the changes of the land use. Kizos et al. [61] reported different situations consequent of the abandonment of the terraced traditional cultivations in Lesvos (Greece), mainly related to the total abandonment of fields, with the invasion of shrubs and woodlands, and with the change of cultivations. We also observed an intermedium situation with the loss of the historical cultivation but the continuous management of the terraces. Indeed, our research showed that the main part of the 79.26 ha of terraced vineyards lost evolved with the dynamic of extensification in meadows (42.9%), which are continuously mowed and managed (Figure 10a). The main changes that follow—forestation by woodlands (26.8%) and shrublands (13.8%)—are the most dangerous because they consist of the total abandonment of the terraced system, less or more recently, respectively (Figure 10b). Indeed, the total lack of management of the terraces causes several problems of hydrogeological risk [62]. The introduction of new cultivations (e.g., the olive groves shown in Figure 10c) were less extended (7.3%) and related to the dynamic of extensification. As cited above, we observed other dynamics (e.g., conifer reforestation) that are very underrepresented, but that concur with the landscape's integrity loss (Figure 10d). Indeed, all of these dynamics change the landscape and threaten its integrity. However, in the study area, we observed that the dynamics of change represented only 25.18% of the area. A similar trend was observed by De Pasquale et al. [63] in the terraced landscape of Vallecorsa (Lazio, Italy), which is inscribed in the

National Register of the Historical Rural Landscapes. Indeed, they reported that from 1954 to 2012 the historical landscape was unchanged for the 71% of the considered area, and that the other dynamics were less represented and mainly related to the abandonment of the traditional cultivations.

Figure 10. The loss of the landscape's integrity consequent of the abandonment of the vineyards and the dynamics of the land-use change: (**a**) meadows continuously mowed and managed (extensification), (**b**) woodlands and shrublands suffering from the total abandonment of the terraced system (forestation), (**c**) introduction of olive groves (extensification), and (**d**) conifer reforestation. In all of these cases, the stone columns once used for the support of the pergola caremiese lost their function but remained as historical landmarks of the landscape.

The results suggested that the historical landscape mosaic is well recognizable in the study area, since the 70.16% of the historical landscape of the middle of the last century is nowadays preserved (HLU = CLU). Agnoletti et al. [64] identified six classes of integrity according to the

percentage of historical land use preserved: I (0–19%), II (20–34%), III (35–49%), IV (50–64%), V (65–79%), and VI (80–100%). The first class indicates that the historical landscape has almost disappeared, while the sixth class indicates a very high permanence of the historical landscape. The belonging of the landscape to the fifth class of the integrity satisfies the parameters to justify its admittance in the National Register (at least the 50% of the historical landscape preserved). It also makes the landscape a potential GIAHS-FAO site because it indicates that the traditional agroforestry system is well preserved and able to guarantee the livelihood of the rural community.

In our research, we further explored the parameter of integrity. Indeed, in addition to the study of the landscape changes, the scientific community recognizes the importance of analyzing the structure and the main features of the landscape in order to assess its integrity [65]. It is also a key point of the GIAHS program as, as we discussed above, the five criteria to be assessed include the analysis of the landscape and seascape features. We identified the stone elements characterizing the landscape that were possible to identify trough photointerpretation: the dry-stone walls and the stone columns once used for the support of the vine pergolas. Obviously, it was possible to identify them only in the terraced surfaces not covered by woodlands, but their quantification allowed us to understand their importance as features of the historical landscape. So, the estimation of 98.34 km of drystone walls is an underestimation because many terraces where the abandonment caused the spontaneous colonization of woodlands cannot be found through photointerpretation. However, the data show the extension of the dry-stone walls that are nowadays managed as in the past and that concur with the maintenance of the landscape's integrity. This result allowed also to increase the knowledge about the

Italian extension of the dry-stone walls, for which the literature is lacking [66]. Similarly, we identified the stone columns that lost their role of support of the vine's pergolas (Figure 10), because the others are covered by pergolas and are not photo-interpretable. Furthermore, we identified those located in meadows consequent of the extensification, while woodlands consequent of the forestation cover them. We identified 6138 stone columns. It is an underestimation that, however, allowed us to understand their enormous and uncountable presence in the study area. These stone columns are a very important heritage, and unique in the world. However, the high number of stone columns which lost their role negatively affects the parameter of integrity because it indicates the historical presence of vine pergolas that have nowadays disappeared. Nowadays, these columns are recognizable and in a good state of conservation but if future planning policies do not support the restoration of the historical pergolas they are in danger of disappearing, and will either be invaded by woodlands or destroyed. Unfortunately, the poor quality of the IGMI's aerial images did not allowed us to make a comparison between the two considered time periods regarding the stone elements, and their impact on the landscape's integrity was based on their current state of conservation analyzable by photointerpretation.

Instead, diachronic analysis was possible for the vine-breeding technique that showed a very high integrity. Indeed, we observed that the traditional pergola caremiese vine breeding technique during the middle of the last century was the only vine-breeding technique used in the study area. Nowadays, we observed the introduction of a new vine-breeding technique: the espalier. Its presence is limited to a little-extended area (only the 5.3% of the total area of vineyards) in the lower part of the slopes where the surfaces of the terraces are more extended (Figure 11a,b). It

allows reducing the efforts and costs in term of hours of work for the cultivation of vineyards [67]. Additionally, also in this case the stone columns once used for the support of pergolas remain but have lost their role. Santoro et al. [68] reported a similar situation with the introduction of rows instead of the traditional pergolas in Cinque Terre (Liguria, Italy), which is a site recognized by UNESCO. They highlighted that the trend is in common with the most of the modern vineyards in Europe and that pergolas completely covering the terrain have an important role in soil erosion containment during rainfall events. For these reasons, the development of policies and action plans useful to recognize the added value for the wine produced through the traditional practices is the first step to make maintenance more convenient to winegrowers in the face of greater efforts. According to this, Torquati et al. [69] highlighted that the preservation of the landscape can be an important driving force to improve the income of winegrowers.

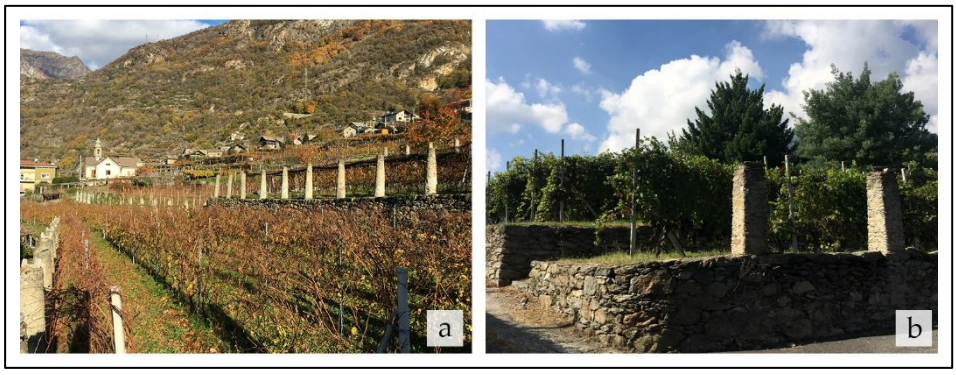

Figure 11. (**a**) The introduction in the lower part of the slopes of the espalier vine-breeding technique in place of the traditional pergola caremiese, which causes a loss of the landscape's integrity. Additionally, the stone columns once used for the support of pergolas remain but have lost their role. (**b**) Detail of terraces where the historical vine-breeding technique was changed causing the loss of the landscape's integrity.

Another aspect that can affect the integrity of the landscape is the fragmentation of the patches that compose it. We observed that during the

considered time period the number of the patches increased and their average area decreased. A similar trend was observed in a Portuguese rural landscape from 1979 and 2002 [70]. The fragmentation of the landscape also emerged in the edge density, which increased most for vineyards compared with the other land uses. Future planning strategies have to favor the consolidation of the fields because the fragmentation and the lack of management expose the terraced systems to multiple problems. The scientific community recognizes that this is a challenge to reduce the social and environmental downsides related to the fragmentation processes [71]. Indeed, for example, the fragmentation of the properties increases the time and costs for the winegrowers during their cultivation activities because they often have to cultivate small vineyards which are distant from each other. At the same time, the abandoned vineyards expose the other neighbors to the increase of phytosanitary problems. Indeed, Ripamonti et al. [72] observed, in the abandoned wild vineyards of the southern Piedmont, a higher presence of the Flavescence dorée of grapevine phytoplasma and its vector *Scaphoideus titanus*, which could affect the neighbors managed vineyards. The Piedmont Region has supported the land consolidation and the recovery of the abandoned fields since 2016 [73]. The adhesion of the study area to national and international programs goes in the direction of its enhancement. Indeed, even if today the integrity of the vineyard terraced landscape considered is good, it is threatened by some criticalities that were observed (abandonment processes and changing of the traditional vine-breeding technique), which are in common with other rural sites in Europe. For this reason most of the authors underlined the need of new policies and future planning strategies aimed at enhance the historical rural landscapes [74,75].

Since the GIAHS approach requires the development of an action plan for the dynamic conservation of the inscribed sites, we identified the land use that requires more attention in the future planning strategies in order to maintain the terraced landscape's integrity. As reported above, the greatest value of the historical index was shown by vineyards (2.11). Indeed, they constitute the land use which most reduced its area during the considered time period. For these reasons, the enhancement of vineyards and the maintenance of the traditional agricultural practices are the first steps for the enhancement of the entire terraced landscape.

5. Conclusions

The research proposed a GIS-based approach to assess the integrity of a potential GIAHS-FAO site with a dynamic perspective. We applied it in a unique vineyard terraced landscape located in Northwest Piedmont (Italy) characterized by vine pergolas supported by stone columns. We analyzed the dynamics of the landscape's mosaic occurring from the middle of the last century to nowadays. The parameter of integrity was explored starting from the land-use changes occurring from 1954 for the southern part of the study area and 1968 for the northern to 2018. The elements that allowed quantifying it were analyzed. The GIS-based approach allowed us to obtain data that were previously unknown, since the available regional cartography was acquired with a less detailed scale. The limit of the approach is that it is strictly connected with the availability of the historical aerial images and their level of definition. The strength is due to the possibility to use its detailed results not only to assess the landscape's integrity but also to influence future planning strategies and policies.

In this direction, the GIAHS program could support the dynamic conservation of the study area. Indeed, its approach recognizes that the rural landscape has not to be considered as a static museum but as a live system coevolved with the rural communities. In this context, the sporadic introduction of new crops (e.g., olive groves) or the limited adaptation of the historical vine-breeding technique to more modern needs could be accepted. On the contrary, future planning strategies will have to be much more attractive for winegrowers in terms of the maintenance of traditional cultivation (vineyards), and agricultural practices (traditional pergola caremiese). Some useful strategies could be to recognize the quality of the historical landscape participating to the national and international programs of enhancement; to involve the recovery of the abandoned vineyards' terraced landscapes; to support the reconstruction of damaged dry-stone walls; to prioritize the recovery of the stone columns, which are important landmarks of the landscape; and to invest resources to attract experiential tourism. The good current terraced landscape's integrity, which is an important starting point, merged with these indications will allow the landscape to guarantee the livelihood of future generations as in the past. It is an important capability that a potential GIAHS-FAO site has to show.

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Chapter V

Landscape Strategies Making for Terraced Landscapes in the European Alpine Region Using a Mixed-Method Analysis Tool

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Abstract: Terraced landscapes are anthropic landscapes that need continuous management. Future planning policies need to develop bottom-up approaches in order to keep into consideration the perspectives of decision makers (DM) and civil society stakeholders (CS). Using a participatory mixed-method, the research identified and prioritized the Strengths, Weaknesses, Opportunities, and Threats (SWOT analysis) perceived as key factors for setting future landscape strategies. The aims were: (i) to develop a methodological framework for the enhancement of the terraced landscapes using a bottom-up approach, (ii) to identify and rank the favorable and unfavorable factors affecting the terraced landscape management in the European Alpine Region, and (iii) to develop alternative and future landscape strategies based on the insight gained with the analysis. The methodology was applied in nine cross-border Italian and Switzerland terraced landscapes characterized by vineyards, agroforestry, and meadows. Firstly, an online focus group was organized with a DM of each study area in order to identify the SWOT items for the enhancement of the cross-border terraced landscapes. Subsequently, a focus group for each study area was organized involving CS. They prioritized the SWOT items based on the local context and territorial issues using a cumulative voting method. Results were normalized and allowed to develop local and supralocal landscape strategies both common for the cross-border terraced landscapes and specific for the main land uses characterizing them.

Keywords: UNESCO cultural landscape; agricultural systems; bottom-up approach; focus group technique; landscape planning; historical rural landscape.

1. Introduction

1.1 Terraced Landscapes Between Values and Threats

Terraced landscapes are distinctive man-made landscapes, traditionally built to obtain land for cultivations in steep slopes (Giordan et al., 2017). They are the consequence of an uninterrupted and adaptive land re-arrangement in terms of use and spatial structure in response to ever-changing economic and social needs (Heider et al., 2021). Terraced landscapes are the results of the coevolution of different features mainly physical, historical, anthropic, and socioeconomic dynamics (Petanidou et al., 2008). These sites are complex systems mainly recognized for their distinctive architectural and historical features, agricultural systems, cultivation practices, productions, and cultivations techniques applied. Indeed, terraces are mainly constructed with dry-stone walls to which are recognized important social, environmental and ecological values (de Madariaga, 2021). For these reasons the United Nations Educational, Scientific and Cultural Organization (UNESCO) recognized in 2018 the "art of dry-stone walling knowledge and techniques" as Intangible Cultural Heritage of Humanity for eight European Countries including Italy and Switzerland (UNESCO, 2018).

Terraces provide several ecosystem services such as runoff reduction, water conservation, erosion control, soil conservation and increase of soil quality, carbon sequestration, enhancement of biodiversity and enhancement of soil fertility (Socci et al., 2019; Stanchi et al., 2012). In this context, the recognition of environmental and societal benefits provided by ecosystem services flows has allowed to develop landscape plans and projects at international level. (Brunori et al., 2018).

However, terraced landscapes require a continuous and active management by farmers often expensive and tiring (Cicinelli et al., 2021). This is one of the causes of their abandonment. The lack of management determines the loss of historical landscapes and serious risks to public safety. Indeed, the abandonment of terraces increases the hydrogeological risk (Agnoletti et al., 2019). Efficient management strategies and preservation policies for terraced landscapes are therefore increasingly important. For example, Ažman Momirski (2019) highlighted the need to increase the planning strategies for the enhancement of Slovenian terraced landscapes.

In Europe the importance of studying and enhancing terraced systems is so well known that specific research projects were dedicated to them since the beginning of this century. For example, in 2005 the European Union financed an Interreg Project called ALPTER aimed at mapping terraced areas, evaluating risks related to the abandonment of terraces, enhancing agricultural products, and promoting the experiential tourism (Tarolli et al., 2014). More recently (2019-2022) another European Project was dedicated to the enhancement of the terraced landscapes. It was called "InTERRACED-NET: Integrated strategies and networks for the conservation and enhancement of the transboundary terraced landscape". The general aim of the project was the participative characterization of the cross-border terraced landscapes in order to develop landscape strategies for their conservation and enhancement (InTERRACED-NET European Project, 2022). These strategies were collected in an action plan for the integrated and sustainable enhancement of the involved terraced landscapes. The specific objectives of the action plan were the implementation of:

(A) innovative forms of public-private cooperation;

(B) territorial marketing and certification strategies;

(C) strategies to increase the ecosystem services and biodiversity;

(D) actions to enhance agricultural and niche local productions.

1.2 Participatory Approaches and Methods for Landscape Strategies Development

From a methodological point of view, there is a rising international awareness of the need to read and examine the landscape regarding its natural, cultural-anthropic and perceptive components (Agnoletti, 2014). Following the European Landscape Convention (ELC, 2000) recommendations concerning the need to consider people's perception in living landscape planning, public consultation has become an increasingly important tool in the decision-making process (Gantar and Golobič, 2015). The participatory approach allows to understand the perspectives and problems of decision makers and civil society stakeholders, and to identify sustainable strategies for historical rural sites (Gullino et al., 2018). According to Gkoltsiou and Mougiakou (2021) for ensuring terraced landscapes' sustainability it is essential to support territorial management choices applying qualitative assessment tools and involving local stakeholders. Pomatto et al. (2022a) highlighted the importance of the involvement of the rural communities in defining landscape strategies for the terraced landscapes enhancement.

SWOT (Strengths, Weaknesses, Opportunities, and Threats) is a well-known strategic planning technique suitable to be applied using top-down (expert-based) or bottom-up (participatory) approaches (Mollenhorst and De Boer, 2004; Khadka and Vacik, 2012). It provides a framework for

identifying policy goals and, furthermore, to define strategies for their achieving (European Union, 2021). The main limitation of the method is that its items are listed as if all were equally important, and they are not related to each other (Valentin, 2005). To go beyond the qualitative examination of the SWOT items, the analysis can be integrated with quantitative techniques aimed to prioritise the SWOT items and to generate strategies based on the relationships among them. Usually, such mixed-methods integrate SWOT analysis with analytic hierarchy processes (AHP) (Bottero et al., 2020; Kişi, 2019; Canto-Perello et al., 2016; Akbulak and Cengiz, 2014), analytic network process (ANP) (Barati et al., 2017; Star et al. 2019) and other Multi Criteria Decision Making methods (MCDM), including those using fuzzy set theory to deal with uncertainty due to unquantifiable, incomplete, or unobtainable information (Khatir and Akbarzadeh, 2019; Grošelj et al., 2016). Novelli et al. (2021) trialled an easy-to-apply mixed method to weight and rank SWOT items for use with non-expert evaluators. However, as other more complex methods, such as AHP and ANP, hybrid approaches are based on the two at a time pairwise comparison of the SWOT items. All techniques based on pairwise comparisons are time-consuming, difficult to handle and require a high level of cognitive effort from the evaluators (Vestola, 2010; Cagliero et al., 2021). This affects the quality of the outcomes and reduce the practicability and validity of the approach when the number of SWOT items is high, and the evaluators are non-experts (Maida et. al. 2012; Novelli et al., 2021). In order to prioritize the SWOT items using an easy-to-apply participatory approach without reducing the number of items included in the analysis, we experimented with a cumulative voting method, a simple and user-friendly method for prioritising a list of items on a ratio scale (Riņķevičs and Torkar, 2013).

1.3 Research Aim

The research developed an expert-based assessment of the cross-border Italian and Switzerland terraced landscapes and their characterization through a participative approach. In this paper we will focus on the bottom-up approach applied. We involved both decision makers (DM) and civil society stakeholders (CS) as local communities to examine the study areas and identify sustainable landscape management strategies. Operatively, we used a mixed method, combining a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis with a cumulative voting method.

The aims of the research were as follows: (i) to develop a methodological framework for the enhancement of the terraced landscapes using a bottom-up approach, (ii) to identify and rank the favourable and unfavourable factors affecting the terraced landscape management in the European Alpine Region, and (iii) to develop alternative and future landscape strategies based on the insight gained with the analysis.

Given the importance of local understanding to guide effective management of terraced landscapes, this paper draws upon participatory fieldwork in European Alpine region, Italy and Switzerland.

2. Materials and Methods

2.1 The Study Areas

The methodology was applied in the territories involved in the InTERRACED-NET European Project: Aosta Valley Region (Italy); Val Grande National Park, Ossola Valley (Piedmont Region, Italy); Lario Intelvese, Monte Barro Park, Valtellina, Montevecchia and Curone Valley Regional Park, (Lombardy Region, Italy); Poschiavo Valley, Mesolcina

Valley (Grisons Cantons, Switzerland). Figure 1 shows the nine cross-border Italian and Switzerland territories considered as study areas.

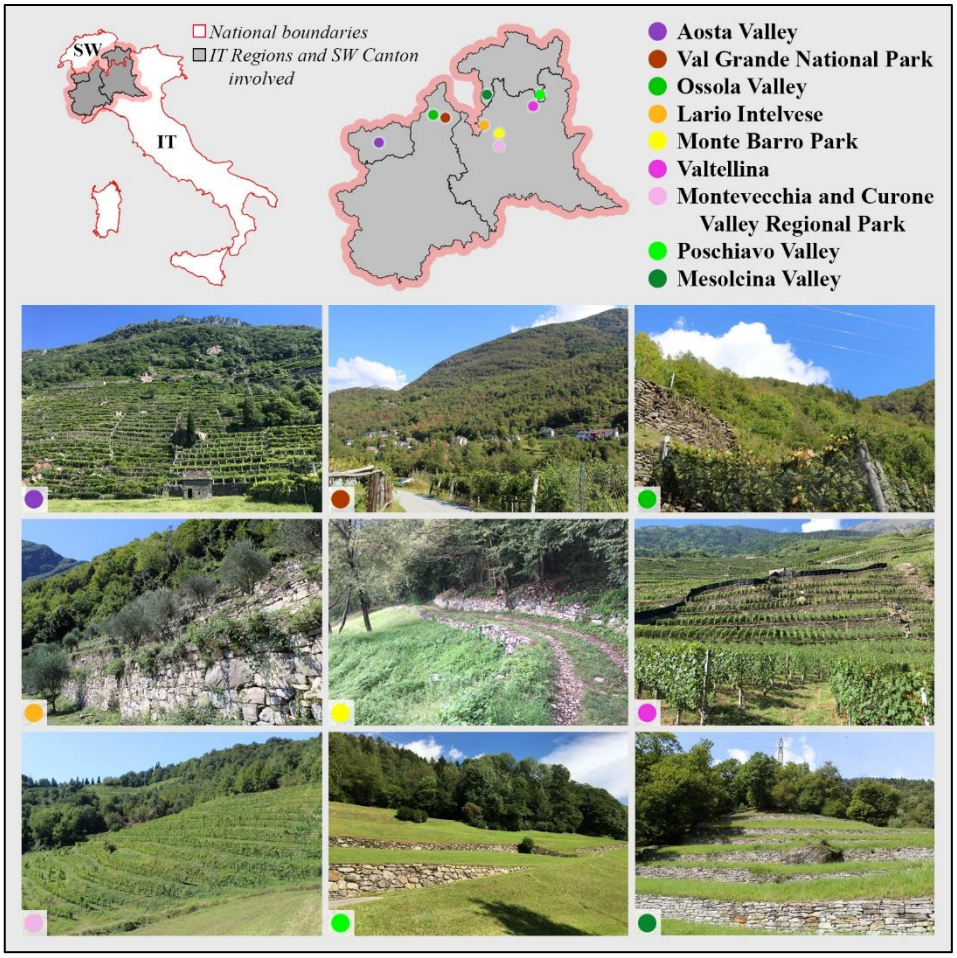

Figure 1. The nine cross-border Italian and Switzerland terraced landscapes considered as study areas.

These areas are characterized by different landscape features and type of boundaries (i.e. administrative boundaries, such as Regions and Parks, or geographical boundaries, such as Valleys). However, in all of them there are extended terraced landscapes characterized by different state of conservation and different land uses. Historically such terraces were dedicated to the agricultural activity. The most intensive cultivations on

terraces characterize the Aosta Valley Region and Valtellina, where viticulture plays a fundamental role. Less intensive viticulture interests also the Montevecchia and Curone Valley Regional Park. The two Switzerland study areas are both related to the presence of terraces dedicated to meadows. Agroforestry is historically characterizing of the Lario Intelvese. Instead, terraces of Ossola Valley, Val Grande National Park and Monte Barro Park once were dedicated to viticulture but nowadays are threatened by the abandonment. Some residual vineyards remain in the first two, while in the Monte Barro they are completely disappeared. Table 1 synthetizes the current main land use of the terraces of the study areas.

Table 1. Main current land uses of the terraces of the study areas.

Main land use of terraces	Study areas
Vineyard	Aosta Valley; Valtellina; Montevecchia and Curone Valley Regional Park.
Agroforestry	Val Grande National Park; Ossola Valley; Lario Intelvese; Monte Barro Park.
Meadows	Poschiavo Valley; Mesolcina Valley.

2.2 Methodological Framework

We used the focus group technique to involve DM and CS in the planning process. To this end, we set up nine focus groups discussions. As a result of the limitations imposed by COVID-19, all of them were performed remotely, using the platform Cisco Webex Meetings. Focus group discussions have been recorded and transcribed for subsequent analysis (Stewart et al., 2007).

As shown in Figure 2, the research was divided into two parts. The first one focused on the identification by DM of the items of the SWOT matrix

at general level of cross-border Italian and Switzerland terraced landscapes. Subsequently, the items of the general SWOT were prioritized by CS at territorial level using the cumulative voting method. Results allowed us to propose indications for alternative and future landscape strategies for the enhancement of the terraced landscapes, starting for the perceptions of the local communities.

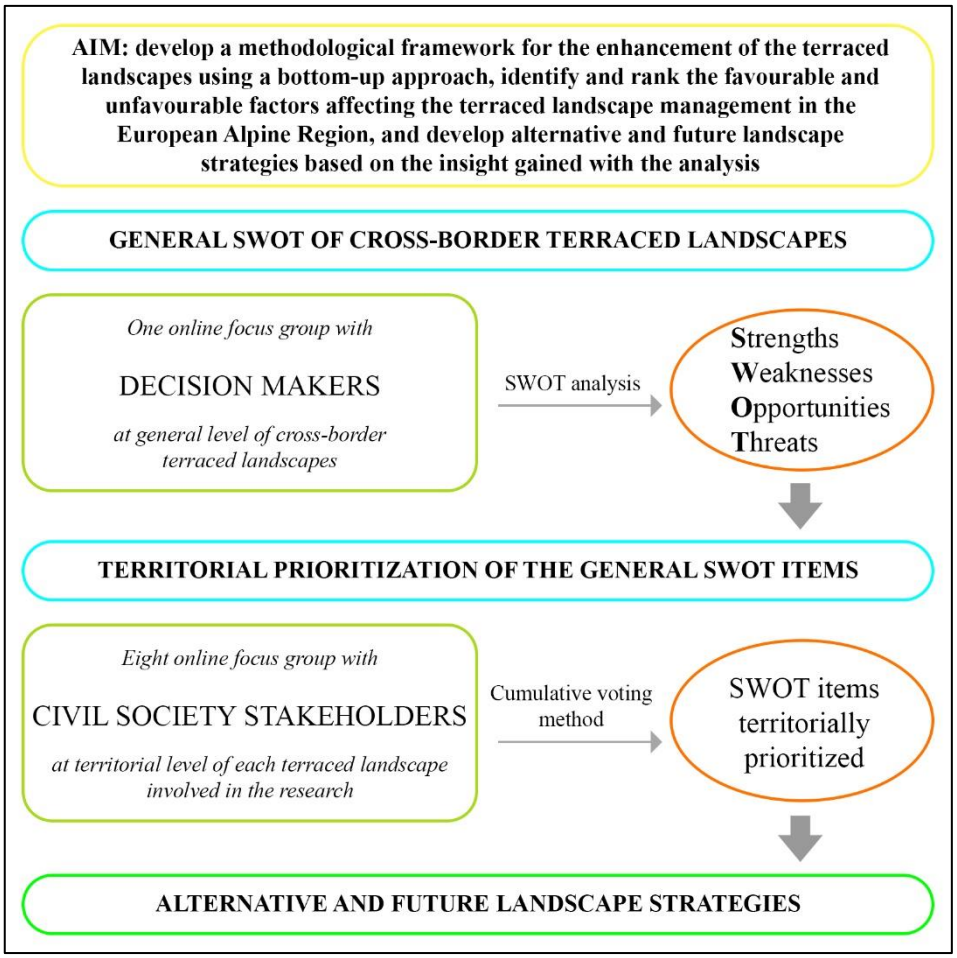

Figure 2. Methodological framework.

2.3 General SWOT Analysis of Cross-border Terraced Landscapes

In the first place, all partners of the InTERRACED-NET European Project were involved to define a general framework of core opportunities and constraints for the conservation and enhancement of the cross-border Italian and Switzerland terraced landscapes. An online focus group was organized in December 2020. Each partner designated a DM of his organization as a participant. During the meeting we described the aims of the project, and the features of the study areas, and we explained the SWOT methodology. Then, the nine DM were asked to discuss one key research question: *based on your experience, which are the strengths, weaknesses, opportunities, and threats for the enhancement of the terraced landscapes?* DM discussed each section of the SWOT matrix suggesting a general list of shared strengths, weaknesses, opportunities, and threats for the cross-border Italian and Switzerland terraced landscapes. In particular, strengths and weaknesses were analyzed as internal factors that and DM have some control over and can try to change or manage. Opportunities and threats were considered as external factors, derived from the environment, market, or regulations outside local actor control (Gamble et al., 2019). Finally, DM were asked to associate each item of the general SWOT matrix to one or more objectives of the action plan of the InTERRACED-NET European Project (A,B,C,D).

2.4 Territorial Prioritization of the General SWOT Items with Cumulative Voting Method

Secondly, we organized and coordinated eight territorial online focus groups (from February to March 2021). For each territory involved in the research, CS were asked to discuss and validate the results of the general

SWOT analysis of cross-border Italian and Switzerland terraced landscapes. Then they were asked to prioritize the SWOT items based on the local context and territorial issues. The two Switzerland territories were merged into a unique focus group due to their similar characteristics. According to Gullino et al. (2018) and Duncan et al. (2020), CS were recruited as local actors characterized by different concepts, tasks, opinions, and roles related to the terraced landscapes. Each partner identified a panel of local CS (n = 8-14) according with these indications. During the territorial focus groups, only the CS participated in order to not be influenced by the presence of DM. Table 2 reports the CS involved (type and number) in the eight territorial focus groups.

Table 2. Type and number of CS involved in each territorial focus group.

Type of stakeholders	**Number of CS participants**							
	Aosta Valley Region (IT)	Val Grande National Park (IT)	Ossola Valley (IT)	Lario Intelvese (IT)	Monte Barro Park (IT)	Valtellina (IT)	Montevecchia and Curone Valley Regional Park (IT)	Poschiavo Valley and Mesolcina Valley (SW)
Environment/ social Association		4	3	1	3	2	2	3
Farmer				3	3			1
Freelance professional	2		1	1			1	
Forestry/ agronomy		1	1	1	1	1	1	
Municipality organization	1	2	2	2	1	2	1	1

Table 2. *Cont.*

Type of stakeholders	**Number of CS participants**							
	Aosta Valley Region (IT)	Val Grande National Park (IT)	Ossola Valley (IT)	Lario Intelvese (IT)	Monte Barro Park (IT)	Valtellina (IT)	Montevecchia and Curone Valley Regional Park (IT)	Poschiavo Valley and Mesolcina Valley (SW)
Protected area organization		2			3		2	2
Tourism/ Hotelier	2		3		1	2	1	2
Wine grower/ Wine producer	3	1			1	3	1	1
Other local organizations					1			
TOTAL	8	10	10	8	14	10	10	10

With the aim to compare the results and define a SWOT matrix at the territorial level responding to the management/conservation objectives of the terraced landscapes, all territorial focus groups were performed with the same operating methods. According to Morris et al. (2011) and Larcher et al. (2013), each focus group followed the same steps separately to avoid influencing each other. In these focus groups we used cumulative voting as methodology for prioritizing the items. The participants of each focus group prioritized the items of the general SWOT of cross-border terraced landscape giving them a score. According to Cagliero et al. (2022), the number of dots (N) which they had available for each section of the SWOT matrix was defined in function of the number of CS participating in the focus group (P) and the number of the items in the section (T). The method

allows to adapt the number of dots to the context of evaluation, using the following formula:

$$N = \frac{\left(\frac{T}{2}\right) * T}{P}$$

Table 3 reports the number of dots available in each territorial focus group.

Table 3. Number of available dots for each section of the general SWOT analysis.

Territorial focus groups	**Number of available dots for each section of the general SWOT analysis**			
	Strengths	Weakness	Opportunities	Threats
Aosta Valley Region (IT)	4	2	3	2
Val Grande National Park (IT)	3	1	2	1
Ossola Valley (IT)	3	1	2	1
Lario Intelvese (IT)				
Monte Barro Park (IT)	2	1	2	1
Valtellina (IT)	3	1	2	1
Montevecchia and Curone Valley Regional Park (IT)	3	1	2	1
Poschiavo Valley and Mesolcina Valley (SW)	3	1	2	1

Each CS could decide to assign all the available dots to a single item or to divide the available dots over several items, knowing that to more dots collected by a single item corresponded an its higher priority. Table 4 reports the questions asked to civil society stakeholders for each section of the SWOT matrix.

Table 4. Questions proposed to civil society stakeholders (CS) during the territorial focus group.

Sections of the SWOT	Questions proposed to CS
Strengths	Referring to your specific territory, we ask you to use your available dots to indicate on which of these strengths you would intervene primarily with policies, actions and financings aimed to the enhancement of the terraced landscape. Your strategy can be aimed at reinforcing of lacking strengths or at investing more in strengths already acquired.
Weaknesses	Referring your specific territory, we ask you to use your available dots to indicate on which of these weaknesses you would intervene primarily with policies, actions and financings aimed to the enhancement of the terraced landscape. Your strategy can be aimed at acting on the weakest weaknesses or on weaknesses more immediate to resolve.
Opportunities	Referring your specific territory, we ask you to use your available dots to indicate on which of these opportunities you would intervene primarily with policies, actions and financings aimed to the enhancement of the terraced landscape.
Threats	Referring your specific territory, we ask you to use your available dots to indicate on which of these threats you would intervene primarily with policies, actions and financings aimed to the enhancement of the terraced landscape.

After explaining the methodology, through the chat of the platform used for the online meeting, we sent live a link of Google Form for each section of the SWOT, reporting the items and the possibility to attribute them the available dots. Indeed, in the literature is recognized the importance of the anonymity of the vote in order to not influence the respondent by the answers provided by the others (Gibbons, 2019; Marcatto, 2017). According to Van Erkel and Thijssen (2016), the proposed order of the items was randomized in order to avoid the primacy effect for which respondents could remember better and prefer the firsts items of the list. Indeed, in the cumulative voting methods the randomized order of the elements proposed to be voted is essential for a good significance of the results (Riņķevičs and Torkar, 2013). At the end of voting, results were

discussed by the participants to evaluate together with the CS the actions and landscape strategies for the enhancement of the terraced landscape.

Subsequently, data collected were further processed. To make all of the data comparable we normalized them. Indeed, as we discussed above, the CS of the different focus group had a number of available dots influenced by the number of participants. We used the min-max normalization technique (Jain et al., 2005):

$$Normalized\ (e_i) = \frac{e_i - E_{min}}{E_{max} - E_{min}}$$

where:

- E_{min} is the minimum value for variable E;
- E_{max} is the maximum value for variable E;
- The normalized value of e_i is comprised from 0 to 1.

Finally, according to Gkoltsiou and Paraskevopoulou (2021) we decided to present the results grouping the study areas in relation to the main current land uses of their terraced landscapes (vineyards, agroforestry, and meadows). We displayed these data graphically.

3. Results

3.1 General SWOT Analysis of Cross-border Terraced Landscapes

In the first focus group, nine DM participated. After a discussion coordinated by us, they identified general strengths, weaknesses, opportunities and threats for the enhancement of the cross-border Italian and Switzerland terraced landscapes. Subsequently we asked them to put in relation the items identified and the objectives of the action plan of the InTERRACED-NET European Project. Figure 3 reports the results of the

focus group, with the items of the general SWOT analysis of the cross-border terraced landscapes and their association with the objectives of the action plan.

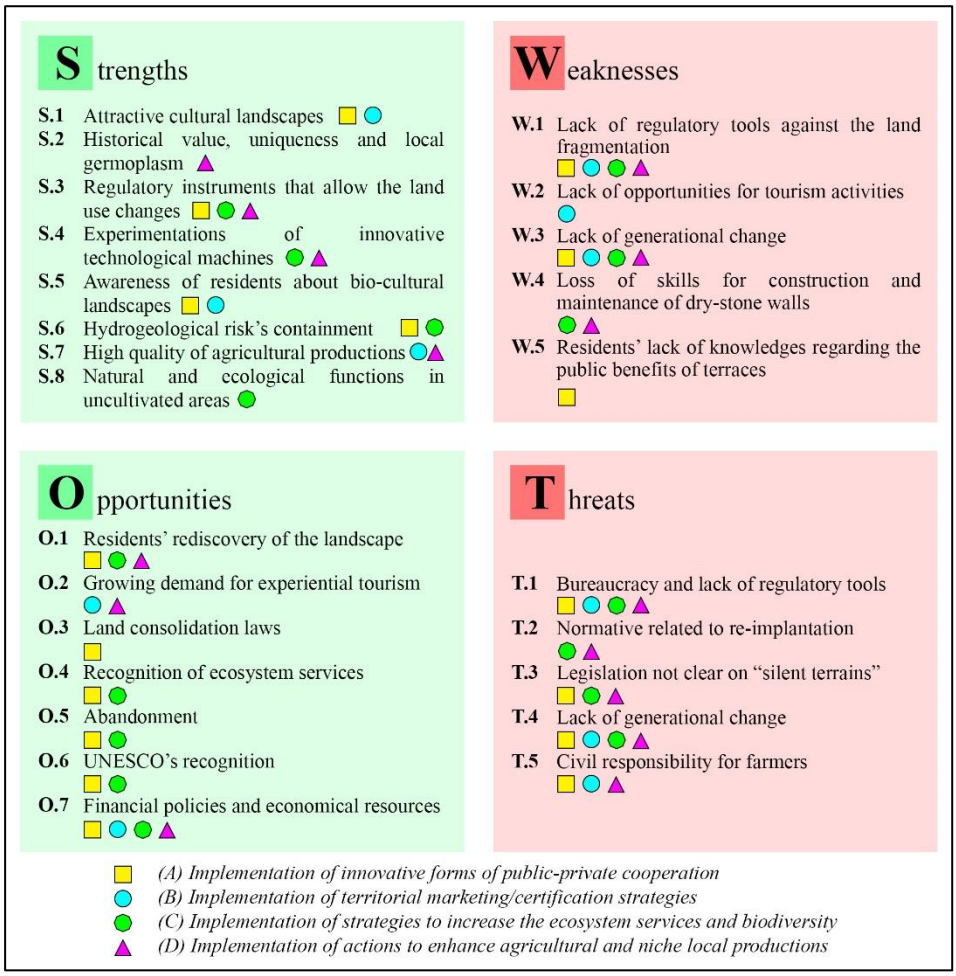

Figure 3. The Strengths, Weaknesses, Opportunities ant Threats (SWOT) for the enhancement of the cross-border Italian and Switzerland terraced landscapes identified by the DM and their association for each items of the SWOT with one or more objectives of the action plan of the InTERRACED-NET European Project (A,B,C,D).

As shown in Figure 3, in relation to the enhancement of the cross-border terraced landscapes, the DM identified eight strengths, five weaknesses, seven opportunities and five threats. In particular, they identified as

strengths the attractive cultural landscapes (S.1), the historical value, uniqueness and local germplasm (S.2), the regulatory instruments that allow the land use changes (S.3), the experimentations of innovative technological machines (S.4), the awareness of residents about bio-cultural landscapes (S.5), the hydrogeological risk's containment (S.6), the high quality of agricultural productions (S.7), and the natural and ecological functions in uncultivated areas (S.8). While, as weaknesses they highlighted the lack of regulatory tools against the land fragmentation (W.1), the lack of opportunities for tourism activities (W.2), the lack of generational change (W.3), the loss of skills for construction and maintenance of dry-stone walls (W.4), and the residents' lack of knowledges regarding the public benefits of terraces (W.5). Among the opportunities DM reported the residents' rediscovery of the landscape (O.1), the growing demand for experiential tourism (O.2), the land consolidation laws (O.3), the recognition of ecosystem services (O.4), the abandonment (O.5), the UNESCO's recognition (O.6), and the financial policies and economical resources (O.7). Finally, the threats that emerged during the focus group were the bureaucracy and lack of regulatory tools (T.1), the normative related to re-implantation (T.2), the legislation not clear on "silent terrains" (T.3), the lack of generational change (T.4), and the civil responsibility for farmers (T.5).

To all of the items were associated by DM one or more objectives of the action plan of the InTERRACED-NET European Project. The most cited was the implementation of innovative forms of public-private cooperation (A) associated to seventeen items, followed by the implementation of strategies to increase the ecosystem services and biodiversity (C), and the implementation of actions to enhance agricultural and niche local productions (D) both associated to fifteen items. Finally, the

implementation of territorial marketing/certification strategies (B) was associated to eleven items. Table 5 describes the items of the general SWOT analysis identified by the decision makers.

Table 5. The description of the items of the general SWOT analysis identified by the decision makers (DM).

Items	Description
S.1	DM recognized the terraced landscapes as attractive cultural sites from the touristic and recreational point of view, in which the quality of the life in high. For they these sites have not only aesthetic values but are also full of meanings, cultural values and potential. In these contexts, DM highlighted that experiential tourism is an important activity to further improve.
S.2	DM outlined the richness, uniqueness and diversity of the terraced landscapes associated with the presence of ancient and local germplasms. Historical cultivars, and ancient specimens characterize these sites. It has been stressed the historical, almost archaeological aspect that characterizes the cross-border Italian and Switzerland terraced landscapes.
S.3	DM recognized in the protected areas the presence of legal regulatory instruments related to forestry for enhancing plant biodiversity, and natural, botanical and floristic features (endemism). Some study areas considered are included in protected areas or regions equipped with specific laws that allow the land use changes in favor of the recovery of abandoned terraced invaded by woodlands. In these areas it is possible to convert unmanaged forest, characterized by invasive species, with other crops such as vineyards or olive groves. DM believe that these cultivations increase the ecosystem biodiversity.
S.4	DM noted that working on terraces is not only expensive a time level but also tiring. Investigating and experimenting innovative technological capable of reducing processing times and farmers' fatigue are considered priorities. In this context, in some study areas considered were developed or are in course of texting positive experiences related to the use of robotics (e.g. for phytosanitary treatments in vineyards).

Table 5. *Cont.*

Items	Description
S.5	Since the terraced landscapes are biocultural landscapes, the DM identified as strength the awareness of the residents and of the whole territory about the biocultural values of the cross-border Italian and Switzerland terraced landscapes.
S.6	DM reported the important public functions that the terraced systems play simultaneously: the estate of the slopes, the protection of the railway and road infrastructures, the protection of the inhabited centers, the maintenance of the hydrogeological structure, and the reduction of the risk from avalanches. They recognize these functions such as ecosystem services.
S.7	DM recognized that the agricultural productions of terraces are characterized by high quality. These productions (e.g. winegrowing, horticultural, fruit-growing, grazing and forage) are considered the essential elements for local agriculture. In these rural sites the agricultural farms are important for the agri-food productions. Their quality is demonstrated by the presence of several certifications (e.g. Denomination of Controlled Origin for wines).
S.8	DM recognized that terraces also perform important naturalistic and ecological functions. These functions are carried out, both in the currently cultivated areas, and in those not productive. The meadows have important values from the floristic and vegetational point of view, as well as the structure of the dry-stone wall which constitutes a micro-niche for several xerophilic species and animals.
W.1	DM outlined the land fragmentation as the main general problem perceived. In this context, the lack of regulatory tools and of governance against the land fragmentation is a general weakness. Indeed, DM highlighted the lack of tools and policies at local level for facilitating the land consolidation.
W.2	DM highlighted the lack of opportunities for tourism activities. Although the terraced landscapes are attractive places from a tourist point of view, there is a lack of trained operators to accompany tourists and tell the story of the terraced systems. Indeed, there are few professional figures employed to the touristic activities who have the knowledge about terraces' history and tradition.
W.3	DM considered the lack of generational change as a general weakness. The abandonment is a widespread phenomenon due both to economic problems and social. New generations are often not interested to continue with the agricultural activity and especially in the areas less suitable and poorly accessible. These areas are abandoned.
W.4	DM outlined the lack of a skilled and trained manpower in the cross-border Italian and Switzerland terraced landscapes. Indeed, over time there has been a loss of skills and professionalism for the maintenance and construction of dry-stone walls.

Table 5. *Cont.*

Items	Description
W.5	Although the structures of the dry-stone walls perform important functions (e.g. hydrogeological risk containment), often citizenship does not realize the public benefits provided by terraces. The functions related to the water regulation and the tightness of the mountain fronts are not recognized a public level.
O.1	During the Coronavirus disease (COVID-19) pandemic period in 2020, people were firstly forced to stay at home, and subsequently to remain within the boundaries of their municipalities. DM observed that these limitations allowed, especially to the new generations, to rediscover their roots and a "new" link with the terraced landscapes. Indeed, most of the residents went for a walk across the terraces and discovered their beauties and values often unknown before.
O.2	DM highlighted that adopting territorial marketing operations is a priority to enhance the terraced landscapes since currently the users of the mountain landscape are mainly interested in wellness, sports, and food and wine but not yet in the terraced structures. However, in these contexts the slow and experiential tourism from the outside of the study areas is increasing and need to be further improved.
O.3	Land fragmentation is a structural and general weakness in all territories but above all in the terraced sites. However, the study areas included in the Italian Piedmont Region can benefit of regional legislative instruments (laws on land associations) in favor of the land consolidation. These tools are recognized by DM as opportunity that could also be extended and applied to the other rural terraced areas involved.
O.4	DM reported that for the enhancement of the terraced landscapes, the recognition of ecosystem services provided by them is a primary need. Indeed, these structures should be considered for their social and environment functions. DM emphasized the ecosystems services provided to the community highlighting especially the hydrogeological aspect. From this perspective they wished that an economic contribution at supralocal level (e.g. national policies) could be recognized to farmers as with their activities safeguard the ecosystem services provided by the terraced systems.
O.5	DM outlined that the abandonment of the terraced areas less suitable for productive purposes (e.g. located in slopes not well exposed to the sun or difficult to reach) is an opportunity for reestablish an efficient and sustainable land use organization. They highlighted the need of specific policies and funds at supralocal level to manage these areas.

Table 5. *Cont.*

Items	Description
O.6	DM reported the importance of the recognition of the "Art of dry-stone walling, knowledge and techniques" as intangible cultural heritage of UNESCO. Indeed, it requires the adoption of common and shared safeguard plans for dry-stone walls, that are important opportunities for the enhancement of the terraced landscapes.
O.7	For the enhancement of internal and marginal areas it would be important to draw on specific financial policies and economical resources (e.g. at national level). In these rural areas, the concept of multifunctionality could be a development opportunity. Moreover, linking the landscape values of the terraces to the touristic and receptive aspects are considered strategic measures.
T.1	DM highlighted that at supralocal level there is an excessive bureaucratization in force and the lack of regulatory tools aimed at the enhancement of the terraced landscapes. They highlighted that the land fragmentation could be recovered and limited also streamlining the bureaucracy.
T.2	DM agreed that the supralocal legislation relating to the possibility of binding replanting, especially for vineyards cultivated on terraces, is a threat. In these conditions it would be necessary to have fewer constraints from the point of view of the possibility of replanting vine because it allows to recover abandoned terraces and obstruct the hydrogeological risk. In some realities there are young winegrowers who, despite having an interest and will to plant new vines, cannot do so as they do not have the rights.
T.3	DM reported that there is currently no clear regulation at supralocal level about the possibilities of management of the “silent terrains” located on terraces. They are those abandoned lands where either the owners have died, or where the current owners are not recognized. Only the study areas included in the Italian Piedmont Region can benefit of regional legislative instruments on “silent terrains”, but the lack in the others is considered by DM a threat for the enhancement of the cross-border Italian and Switzerland terraced landscapes.
T.4	The land abandonment is mainly related to the lack of adequate generational change. DM outlined that this phenomenon could be limited with external economic support and policies that allow young people to buy or rent rural small isolated or remote terraced areas. Currently these supports are absent.

Table 5. *Cont.*

Items	Description
T.5	DM reported that to farmers is recognized a civil and sometimes criminal liability responsibility about the hydrogeological instability and the possibility of collapse of the dry-stone walls, above all where they are located near the infrastructures or inhabited centers. Furthermore, also the responsibility of accidents occurred during touristic activities (people who have a walk or athletes during races that get hurt or fall from the terraces) is attributed to farmers. This condition makes incompatible the use of terraces for touristic purposes. DM observed that civil responsibility for farmers is a threat which need to be solved with the development of a supralocal apposite legislation.

3.2 Territorial Prioritization of the General SWOT Items with Cumulative Voting Method

The results of the territorial prioritization of the general SWOT analysis with cumulative voting method allowed us to identify common and specific Strengths, Weaknesses, Opportunities and Threats. They also highlighted that among the different cross-border Italian and Switzerland terraced landscapes there are differences and similarities. Indeed, we observed that some SWOT's items identified by DM are perceived as priority by all of the CS crosswise, while others are influenced by the main current land use that characterizes the study area.

Indeed, as shown in Figure 4a, attractive cultural landscapes (S.1) is considered the most significative strength for all terraced landscapes. Similarly, the high quality of agricultural productions (S.7) was reported as priority in most of the terraced landscapes considered, independently by the land use that characterizes them. The hydrogeological risk's containment (S.6) is mainly perceived as important strength by CS belonging to vineyards and agroforestry terraced landscapes. By contrast, for meadows landscape, the regulatory instruments that allow the land use changes (S.3) and the experimentations of innovative technological

machines (S.4) are not considered priority strengths. Finally, the natural and ecological functions in uncultivated areas (S.8) emerged mainly for agroforestry terraced landscapes, particularly for Monte Barro Park and Lario Intelvese.

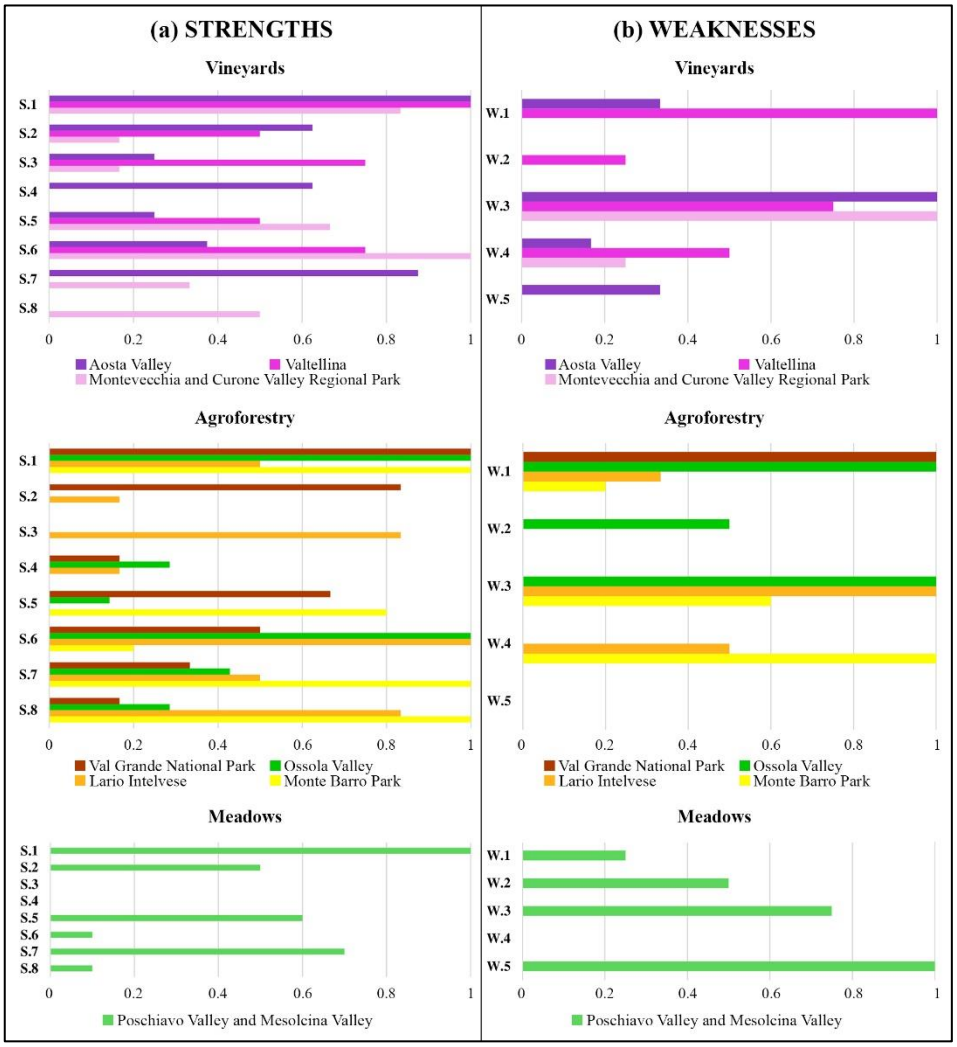

Figure 4. The results of the territorial prioritization of the general SWOT analyses with cumulative voting method grouped for the main current land uses characterizing the study areas: (**a**) strengths, and (**b**) weaknesses.

Regarding the weaknesses (Figure 4b), the lack of generational change (W.3) is considered a priority weakness to be solved for almost all terraced

landscapes. While, the lack of regulatory tools against the land fragmentation (W.1) emerged mainly for vineyards and agroforestry terraced landscapes. By contrast, the residents' lack of knowledges regarding the public benefits of terraces (W.5) is the most important weakness for meadows terraced landscapes. The loss of skills for constructions and maintenance of dry-stone walls (W.4) emerged as priority for agroforestry terraced landscapes above all of the Monte Barro Park, while it was no reported by the CS belonging to meadows.

Figure 5a shows that the growing demand for experiential tourism (O.2) and the recognition of ecosystem services (O.4) are considered priority opportunities to further improve for all CS independently from the land uses characterizing their terraced landscapes. Also, the UNESCO's recognition (O.6) is considered important by most of the CS involved independently by the land uses. By contrast, the financial policies and economic resources (O.7) is an opportunity mainly considered for vineyards and agroforestry terraced landscapes.

Finally, as shown in Figure 5b, the lack of generational change (T.4) is considered the most significative threat for all of terraced landscapes. While, the bureaucracy and lack of regulatory tools (T.1) is a priority threat mainly for vineyards. Only for agroforestry terraced landscapes the legislation not clear on "silent terrains" (T.3) is considered a threat, not for the others. Similarly, the normative related to the re-implantation (T.2) and the civil responsibility for farmers (T.5) are priority threats to be solved specifically for terraced landscapes characterized by vineyards.

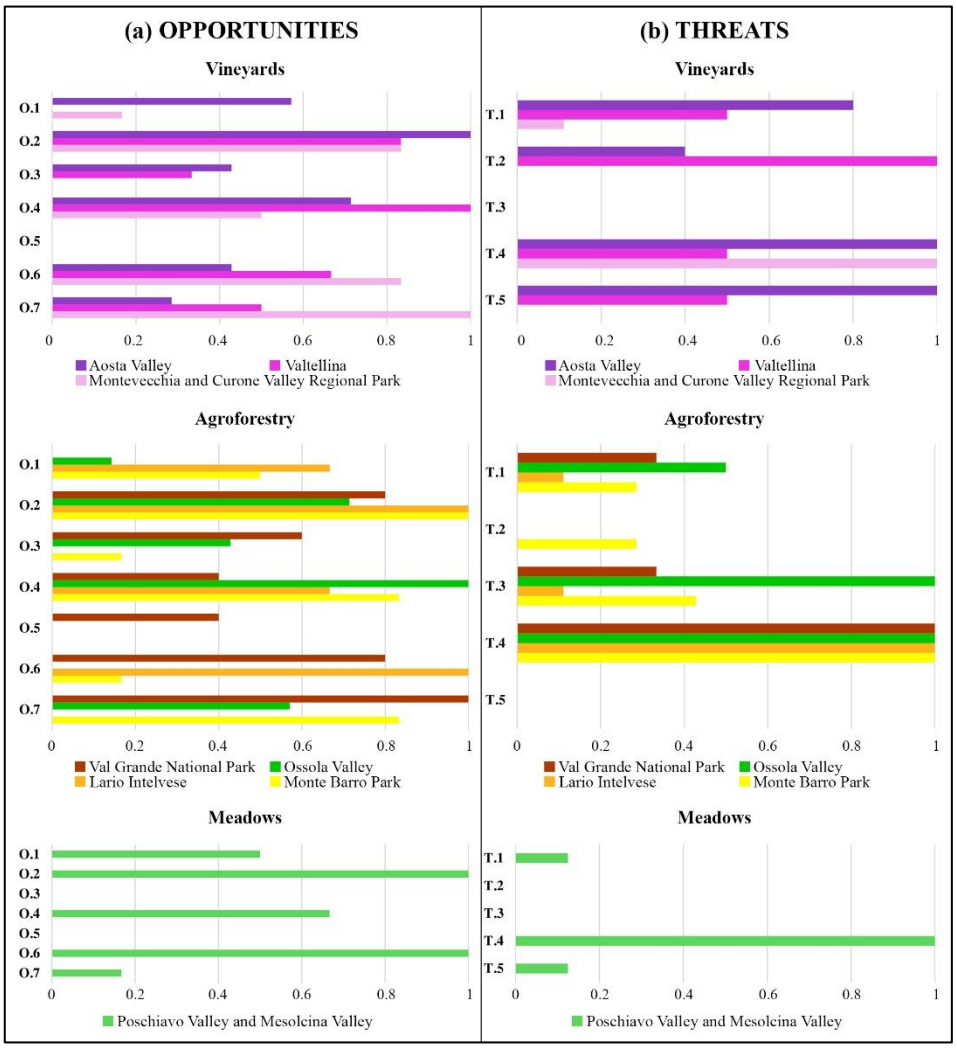

Figure 5. The results of the territorial prioritization of the general SWOT analyses with cumulative voting method grouped for the main current land uses characterizing the study areas: (a) opportunities, and (b) threats.

4. Discussion

The research developed an innovative bottom-up approach to involve the rural communities in the decision processes for the terraced landscape's planning in the European Alpine Region. It is a challenge reported by many authors at the international level. Indeed, according to Gullino et al. (2015) for enhancing rural landscapes is imperative to ensure a dynamic

sustainability through the definition of an integrated participatory planning approach. In this context, in agreement with Kerebel et al. (2019) using multi-level groups of stakeholders is a primary step. Fusco Girard et al. (2019) underlined that the regeneration of the terraced landscapes has to induce the implementation of circular processes mad up with local actors. Similarly, Zoumides et al. (2017) shared the importance of the involvement of the rural communities for starting participatory projects aimed at the terraced rehabilitation. They reported that in Cyprus the stakeholders showed a high awareness on the multiple values of the terraced landscapes, and together were involved in participatory soil-conservation activities (i.e. dry-stone walls reconstruction). The authors underlined that their involvement, especially young, is a critical start point to ensure the transferability of knowledges and the enhancement of the terraced landscapes. It is in line with what emerged in the SWOT analyses made up with the decision makers belonging to the involved study areas. Indeed, DM identified as strengths the cultural and the environmental benefits of the terraced landscapes, and the residents' awareness about them. By contrast, the decision makers underlined that the terraced landscapes identified as study areas are affected by the lack of generational change. They reported it as both a weakness and a threat. Indeed, DM highlighted that it is influenced by internal factors (social conditions), and by external factors (supralocal economic support and policies). This is in line with many authors that recognized in the lack of the generational change one of the causes that concur to the abandonment of the terraces (Davies and Moore, 2016; Kizos et al., 2010). Instead, the growing demand for experiential tourism was identified by the decision makers as important opportunity for the enhancement of the terraced landscapes. According to Tian et al. (2016), the tourism can contribute to the

agricultural development of terraces when it became an integral part of it. Indeed, Terkenli et al. (2019) highlighted that the enhancement of the terraced systems does not need to an irresponsible mass tourism but needs to an extensive aware tourism interested to the multiple values of the landscape and its traditional products. To attract and manage this type of sustainable tourism, the authors reported the importance of professionally equip, train, and skill the local communities and farmers. It is a need emerged also in the study areas considered, since the lack of opportunities for tourism activities was reported as weaknesses. Similarly, the bureaucracy and the lack of regulatory tool were reported by DM both as weaknesses, and threats because they are influenced by local and supralocal policies. Santoro et al., 2021 showed that the main problem evidenced by the farmers of the terraces of Cinque Terre (Italy) is the excessive bureaucracy. Shirvani Dastgerdi and Kheyroddin (2022) highlighted that the resilience of the terraced cultural landscapes has to be improved with specific policies at national levels with participatory approaches involving local stakeholders. Their lack of knowledges regarding the public benefit of terraces emerged in our SWOT analysis as weaknesses to be solved. At the same time, DM reported the loss of skills for construction and maintenance of dry-stone walls that affect the study areas. About that, the literature recognizes that the recovery of the traditional skills is critical for the enhancement of the terraced landscapes (Čurović et al., 2019). Gravagnuolo and Varotto (2021) reported that nowadays these knowledges are mainly preserved by older farmers and are getting lost. The authors highlighted that the inscription of the "Art of dry-stone walling knowledge and techniques" in the in the Representative List of the Intangible Cultural Heritage of Humanity of UNESCO is a strategic start point for the recovery of the traditional skills for the management of

the dry-stone walls. Also, the decision makers involved in our research evidenced this UNESCO's recognition as important opportunity for the enhancement of the cross-border Italian and Switzerland terraced landscapes.

Given the strengths, weaknesses, opportunities and threats for the enhancement of the cross-border terraced landscapes identified by decision makers, during the second part of the research we asked the civil society stakeholders to prioritize them in relation to their specific territories. In order to develop the strategies, we took into consideration all of the four parts that make up the SWOT analysis. Indeed, the strengths and the opportunities require the further improvement of the objects of the items at local and supralocal level respectively. While, the weaknesses and the threats require the development of local, and supralocal specific policies. Furthermore, as described above (Table 4), for all parts of the SWOT, the CS were asked to use their available dots to indicate on which items they would intervene primarily with policies, actions, and financings. The methodology applied and the results achieved allowed us to capture the particular characters of the terraced landscapes considered. We observed similarities and differences between vineyards, agroforestry and meadows terraced landscapes. Considering the results from SWOT analysis made up with DM and the prioritization of the items by CS, alternative and future landscape strategies for the enhancement of the terraced landscapes were identified. They were divided in strategies at cross-border level and specifics for the different land uses (vineyards, agroforestry, meadows). Table 6 synthetizes the strategies identified, considering the results from the SWOT analysis and the prioritization of its items.

Table 6. The alternative and future landscape strategies for the enhancement of the terraced landscapes that emerged as need at cross border Italian and Switzerland level and specifically for the different main land uses of terraces, to be developed at local or supralocal levels (Figures 4 and 5).

Items	Alternative and future landscape strategies for the enhancement of the terraced landscapes
Cross-border Italian and Switzerland	
Attractive cultural landscapes (S.1) High quality of agricultural productions (S.7) Growing demand for experiential tourism (O.2)	• Developing measures for the conservation of the historical elements of terraced landscapes. (1) • Making more attractive for farmers with economic financings the maintenance of traditional agricultural practices and agricultural productions than the others not linked with the territories. (1) • Recognizing the importance of the typical local products. (1) • Developing new local certification marks and improving those that already exist. (1) • Improving the touristic attractivity of the terraces. (1) • Organizing touristic activities. (1) • Training the local touristic operators. (1) • Improving the multifunctionality of the farms. (1) • Participating to national and international programs of enhancement. (1) • Developing specific founds and projects to support the tourism. (2)
Lack of generational change (W.3, T.4)	• Developing policies to support young farmers to maintain the cultivation on terraces. (1) • Dedicating specific founds to encourage young people to maintain cultivated the inherited terraces or buy and recovery the abandoned ones. (2) • Financing young farmers' income and programs with economic resources. (2)
Recognition of ecosystem services (O.4) UNESCO's recognition (O.6)	• Developing policies to recognize the role of the terraced landscapes in ecosystem services provision. (2) • Providing economic measures to farmers in order to manage the terraces and to improve their ecosystem services provision. (2) • Dedicating specific resources, and developing common and shared safeguard plans for the management of the dry-stone walls. (1), (2)

Table 6. *Cont.*

Items	Alternative and future planning strategies for the enhancement of the terraced landscapes
Vineyards	
Bureaucracy and lack of regulatory tools and (T.1)	• Simplifying the bureaucracy regarding the management of vineyards terraced landscapes. (2) • Facilitating the land consolidation. (2) • Simplifying the bureaucracy for property transfer and recovery of abandoned terraces. (2)
Normative related to re-implantation (T.2)	• Reviewing the normative related to the re-implantation of vineyards on terraces, allowing the winegrowers to recover abandoned vineyards and to plant vines without legislative obstructions. (2)
Civil responsibility for farmers (T.5)	• Developing a clear normative regarding the civil responsibility for accidents occurred during touristic activities on terraces, relieving farmers from it. (2)
Agroforestry	
Natural and ecological functions in uncultivated areas (S.8)	• Improving the natural and ecological functions in uncultivated areas. (1) • Managing uncultivated areas in order to avoid the expansion of invasive species, and the obstruction of the drainage system of the dry-stone walls. (1)
Loss ok skills for construction and maintenance of dry-stone walls (W.4)	• Developing the transferability of knowledges about the construction and maintenance of dry-stone walls to the new generations. (1) • Organizing specific courses and financing the formation of professional figures capable to manage the agroforestry terraced systems. (1)
Legislation not clear on “silent terrains” (T.3)	• Developing a specific normative regarding the management of the “silent terrains”, allowing their recovery at productive purposes, inspiring to the territories that at the regional level already have specific tools. (2) • Improving the knowledge of the local communities on the existence of specific tools on “silent terrains” in the territories that can already take advantage of them. (1)

Table 6. *Cont.*

Items	Alternative and future planning strategies for the enhancement of the terraced landscapes
Vineyards and agroforestry	
Hydrogeological risk's containment (S.6)	• Improving the hydrogeological risk's containment capability of terraces. (1) • Developing specific projects of dry-stone walls' management with traditional techniques. (1)
Lack of regulatory tools against the land fragmentation (W.1)	• Developing policies for facilitating the land consolidation. (1) • Stimulating the formation of networks between little and near farms. (1) • Improving the knowledge of the local communities on the existence of specific tools against the land fragmentation in the territories that can already take advantage of them. (1)
Financial policies and economical resources (O.7)	• Improving the multifunctionality of the vineyards and agroforestry terraced landscapes, and their touristic potential. (1) • Developing specific financial policies and economic resources for the enhancement of the terraced landscapes. (2)
Meadows	
Residents' lack of knowledges regarding the public benefits of terraces (W.5)	• Involving residents in the decision processes with participatory approaches. (1) • Increasing the awareness of residents about the public benefits of terraces characterized by meadows. (1) • Organizing meetings, workshop, and conferences on the topic. (1)

(1) Strategy to be developed at local level.
(2) Strategy to be developed at supralocal level.

As shown in Table 6, the attractive cultural landscapes (S.1), the high quality of agricultural productions (S.7), and the growing demand for experiential tourism (O.2) need to be further improved in all of terraced landscapes involved, independently by their main land uses. For doing that it is critical to develop at local level measures for the conservation of the historical elements of the terraced landscapes, that are at the basis of their cultural attractivity. Indeed, the implementation of the municipal master

plans was reported by Andresen and Curado (2003) as the prime local land management instrument for the conservation and the improvement of the terraced landscapes of Douro Valley (Portugal). According to Pomatto et al. (2022b), the permanence of the historical features of the cultural terraced landscapes, can be improved making more attractive for farmers with economic financings the maintenance of traditional agricultural practices and agricultural productions than the others not linked with the territories. Moreover, the high costs faced by farmers to maintain these poor mechanizable systems can be rewarded trough the recognition of the quality of the products by the market thanks to the certifications of quality (Borrello et al., 2022). For this reason, the importance of the typical local products has to be recognized developing new local certification marks (e.g. municipal designations of origin), and further improving those that already exist (e.g. Denomination of Controlled Origin, Protected Geographical Indication). The growing demand for experiential tourism is an opportunity that requires the improvement of the touristic attractivity of the terraces. To organize touristic activities linked to the attractive cultural landscapes and their high-quality agricultural productions is an important future strategy. As discussed above, it is also necessary to train the local touristic operators. Another critical strategy is represented by the improvement of the multifunctionality of the farms. Terkenli et al. (2018) reported that in Valtellina, which is one of the study areas considered in our research, this topic linked to the tourism is considered a priority. Finally, according to Pomatto et al. (2022a), in order to facilitate the knowledge about these landscapes outside the systems, it is important to participate to programs of enhancement at supralocal level: national (e.g. National Register of Historical Rural Landscapes for Italy), and international (e.g. GIAHS/FAO Program). Finally, the growing demand

for experiential tourism needs to be supported at supralocal level with specific founds and projects. Instead, to contrast the lack of generational change (W.3, T.4) the first one strategy is to develop local policies to support young farmers to maintain the cultivation on terraces. Secondly, it is important to dedicate at supralocal level specific founds to encourage young people to maintain cultivated the inherited terraces or buy and recovery the abandoned ones. Indeed, the unprofitable terraced cultivations, the difficulty working on terraces and their difficult accessibility make specific policies necessary. In this context, financing young farmers' income and programs and founding economic resources are the way to support the future agricultural activity on terraces. Indeed, for maintaining the cultivations over time, and to support the young farmers activity it is imperative to increase the local economy and to establish financial support to private farmers above all young. Furthermore, independently to the main land uses, emerged also the need to further improve the recognition of ecosystem services provided by the cross-border Italian and Switzerland terraced landscapes (O.4). It is a challenge recognized by many authors (Bieling and Plieninger, 2013; Yuan et al., 2022). A useful strategy is to develop at supralocal level policies aimed at the recognition of the important role of the terraced landscapes in ecosystem services provision. Indeed, providing economic measures to farmers in order to manage the terraces, and to improve their ecosystem services provision is critical. Finally, in all of the study areas it is necessary to dedicate specific local and supralocal resources, and to develop common and shared safeguard plans for the management of the dry-stone walls in order to take the opportunity of the UNESCO's recognition (O.6).

Regarding vineyards terraced landscapes emerged the necessity of some specific strategies (Table 6). The first ones are aimed at solving the bureaucracy and lack of regulatory tools at supralocal level (T.1). It is in line with the literature which recognizes that the excessive bureaucracy is often a disincentive for farmers (Gennai-Schott et al., 2020). A good strategy is to simplify at supralocal level the bureaucracy regarding the management of vineyards terraced landscapes. Also, it is critical to facilitate the land consolidation, and to simplify the bureaucracy for property transfers and recovery of abandoned terraces, especially for young farmers. Another strategy for vineyards terraced landscapes is aimed at reviewing at supralocal level the normative related to the re-implantation of vineyards on terraces (T.2). Allowing the winegrowers in this condition to recover the abandoned vineyards and to plant vines without legislative obstructions is imperative. Indeed, in Italy the national normative establish that before planting a new vineyard the winegrower must require the authorization, that is granted only for a maximum of hectares previously defined at the national level every year (Masaf, 2022). It is clear that in terraced contexts, where the recovery of abandoned surfaces is a priority, these limitations are damaging. Finally, a threat to be solved especially in vineyards terraces is the civil responsibility for farmers for accidents occurred during touristic activities (T.5). It makes necessary the development at supralocal level of a clear normative regarding the topic, relieving farmers from the responsibility. Indeed, the literature recognizes that vineyards terraced landscapes are particularly appreciated by tourists (Santoro et al., 2020). However, the civil responsibility for accidents make the winegrowers afraid to make available their terraces for touristic activities.

In agroforestry terraced landscapes it has been evidenced that the main needs are related to the development of strategies aimed at avoid the further abandonment of terraces, and the loss of their multiple values (Table 6). Firstly, it is necessary to further improve the natural and ecological functions in uncultivated areas (S.8). A good strategy could be to manage these contexts at local level in order to avoid the expansion of invasive species, and the obstruction of the drainage system of the dry-stone walls. According with this, in these contexts often characterized by the abandonment, also emerged the necessity to prevent the loss ok skills for construction and maintenance of dry-stone walls (W.4). So, it is necessary to develop the transferability of knowledges about the construction and maintenance of the dry-stone walls to the new generations. With this aim it is useful to organize at the local level specific courses and financing the formation of professional figures capable to manage the agroforestry terraced systems. Finally, the legislation not clear on "silent terrains" (T.3) is a dangerous threat in contexts particularly affected by the abandonment of the cultivations. Indeed, the presence of abandoned lands where either the owners have died, or where the current owners are not recognized, constitutes a big problem for the entire terraced systems. It makes critical the development at supralocal level of a specific normative regarding the management of the "silent terrains", allowing their recovery at productive purposes. The Italian Piedmont Region has legislated since 2016 on this topic, promoting the formation of "land associations" (Regional Law nr. 21, 2nd November 2016). Surprisingly, the civil society stakeholders of the two study areas belonging to this region (above all Ossola Valley, but also Val Grande National Park) reported this threat as priority to be solved. This result makes it clear that it is also necessary to improve the knowledge of the local communities on

the existence of specific tools on “silent terrains” in the territories that can already take advantage of them.

The results of the territorial prioritization of the items of the general SWOT suggested that some priorities are common among terraced landscapes characterized by vineyards and agroforestry. Probably, it is due to the strictly connection among them, since in some study areas the agroforestry is the consequence of the abandonment of terraces once dedicated to the viticulture. Firstly, as shown in Table 6, in these contexts the further improvement at local level of the hydrogeological risk’s containment (S.6) capability of terraces is a priority. Using a participatory spatial SWOT analysis Gkoltsiou and Mougiakou (2021) defined strategic plans and sustainable development strategies. For terraced hinterland areas, the authors identified as guidelines the maintenance and the restoration of the abandoned terraces and the conservation of traditional agricultural practices. Sakellariou et al. (2021) underlined the importance of guarantee the preservation of this important function of the terraced landscapes, avoiding their structural damage. Therefore, it is necessary to develop specific projects of dry-stone walls’ management with traditional techniques, above all in areas particularly critical for the public safety (proximity to infrastructures or inhabited centres). Other criticalities to be solved at local level emerged in vineyards and agroforestry terraced landscapes is the lack of regulatory tools against the land fragmentation (W.1). To solve this weakness, it is necessary to develop at local level policies for facilitating the land consolidation and stimulate the formation of networks between little and near farms on terraces dedicated to viticulture or agroforestry. Also, in this case the CS belonging by the study areas included in the Piedmont Region, which is equipped by the specific law cited above, underlined the need to further improve policies at local

level on this topic. It is therefore useful to improve the knowledge of the local communities on the existence of specific tools against the land fragmentation in the territories that can already take advantage of them. Finally, it was evidenced that in vineyards and agroforestry terraced landscapes it is necessary to advantage of the opportunity of financial policies and economic resources at supralocal level (O.7). Further improve the multifunctionality of these systems and their touristic potential, and developing at supralocal level specific financial policies and economic resources for the enhancement of the terraced landscapes are good strategies.

To oppose the residents' lack of knowledges regarding the public benefits of terraces in meadows terraced landscapes (W.5), we think that their involving in the decision processes using participatory approaches is a fundamental strategy. For historical landscapes, this need was also outlined by Aimar et al. (2021). The authors have expressed the importance to apply multidisciplinary studies supporting the inclusion of participatory approaches. For these reasons in these contexts it is also useful to increase the awareness of residents about the public benefits of terraces, and to organize at local level meetings, workshop, and conferences on the topic (Table 6).

5. Conclusions

In this research, we have analyzed and compared historical terraced landscapes in the European Alpine Region. We have analyzed the main strengths, weaknesses, opportunities and threats perceived by focus group participants in relation to the enhancement of the cross-border Italian and Switzerland terraced landscapes. Focus group participants (DM and CS)

have outlined the priority importance to manage and conserve the terraced structures as walls by carrying out recovery and rural development projects both locally, nationally, and internationally. The terraced study areas considered are characterized by distinctive architectural and historical features, agricultural systems, land uses, cultivation practices, productions, and traditional cultivations techniques. DM and CS think that terraced systems play different roles and perform important functions. Indeed, they recognize to these structures social, environmental, and ecological values. Nowadays some of them continue to be managed, others are residually cultivated, while still others are completely affected by the abandonment processes.

We think that the effective planning for manage terraced landscapes requires approaches that integrate the plurality of stakeholder values. The methodological framework used in our study allowed us to identify common and specific strengths, weaknesses, opportunities and threats that should be translated in tangible actions and rural development plans. Moreover, the research has demonstrated that the recognition of items is a primary step in effectively informing future strategies and policies for rural land management and planning. This methodology is an aid decision-making tool for land use policy, planning, design and management of terraced landscapes in the European Alpine Region, that could be replicated in future in other terraced contexts.

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Chapter VI

Conclusions and Future Perspectives

The research achieved the key goal of analyze, evaluate, and increase the knowledge about the historical rural heritage constituted by the terraced landscapes in the European Alpine Region. The study focused on the terraced systems of the Northwest Italian Alpine Arc (Piedmont, Aosta Valley, Lombardy and Liguria Regions), and two cross-border terraced landscapes of Switzerland. The knowledge was integrated during experiences in Portugal and Spain, in the context of international conferences and scientific exchanges.

The first aim of the research was the development of an innovative scientific methodological approach from the characterization to the dynamic conservation of the terraced landscapes, replicable in other similar contexts internationally. It was developed across the Chapters from II to V, and was applied at different case studies. The methodology allowed to link the expert-based assessment with the participatory evaluation, since considered the perception and perspectives of rural communities as a priority. Indeed, according to the GIAHS-FAO approach, the historical landscapes and the humans coevolved together (Wang et al., 2021). This strictly connection was explored in detail in Chapter III, applying the methodology in the vineyard terraced landscape of the Ivrea Morainic Amphitheatre. The analysis was carried out through the administration of an online questionnaire to winegrowers. They showed a high awareness about the identity elements of the terraced landscape. The answers allowed to evaluate the future development prospects as perceived by them. Indeed, for the future almost all winegrowers prefer the maintenance of the historical landscape elements, although some of them do not consider this

condition the most likely in the future. This finding made evident the need of future landscapes strategies to support the historical cultivations and agricultural practices.

The second aim of the research was the analysis of the historical elements of the terraced landscapes (Chapters II and III). In line with Deng et al. (2021), it was observed that terraced landscapes are characterized by many values and some threats. During the field inspections and meetings with the farmers, was noted that they support multiple historical land uses, linked to the agriculture for foods, or flowers and ornamental cut fronds production (Chapter II). In some Italian regions considered, terraces are particularly dedicated to one land use, as for example in Aosta Valley where they are mainly related to the viticulture. While, in others the terraced landscapes are complex mosaics of different land uses. Indeed, in Liguria Region on terraces were observed vineyards, olive groves, citrus groves, horticultural and ornamental crops. They take advantage of the Mediterranean climate and their compresence is due to the historical socioeconomic characteristics of the region. On the other hand, some terraced landscapes showed high levels of abandonment, where the agricultural crops have been almost completely replaced by the invasion woodlands (e.g. Monte Barro, Lombardy and Val Grande, Piedmont).

The third aim of the research was the evaluation of the dynamics and their landscape impact. The analysis was performed in qualitative terms in Chapter III and in quantitative terms in Chapter IV. The land use dynamics observed were related to the abandonment or to the introduction of more modern agricultural systems, where it is possible. It is in line with the European trend, where regarding vineyards, in recent times were introduced more modern vine breeding techniques than the traditional

(Santoro et al., 2021). The research outlined that some of these dynamics bring to little impact on the perception of the terraced landscapes, as for example the small changes with the partial use of wires in place of wooden poles in the *pergola caremiese*, Piedmont (Chapter III). While other dynamics are changing completely the aesthetic values of the landscapes. It is the case of the replace of vine pergolas with espaliers, detected both in the Ivrea Morainic Amphitheatre (Piedmont) and in Cinque Terre (Liguria). Similarly, the change of crops (e.g. olive groves in place of vineyards) or the invasion of shrublands and woodlands affect the historical values of the terraced landscapes. Besides that, the abandonment causes the several problems described of hydrogeological instability Furthermore, the assessment of the terraced landscape's integrity whit high-level of detail and the cartographic analysis carried out with QGIS software, were useful tools (Chapter IV). A detailed mapping of terraces (land use and linear extension of the dry-stone walls) was produced, also contributing to increase the terraced landscapes mapping, already underlined as a lack at the national level (Varotto et al., 2019).

The last aim of the research was the development of future landscapes strategies for recover and strength the terraced landscapes (Chapter V). The knowledges acquired through the analyses and evaluations of the terraced landscapes, performed from Chapter II to IV, were further debated with the decision makers and the civil society stakeholders. Indeed, their active participation in rural landscape planning and management is considered a priority by many authors (Rizzo et al., 2022; Shirvani Dastgerdi and Kheyroddin, 2022). For this reason, in Chapter V a participatory methodology was applied to the terraced landscapes of the European Alpine Region belonging to the cross-border Italian and Switzerland terraced landscapes. Different online focus groups with the

local communities were organized. The SWOT analysis made up with the decision makers highlighted the Strengths, Weaknesses, Opportunities and Treats for the enhancement of the terraced landscapes. While the territorial prioritization performed with the civil society stakeholders outlined the need of landscape strategies common to all of the terraced landscapes, and others influenced by their main land uses.

The outcomes allowed also to verify the assumption of the PhD research that the terraced landscapes are historical rural heritages, in continuous coevolution with man, to dynamically conserve. Indeed, the research confirmed that the development of landscapes strategies aimed at reconciling the historical biocultural values with the current needs is a priority. The high-quality of the terraced landscapes products needs to be recognized in order to reward the farmers for the big efforts done for cultivating in these contexts. Ferreira and Sánchez-Martín (2022) reported the strategic role of agritourism promotion for the enhancement of the terraced landscapes in the cross-border Iberian Regions. Similarly, the PhD research detected the need of the experiential tourism improvement.

In this context, the dynamism that characterizes the rural landscapes need to be recognized. A static conservative approach, that considers the terraced landscapes as museums, cannot be adopted. By contrast, their dynamic conservation is recommended. With this perspective, the innovations required by the current needs have to be accepted. It is the case of the innovative technological machines in course of experimentation in the cross-border Italian and Switzerland terraced landscapes, as evidenced by the decision makers. Similarly, the cited small changes of the *pergola caremiese* allow to optimize the treatments of the vines, reducing their environmental impacts and coasts for farmers. However, the future

landscapes strategies will have to promote the historical values of the terraced landscapes. Indeed, making more attractive for farmers, with economic founding support, the maintenance of the historical landscapes elements than the others not linked with the territories is a challenge. The PhD results confirmed that the future landscape strategies must be aimed at limiting the abandonment of terraces and at encouraging their recovery.

The theme of the innovation respectful of the historical values of the terraced landscapes need to be further explored in the future. Sustainable agronomic techniques will have to consider the future challenges related to the environmental, social, and economic needs. Praticò et al. (2022) recognized that specific planning measures, including the technological innovation, will improve the stability of these contexts. Dimopoulos et al. (2023) reported the necessity of programs and participatory rural planning processes aimed at developing multiple level and integrated enhancement policies. According to Zoumides et al. (2022), these policies will have to be targeted, effective, and determined by the sites-specific characteristics. Following these indications, the terraced landscapes will continue to transmit their historical rural heritages to the future generations.

In conclusion, the PhD research faced whit the theme of the terraced landscapes recovery and strength, considering different case studies in which the developed methodology was applied. It contributed to the scientific international debate on the topic, increasing the knowledge, providing an innovative approach replicable in other terraced landscapes in the European Alpine Region, and developing future landscapes strategies. The methodology can be further improved in future, considering other case studies, and evaluating the application of the developed strategies.

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Summary

With the key goal of analyze, evaluate, and increase the knowledge about the historical rural heritage constituted by the terraced landscapes in the European Alpine Region, the aims of the research were: (I) to develop an innovative scientific methodological approach from the characterization to the dynamic conservation of the terraced landscapes, through expert-based assessment and participatory evaluation, (II) to analyze the historical elements of the terraced landscapes, (III) to evaluate the dynamics and their landscape impacts, (IV) to develop future landscapes strategies for recover and strength the terraced landscapes.

The developed methodology was integrated, interdisciplinary, and considered a multiscale approach. Experts performed cartographical analyses using QGIS software, historical and archival analyses, and field inspections. The local communities were involved with online questionnaires and focus groups. During these meetings the SWOT analysis and the cumulative voting method were experimented.

The results allowed to achieve the aims of the research, and showed that the terraced landscapes considered are characterized by different states of conservation, due to some dynamics of change less or more impacting on the historical elements of the landscapes. According to the GIAHS-FAO approach, their conservation needs an holistic and dynamic perspective. Alternative and future landscape strategies were developed. Some of them are common for all terraced landscapes considered, while others are specific and influenced by their main land uses. Their application in the terraced landscapes will allow the recovery and strength of the historical rural heritage in the European Alpine Region, and the continuous livelihood of the rural communities.

Other activities carried out during the PhD

Publications on ISI/Scopus Journals (* corresponding author)

Pomatto E.*, Gullino P., Novelli S., Devecchi M., Larcher F. Landscape Strategies Making for Terraced Landscapes in the European Alpine Region Using a Mixed-Method Analysis Tool. Submitted to ISI/Scopus Journal.

Pomatto E.*, Devecchi M. and Larcher F., 2022. Assessment of the Terraced Landscapes' Integrity: A GIS-Based Approach in a Potential GIAHS-FAO Site (Northwest Piedmont, Italy). Land 11(12), 2269. DOI: 10.3390/land11122269.

Pomatto E.*, Devecchi M. and Larcher F., 2022. Coevolution between Terraced Landscapes and Rural Communities: An Integrated Approach Using Expert-Based Assessment and Evaluation of Winegrowers' Perceptions (Northwest Piedmont, Italy). Sustainability 14(14), 8624. DOI: 10.3390/su14148624.

Larcher F., Pomatto E.*, Battisti L., Gullino P. and Devecchi M., 2021. Perceptions of Urban Green Areas during the Social Distancing Period for COVID-19 Containment in Italy. Horticulturae 7, 55. DOI: 10.3390/horticulturae7030055.

Gullino P., Pomatto E., Gaino W., Devecchi M. and Larcher F.*, 2020. New Challenges for Historic Gardens' Restoration: A Holistic Approach for the Royal Park of Moncalieri Castle (Turin Metropolitan Area, Italy). Sustainability 12, 10067. DOI: 10.3390/su122310067.

Battisti L., Pomatto E., and Larcher F.*, 2020. Assessment and Mapping Green Areas Ecosystem Services and Socio-Demographic Characteristics in Turin Neighborhoods (Italy). Forests 11(1), 25. DOI: 10.3390/f11010025.

Publications on Book Chapter

Pioletti A.M., Devecchi M., Pomatto E., Privitera D. (2021). Il paesaggio vitato eroico: esperienze di eredità tra Valle d'Aosta e Sicilia. In: Castiglioni B., Puttilli M., Tanca M. (a cura di) Oltre la Convenzione: pensare, studiare, costruire il paesaggio vent'anni dopo. Società di Studi Geografici. ISBN: 9788890892677.

Publications on Conference Proceedings

Pomatto E., Gullino P., Devecchi M. and Larcher F., 2022. Assessment of heroic terraced landscapes in Aosta Valley (Italy) using a holistic approach. In: Wolski J., Regulska E., Affek A., Editors, 2022. *IALE 2022 European Landscape Ecology Congress Book of Abstracts*. Institute of Geography and Spatial Organization, Polish Academy of Sciences, Warsaw, Poland. DOI: https://doi.org/10.7163/Konf.0004 ISBN: 978-83-61590-99-6.

Pomatto E., Gullino P., Devecchi M. and Larcher F., 2022. Heroic viticulture and terraced landscapes' characterization: the case study of Aosta Valley (Italy). In: Baptista A., Editor, 2022. *Extreme viticulture: from a cultural landscape to an economic and environmental sustainability - Book of proceedings*. Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal. ISBN: 978-989-704-471-7.

Pomatto E., Devecchi M., Larcher F. and Gullino P., 2022. Agriculture and natural resources for valorizing peri-urban historical landscapes: the case study of Stupinigi Royal Natural Park (Metropolitan City of Turin, Italy). In: Romano D., Bretzel F. and Toscano S., 2022. *Proceedings of the VIII International Conference on Landscape and Urban Horticulture*. Acta Horticolturae 1345, pp. 91-96. DOI: 10.17660/ActaHortic.2022.1345.12.

Larcher F., Battisti L., Pomatto E. and Devecchi M., 2021. Woody species and supporting ecosystem services: the case study of the city of Turin (Italy). In: Scariot V. and Beccaro G.L., Editors, 2021. *Proceedings of the IV International Symposium on Woody Ornamentals of the Temperate Zone*. Acta Horticolturae 1331, pp. 181-186. DOI: 10.17660/ActaHortic.2021.1331.25.

Presentations at International Conferences (* presenting author)

IALE 2022 European Landscape Ecology Congress. Making the Future, Learning from the Past. Online, 11-15 July 2022.

Oral presentation: *Assessment of heroic terraced landscapes in Aosta Valley (Italy) using a holistic approach*.

Pomatto E.*, Gullino P., Devecchi M., Larcher F.

VII International Congress on Mountain and Steep Slopes Viticulture. Vila Real (Portugal), 11-14 May 2022.

Poster presentation: *Heroic viticulture and terraced landscapes' characterization: the case study of Aosta Valley (Italy).*

Pomatto E.*, Gullino P., Devecchi M., Larcher F.

VIII Conference on Landscape and Urban Horticulture. Online, 15-17 December 2021.

Oral presentation: *Agriculture and Natural Resources for Valorizing Peri-Urban Historical Landscapes: The Case Study of Stupinigi Royal Natural Park (Metropolitan City of Turin, Italy).*

Pomatto E.*, Devecchi M., Larcher F., Gullino P.

5th European Agroforestry Conference. Agroforestry for the transition towards sustainability and bioeconomy. Online, 17-19 May 2021.

Oral presentation: *Enhancing Terraced Landscapes for Ensuring a Sustainable Development of Traditional Agroforestry Systems. A Case Study in Piedmont (Italy).*

Pomatto E.*, Gullino P., Devecchi M., Larcher F.

IV International Symposium on Woody Ornamentals of the Temperate Zone. Online, 3-4 March 2021.

Poster presentation: *Urban shrubs and ecosystem services: the case study of the City of Turin (Italy).*

Larcher F., Battisti L., Pomatto E.*, Devecchi M.

Presentations at National Conferences (* presenting author)

III Convegno AISSA#UNDER40. Bolzano, 14-15 July 2022.

Oral presentation: *Evaluation of different ornamental perennial species combinations for weeds' containment in the urban environment*.

Pomatto E.*, Caser M., Gaino W., Devecchi M., Larcher F.

Congresso Nazionale SIEP-IALE. I Paesaggi Italiani verso il 2030: identità, cura e prospettive. Palermo, 25-27 November 2021.

Oral presentation: *Caratterizzazione partecipata dei paesaggi terrazzati della viticoltura eroica: casi studio nell'Arco Alpino*.

Pomatto E.*, Gullino P., Devecchi M., Larcher F.

XIII Giornate Scientifiche SOI: I traguardi di Agenda 2030 per l'ortoflorofrutticoltura italiana. Online, 22-23 June 2021.

Oral presentation: *Valutazione dell'interazione tra diverse combinazioni di specie erbacee perenni ornamentali nel contenimento delle infestanti*.

Pomatto E.*, Devecchi M., Larcher F.

Attending to Conferences

- 1° Convegno Nazionale di Orticoltura e Floricoltura SOI. Pisa, 14-16 June 2022.
- 2020 UNISCAPE International Conference - 20th Anniversary Celebration of the European Landscape Convention. *Cultivating Continuity of the European Landscape. New Challenges, innovative perspectives*. Online, 16-17 October 2020.
- Convegno Le Mappe dei Paesaggi Rurali per la Valorizzazione e la Salvaguardia delle Attività e delle Tradizioni Agricole delle Comunità Locali. Torino, 15th October 2020.
- 5° Conferenza Internazionale sui Parchi e Giardini Storici. *Interventi contemporanei nei parchi e giardini storici*. Online, 17th and 24th July 2020.
- Il futuro dei terrazzamenti sul territorio del Montalbano tra criticità e sviluppo. Cerreto Guidi, 22nd February 2020.

Attending to Seminars

- Riqualificazione green delle realtà urbane: esperienze di ricerca nel settore florovivaistico. Agliè, 29th June 2022, duration 1 hour.
- A placed based approach to rural landscape planning. Methods and applied experiences. Turin, 26th May 2022, duration 2 hours.
- Il Ruolo dell'Ecologia del Paesaggio nei e per i Paesaggi dell'Antropocene. Online, 23 May 2022, duration 6 hours.
- Viticoltura Eroica, Montagna e Territorio un Legame Imprescindibile. Darfo Bario Terme, 23th April 2022, duration 3 hours.
- I Paesaggi Vitivinicoli Italiani. Online, 14th March 2022, duration 4 hours.
- English Scientific Writing for Italians. Grugliasco, 27th January 2022, duration 1 hours.
- Seminar cycle: Incontri con il Paesaggio 2021/2022. Online, duration 11 hours.
- Mediterranean Diet and Agricultural Heritage: the flavours of the land, (FAO). Online, 28th May 2021, duration 2.5 hours.
- Seminar cycle: Quale Futuro per i Paesaggi Urbani? Sfide e Prospettive. Online, 20th, 24th and 26th May 2021, duration 6 hours.
- Rilevamento remoto e nuove applicazioni in viticoltura: primi risultati in vigneti canavesani. Online, 15th May 2021, duration 2.5 hours.
- Seminar cycle: Un Ora di Verde. Agliè 2021, duration 4 hours
- Analysing green places in your city with Copernicus. Online, 27th April 2021, duration 1 hour.
- Living walls come soluzioni per l'ecosistema urbano. Grugliasco, 20th April 2021, duration 2 hours.

- Il Piano Paesaggistico nell'Eporediese: la Ricerca. Online, 15th April 2021, duration 3.5 hours.
- I Paesaggi Olivicoli Italiani biodiversi e identitari. Online, 15th March 2021, duration 3 hours.
- Fostering engagement in the Earth observation and Geographical Information sector through EIT Climate - KIC activities. Online, 11th February 2021, 1 hours.
- Globally Important Agricultural Heritage Systems and Ecosystem Restoration (FAO). Online, 26th January 2021, 2 hours.
- Il Patrimonio Agricolo Mondiale (GIAHS) – L'Agricoltura Italiana e il Futuro del Pianeta. Online, 21st January 2021, duration 2 hours.
- Valutare e valorizzare il paesaggio rurale. Metodi, strumenti, esperienze. Online, 27th November 2020, duration 3 hours.
- Seminar cycle: Incontri con il Paesaggio 2020/2021. Online, duration 12 hours.
- Obiettivi e proposte per una transizione sostenibile nell'era dell'Antropocene. Online, 13th October 2020, duration 1 hour.
- P come Paesaggio. Tutela, Valorizzazione e Pianificazione per un Piemonte Sostenibile. Online, 9th July 2020, duration 4 hours.
- Quali prospettive per il territorio astigiano dopo il lockdown per COVID-19? Online, 19th June 2020, duration 1.5 hours.
- Da UNESCO e FAO nuovi strumenti per la valorizzazione dei paesaggi viticoli eroici. Forte di Bard, 1st December 2019, duration 2 hours.
- Storia ed ecologia dei paesaggi agrari e forestali in Italia. Turin, 7th November 2019, duration 2 hours.

Participation to Research Projects

- Scholarship research projects titled: *Sviluppo di attività scientifico-didattiche sui temi delle aree verdi e del paesaggio* (Supervisor Prof. Marco Devecchi, University of Turin, duration 8 months from 8th August 2022).
- Scholarship research projects titled: *Innovazione tecnologica a supporto della tradizione versus il cambiamento climatico nel Sito UNESCO* (Supervisor Prof. Federica Larcher, University of Turin, duration 7 months from 27th December 2021).
- Scholarship research projects titled: *Studio dei paesaggi agrari terrazzati* (Supervisor Prof. Federica Larcher, University of Turin, duration 14 months from 26th October 2020).
- Scholarship research projects titled: *Valorizzazione e fruizione del parco storico del castello di Moncalieri come esperienza di studio e didattica* (Supervisor Prof. Federica Larcher, University of Turin, duration 7 months from 23th March 2020).
- Project for the research support titled: *ROSARUM – Realizzazione di un roseto sperimentale per la conservazione del patrimonio rosicolo storico del Basso Monferrato nella Fortezza di Verrua Savoia* (Supervisor Prof. Valentina Scariot, University of Turin, December 2019).

Attending to Courses

- Bibliography and Bibliometry (20 hours).
- Advanced Statistics (40 hours): Mixed Models, Correspondence analysis, Multivariate statistics of Ecological data, Cluster Analysis, Time series analysis and prediction in R.

- Academic English (30 hours).
- Result dissemination (24 hours): Drafting images for scientific purposes, Ethics in publication, The Editors' opinion, Scientific communication and social networks.
- The research context (2 hours)
- Adaptation of Food/Non-food Crops and Forests to Climate Change (16 hours): Climate and climate change, The role of Remotely Sensed Open Data for mapping climate change effects.
- Transizione sostenibile. Le nuove prospettive del periurbano. Organized by Regione Piemonte.

Educational Activities

- Co-supervisor of a three-year degree thesis at the Department of Agricultural, Forest, and Food Sciences, University of Turin (2022). Degree course in Agricultural Sciences and Technologies (L25). Title: Terraced Rural Landscapes as a Bio-cultural Heritage to be Preserved. Supervisor: Prof. Federica Larcher.
- Seminar given in the context of the Atelier of Landscape Planning – Module of Rural Landscape Planning at the Interuniversity Department of Regional and Urban Studies and Planning, Polytechnic of Turin. Title: Paesaggi terrazzati tra valori, criticità e prospettive di valorizzazione. Responsible of the module: Prof. Federica Larcher.
- Collaboration in the context of the Laboratory of Landscape Ecology at the Department of Agricultural, Forest, and Food Sciences, University of Turin (2020-2022). Degree course in Agricultural Sciences and Technologies (L25). Responsible of the Laboratory: Prof. Federica Larcher.

Other Activities

- Revisor for research papers on ISI/Scopus Journals (Landscapes Research, Land, and Heritage).
- Member of the organizing and scientific committee of the course titled: Rethinking the Future for the better: environment and social inclusion in scientific events (Italian Society of Landscape Ecology, November 2022).
- Member of the organizing committee of the Summer School titled: *Il paesaggio: 100 anni di strategie di tutela e valorizzazione* (University and Polytechnic of Turin, September 2022).
- Member of the organizing committee of the seminar cycle titled: *Quale Futuro per i Paesaggi Urbani? Sfide e Prospettive* (Italian Society of Landscape Ecology, May 2021).
- Member of the Editorial Board of the Proceedings of the VII Conference on Landscape and Urban Horticulture, IV Conference on Turfgrass Management and Science for Sports Fields and II Symposium on Mechanization, Precision Horticulture, and Robotics Istanbul, Turkey, 2018. Acta Horticulturae 1279 (2020). ISBN 978 94 6261 279 2.

Awards

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