CENTENARY OF THE OIV
45th WORLD CONGRESS OF VINE AND WINE
14-18 OCTOBER 2024 FRANCE-DIJON
OIV

Available on | IVES Conference Series vine & wine

DOI : https://doi.org/10.58233/GhQUn7vo

Vitiforestry as innovative heritage. Adaptive conservation of historical wine-growing landscapes as response to XXI century's challenges.

Bianca Maria Seardo[1]

[1]Study and Research Centre for Mountain Wine Landscapes owned by Figliej Winery

Abstract. Traditional agricultural and agro-pastoral systems (prior to industrial revolution) often have the characteristic of being *multiple* systems, in which multiple crops are hosted simultaneously on the same plot. These agro-systems have usually shaped landscapes now recognized worldwide worth of conservation. Currently research suggests to study more in depth the potential of multiple agro-systems that could allow modern viticulture to adapt to the challenges posed by climate change. Integrating apparently distant fields of research on agronomy and landscape studies, the paper suggests that some adaptive approaches and techniques for viticulture facing the climate change may find reference in traditional wine-growing landscapes that already adopt solutions of multiple use of the cultivated land, namely: i) vineyard intercropping; ii) permanent natural grass cover in the vineyards and their managing through grazing; iii) woodlands surrounding the vineyards; iv) historical pergola training system. Structural and spatial shifts towards higher lands in the viticultural potential of many wine regions affected by climate change put in light that wine-growing landscapes could be under pressure, but from historic rural landscapes (new) conditions for adaptation could arise.

1. Challenges posed to wine-growing and landscape conservation by climate change

This paper aims to pose some issues that link two apparently distant fields of research: wine-growing and landscape heritage conservation.

As an "urban/rural" divide exists, also an "agricultural/forestry" divide has been highlighted in land studies [1]; moreover a similar gap between agronomic development and landscape management has been addressed by different authors both in land studies [2] and at the policy level [3].

Furthermore the occurrence of increasingly extreme climate events that exacerbate the need to adapt production techniques in the agricultural field, increasingly shows the distance between super-productivist [4] and conservationist thinking.

The most consistent features triggered by global warming on wine-growing are widely treated in current literature and a partial list [5] can be the following: longer growing season, earlier phenology, faster ripening, higher incidence of overheating stress and sunburn, higher frequency of extreme weather events. Undoubtedly also spatial shifts in the viticulture potential of main wine regions as effect of climate change can be already detected [6].

Beyond this, while agriculture system may be more flexible, landscape heritage policies face the hard task to preserve a fixed heritage in a fast changing world as intactness and integrity have been the foundation of conservation principles in a stable environmental context [7]. In such heritage landscapes the mission is twofold: on the one hand to preserve the characterizing aspect that confers the element of outstanding value, on the other hand maintain the agricultural activity - shaping that same landscapes - alive.

Traditional agricultural and agro-pastoral systems (prior to industrial revolution) often have the characteristic of being *multiple* systems, in which multiple crops are hosted simultaneously on the same plot. Vine intercropping has long shaped the rural landscapes of Southern Europe and other parts of the world as peasant agriculture has survived, but this practice has been largely abandoned for the need of crop specialization and increasing yield and quality.

Currently research suggests to study more in depth the potential of multiple agricultural systems in order to detect those embedded characteristics that could allow nowadays viticulture to adapt to the challenges posed by climate change. In the view of many, agroforestry could actually respond to the global need to increase food production

whilst improving also socio-environmental benefits (i.e. the stocking of greenhouse gases, regeneration of soil nutrients, preservation of landscape complexity and biodiversity), tending to the so-called "sustainable intensification" [8].

1.1. Definying agroforestry and vitiforestry

Definition given by the AGFORWARD project [1] states that agroforestry is ''the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions''. It is in agreement with the one proposed by the FAO [9], which also adds that agroforestry "diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels". The European Commission gives a "landscaping" definition of agroforestry, a land-use system "where...the trees may be arranged as single stems, in rows or in groups, while grazing may also take place inside parcels (silvoarable agroforestry, silvopastoralism, grazed or intercropped orchards) or on the limits between parcels (hedges, tree lines)" [10].

Different agroforestry systems are actually identified: arable agroforestry, livestock agroforestry or silvopasture systems combining woody with forage and animal production, high value tree agroforestry, homegarden systems, forest gardening, windbreak and riparian buffer systems [11].

Many types of traditional agroforestry systems have been described, for example: the Dehesa (in South Western Spain) and Montado (in Portugal) [12] known as rangelands occupied by scattered oak trees and recurrent cereal cropping, an orchard-like system also producing feed-stuff for domestic animals and forestry resources; the Streuobst in temperate Europe [13] consisting of tall trees of different types and varieties of fruit, belonging to different age groups, which are dispersed on cropland, meadows and pastures in a rather irregular pattern.

Methodological in-depth analysis propose different classifications of agroforestry systems based respectively on their: components, spatial and temporal arrangement, function, agro-ecological zone and socio-economic aspects [11].

Vitiforestry is a less defined concept across the literature; generally it refers to different patterns where vine cultivation is combined in mixed systems encompassing other trees, shrub or grass cover, even grazed.

1.2 Extent of agroforestry...and vitiforestry?

Estimates on the extent of agroforestry depend on the concept definition, the scale, the spatial resolution of the available data and the type of analysis.

Zomer et al. [14] found that the global extent of agroforestry covers more than 43% of all agricultural land globally and interests more than 900 million people.

Den Herder et al. [15] made an attempt to quantify more precisely agroforestry extent in Europe 27 finding it is about 15.4 million ha, the equivalent of 8.8% of the utilized agricultural area, with livestock agroforestry largely prevailing on arable and high value tree agroforestry. Spain, France, Greece, Italy, Portugal, Romania and Bulgaria show the largest absolute area. Mosquera-Losada et al. [16] calculated that European agroforestry occupies 19.77 million ha most of which (about 90%) linked with silvopasture practices, homegardens (8.35%) and silvoarable (less than 1%). No data are available for forest farming, whereas riparian buffer strips and hedgerows cover 1.8 million ha.

The datasets available for mapping multiple systems are under development and the data they collect show a sufficient approximation when considering nation-scale territories. The search for spatial information on multiple systems encompassing vineyards appears – from the researches just described – even more difficult although these have been a traditional practice especially in the Mediterranean area.

Moreover, if on the one hand mixed systems have been declining in favor of monocultural land uses, on the other hand in some geographical contexts agroforestry systems are no longer recognised, therefore not mapped even if they exist [17].

2. Matching landscape conservation and climate change adaptation in terraced vineyards in Italian Alps, a study-case

2.1. A historical but not recognized vitiforestry landscape

Traditional wine-growing landscapes are still present in Europe, especially in mountain or hill areas which have remained on the margins of the intensive development of modern viticulture. Several wine-growing landscapes are protected under world lists (UNESCO, FAO), but any of them is focussed on the preservation of traditional complex systems of vine intercropping or vitiforestry.

The illustration of the following case-study suggests that some features of viti-forested and viti-intercropped traditional landscapes may also be susceptible to be considered in the design of new vitiforestation practices.

The study case encompasses an area of about 116 ha, that corresponds to the area where wine-growing region of Settimo Vittone and Carema in Piedmont - Italy, specifically liying at the entrance to the morainic amphiteater of Ivrea. Here, at least since three centuries, the vineyards have been cultivated on terraces created to consolidate the mountain slopes, providing flat land for cultivation and for managing the flows of river and rainwater. Vineyard are generally accessible only by pathways and, on steep slopes, managed without use of machineries. The terraces made in dry-stone walls host vineyards trained on pergola (the traditional high-trellis system) supported by stone columns, shaping a unique and unmistakable landscape [Picture 1].

In this area wines are Carema AOC, Canavese Nebbiolo AOC, Canavese Rosso AOC and Canavese Bianco AOC. The vineyards are characterized by a polycultural imprint that is locally little considerated, but substantially valuable from an expert point of view. However the Figliej Winery, in Settimo Vittone, is rediscovering this landscape also for its vitiforestry implications. For this reason, the study area is taken into consideration at two different scales: the macro-territorial one and the micro-territorial other referred only to the Winery's lands.

2.2. Methodology

Considering the relevance accorded to landscape by the European Landscape Convention [18] and its implications in territorial policies and planning tools, methodologies have been developed to identify and assess different landscapes, their characteristics and even changes [19].

Since the landscape is the product of the relationships between human and natural factors, there are numerous disciplines that contribute to its analysis: geology, ecology, history, aesthetics, urban planning, economics. However, if the aim of landscape analysis is its management, a synthesis is necessary among the different frameworks. In this regard Cassatella et al. [20] have proposed and applied the so-called «structural interpretation of the landscape» method.

This method has been applied to the study-case wine-growing landscape, thus highlighting some relevant landscape features [21]. In this paper we selected some of these landscape features more significant in term of vitiforestry: i) historical pergola training system; ii) the presence of other crops or agrarian uses within the vineyard (vegetable plants, fruit trees, animal grazing); iiI) the presence and management of natural grass cover in the vineyards; iv) the presence of woodlands surrounding the vineyards. Subsequently, we propose to link these features worth of landscape conservation (formally recognized by national or local regulations) to their actual and potential role for vitiforestry, by associating to each of them i) the role in structuring the landscape and connected landscape values (by expert-based evaluation); ii) the empirical evaluation by the Winery owners as part of their vitiforestation system; iii) potential services and disservices relating to vitiforestation highlighted in the literature. Table 1 summarizes the most relevant results, while they are discussed below.

Finally, it is also necessary to make it clear that the Author has a double role, both as a researcher and as the owner of the Winery, and that this paper moves from ambition of enriching the debate about vitiforestry by relating fields of knowledge and different points of view.

2.3. Pergola training system

The pergola is a characterizing element of this traditional landscape, suffice it to say that in the study area it still concerns around 90% of the currently cultivated vineyards [17] [Picture 2].

The pergola is made of four levels of superimposed beams and creates a horizontal floor for the development of the vine canopies approximately 1-2 meters above the ground. The main reasons for its use since several centuries in this area can be traced back to: i) the distance of clusters from the ground level in order to avoid frost damage, ii) the creation of a vast aerial surface parallel to the ground on which to run specific grape varieties (such as Nebbiolo and Erbaluce) which tend to produce fruit-buds after several leaf-buds.

In the study-case traditional landscape, the suitability of this particular training system for vitiforestry lies in the space free from cultivation that is created under the canopy of the vines and which can therefore be exploited both for other crops (§2.2) and grazing (§2.3) in situations where the space for agrarian uses is limited, such as on terraced slopes.

More generally, the pergola (or similar high-trunk trellis systems) may be introduced also in other geographical contexts, due to its potential in regulating some pressures posed by climate change: its suitability for more complex vitiforestry systems should be therefore considered. A recent review by Del Zozzo et al. [5] deepens the role of different vine training systems in adapting to climate change. Final results of the complex evaluation proposed by the authors position the pergola (together with single-high-wire, Geneva double courtain and Scott-Henry) in second high-scoring position (exceeded only by the Raggi-Bellussi) for the following set of characteristics: high cordons (useful in case of frost and winter injury events), good potential to control vigor and, concurrently, leaf cover preventing or mitigating clusters from overheating and sunburn; general good attitude to high-yielding that can better exploit a longer growing season due to climate change and have a better ripening potential.

Other studies are also deepen the knowledge about the incidence of different training systems and canopy management on the Winkler Index [22] and on maintaining better microclimate in the fruiting area [23], suggesting at least to reconsider the ideotype quality vineyard associated to a lower-trunk one.

On the other hand, of course, laborious and expensive planting and almost no susceptibility to mechanization of these training systems should be considered in new plantations, together with other factors such as site-specific environmental variables and scion-rootstock characteristics.

In the study area pergola trellis shape a proper landscape, thus it should be considered a *characterizing* factor for its *rarity*, creating an iconic texture which confers *recognisability* to this specific landscape. Moreover it embeds a *symbolic* value for the community (who has started the formal process to list it within the National Register for Rural Historical Landscapes) and valuable of «outstanding national interest» officially protected by the Regional Landscape Plan.

All the vineyards owned by Figliej winery are trained on pergola. This training system has been experienced since

centuries in the area and embeds and identity and affective value for the owners. Moreover they attribute several services to this training system in the climate change such as the defense of clusters from increasingly frequent hailstorms; the gradual maturation of the grapes and therefore keeping low alcohol content and good acidity degrees for aging wines. Moreover the pergola is suitable for sheep to graze under the vines (also near the trunk) without risk for canopies and clusters to be damaged, thus favouring also organic fertilizing. Finally, in the Winery view, pergolas create a sheltered and aesthetically valuable space under which to carry cultural or family activities. Pergola trellises embed so many positive values and exert so many functions that the company marketing is largely based on it.

2.4. Vine intercropping

Vine intercropping by means of trees and other crops is no new issue in the long history of viticulture. In different parts of Italy, France, Portugal and even in South Bolivia some remnant still productive testimonies can be found. In France, vines trained on other trees constitute the so-called "vigne mariéè" [24], in Portugal "vinha do enforcado" [25]; in Italy the "coltura promiscua", "vite maritata" or "piantata" are systems which are likely to encompass two or three other types of crops beyond the vines [26] shaping astonishing landscapes; at the beginning of the XXth century, Henry Desplanques numbered the tree species on which vine were growing, counting eight species of timber trees, beyond trees grown for useful fruit and leaves [27].

The (re)introduction of trees in vineyard is probably one of the most investigated aspects of vitiforestry. Generally researches concentrate on row-planted vineyards intercropped with alley- or isolated trees.

Potential effects of planting trees in the vineyard are multiple, complex and deeply interconnected. Actual state-of-the-art about the knowledge on the effects of trees on vineyard is discussed by many authors [28 29 30], to mention just a few studies referring to much other literature]. The presence of trees affects first of all solar-radiation interception with different consequences on the vineyard depending on whether the trees are located to the north or south of the vine-rows. Vines exposed on the north face of the trees could undergo the potential containment of heat peaks and the increase in their leaf humidity, but at the same time decrease in the photosynthetic potential should arise; for the vines located south of the trees yield could increase but at the same time the risk of cluster exposure to overheating. The second major mechanism by which trees modify microclimate of the vineyard concerns access to water which means on the one hand microclimate regulation and on the other potential competition with the vines. Moreover the presence of scattered trees in the vineyard can contribute increasing the turbulent flows of air attenuating temperature peaks e reducing vine leaf humidification, but at the same time as cold air is slowed down, risks of frost could increase. Nonetheless trees can both increase or decrease water and nitrogen availability [31] for vines depending on specific variables [32]. in fact, topography, distance between trees and vines, plantation density and layout, height, porosity and shape of the tree canopy and other variables impact on the effects of the tree on vines and make it necessary to evaluate site-specific characteristics in order to infer potential benefits and risks. Moreover, more detailed modelling is currently developing [33] and longer-term monitoring is needed [28].

Beyond trees, vines can be intercropped by bush- or grass-like crops. Generally these crops are expected to provide several services to the vineyard: protection from soil erosion, water purification, nutrient retention, improved soil-structure, significant contribution to weed-pest-desease control [34 35 36] as well as regulative effects on grapevine growth with beneficial effects on grape yield and quality indices [37]. Disservices should also be highlighted when intercrops severely compete for primary resources with vines or provide habitat for pests and pathogens [Smith]. Recent studies have addressed vine-intercrops of particular interest in the current market for their derived products, such as aromatic plants (thyme and oregano) [39] and medicinal plants [40], or for their potential to deter pathogens [41]. Effects on vine yield seem ecouraging, when intercrops are properly managed [39].

In the study area vine intercropping results more densely present in vineyards on slopes lower than 30%: in this terraces traditional landscape is shaped by different crops on the same plot. The particular spatial organization resulting constitutes a *characterizing* landscape pattern. Crops associated to vineyards are: vegetables, many species of fruit trees, ornamental and healing plants, but also animal breeding is present with cows, goats, sheep stables, chicken and rabbit coops. Extensive meadows, olive and chestnut plots are interspersed with the vineyards. In this area vines intercropping embeds also an *identity* value due to its widespread traditional presence. In particular, potatoes, legumes and other vegetables are occasionally planted at the foot of the same vines, with the dual purpose of food use and aid to the fertility of the soil. This particular polyculture associated to vineyards is also consolidated in the collective imagination, as can be seen from the names attributed to the single terraces in Figliej' plots: many of them are named not by virtue of the presence of a vineyard, but rather by the type of cultivation associated with it: in the region called "darecà" of the Figliei hamlet, the terraced vineyard are called "banca dij patati", "banca dij galine", "banca dij pois" [potatoes terrace, chickens terrace and peas terrace]

Other trees scattered among the vineyards are *Salix spp.*, used to tie the vine shoots to the pergola trellis. Increasing the slope, the cultivation complexity decreases and the vineyard is associated to fruit trees and ornamental shrubs and willow trees.

Scenic landscape diversity and *sense of nature* are other landscape values delivered by vines intercropping with both vegetables and fruit or other useful trees.

2.5. Natural grass cover under the vines and meadows adjacent to the vineyards

In terms of agroforestry, the grass cover under the vineyards impacts microclimate regulation through water transpiration and sunlight reflection [42], but it has been shown that grass cover crops in vineyards (at least under Mediterranean climate) - while helping reduce vine vegetative vigour through the reduction of leaf area and intrinsic water use efficiency - should be carefully chosen in order to prevent competition for water [43].

Normally, the selection of grass cover species for vineyards has two different objectives: i) improving soil nitrogen availability for the vine and soil organic carbon through perennial grass and legume mixture [44] and/or ii) increasing biodiversity of grape beneficial insects choosing grass cover should according to the size and shape of the blossoms more suitable to attract beneficial insects able to access the flowers' pollen and nectar [45].

In the terraced landscape of Settimo Vittone and Carema, the management of grass cuttings in the vineyard depends on the strategies of each winemaker and on the climatic trend. In the vineyards where chemical weed control is not practiced, the vegetal cover is provided by spontaneous grass species. Self-seeding colonization of grass species is justified also by the fact that historically the vineyards have also been a resource for animal grazing.

Natural grass cover evaluated as a landscape feature is a *qualifying* factor with values linked to the *sense of nature* and *aesthetical beauty* especially connected to the flowerings of wild herbs beyond its social-economic value linked to animal grazing and the resulting production chains (milk and its derivates and meat, typical dishes).

In the Winery vineyard plots the number and the timing of mowings depend on the climatic trend of the year and generally respond to two principles: the management of the humidity under the vineyard and the maintenance of the diversity of grass species. The floristic diversity is being censused: for most grape beneficial insects, including parasitic wasps, the most helpful blossoms should be small and relatively open, plants from the *Compositae* and *Umbelliferae* families are especially useful [45]. Currently under the vineyards it is possible to detect both species of the *Compositae* (*Achillea millefolium* L., *Hypochaeris radicata* L., *Leucanthemum vulgare* Lam., *Taraxacum campylodes* G.E.Haglund, *Tragopogon pratensis* L.) and *Umbrelliferae* families (*Aegopodium podagraria* L., Berula erecta Huds. Coville, *Daucus carota* L.,).

Moreover about 50 species of wild herbs growing in meadows, woodlands, ecotonal habitats and vineyards are used for foraging purpose.

In the Winery plots until year 2000, the vineyards were grazed by cows, then grazing was interrupted until year 2010. Since then a flock of sheep has started grazing again. The chosen breed of sheep is the Barégeoise, a non-native one, but original of the French Pyrenees. The choice was dictated by the lower height of the Barégeoise compared to the Italian-native Biellese breed. In facts, the size of the Barégeoise sheep allows grazing under the pergola trellised vines, without the vines or bunches damages. The sheep are raised throughout the year solely on pasture (from spring to autumn) and hay from the winery's meadows (in winter), feeding in a close cycle only on the winery's land. Grazing is carried out in the vineyards in the months in which non phytosanitary treatments are carried out, while in the rest of the time grazing takes place in the surrounding pastures. No type of feed or other food of industrial origin is used.

Two positive effects of the reintroduction of sheep have been highlighted in the experience of the Winery: i) supplying the vineyards with non-synthetic organic matter; in year 2024 mature (one year) sheep manure was examined: fungal hyphae with a diameter greater than 8µm where found; fungal hyphae are commonly 3−10 µm in diameter [46]. In viticultural regions, the Arbuscular mycorrhizal fungi-grapevine symbiosis was pointed out as a key component of the vineyard system [47]; ii) helping maintaining the traditional mixed-use patterned landscape encompassing endangered ecosystems: since sheep can graze in the vineyard only in certain periods of the year (April-May and October-December), their nourishment implies that the winery has at its disposal plots dedicated only to grazing and haymaking. These plots are located in the surrounding of the vineyards and stables, maintaining a mosaic of different but adjacent ecosystems favoring the proximity of pollinating insects and useful predators. These meadows-plots occur with extensive management of permanent grasslands, but their floristic impoverishment is an European-wide issue [48] due to abandonment or, on the opposite, to intensive fertilisation, mowing and grazing [49]. They occur on the eutrophic and mesotrophic locations and are described as communities of *Arrhenatherion elatioris* (Koch) including approximately 150 species of vascular plants and being identified as valuable conservation habitat n.6510 in the EU Habitat Directive.

Finally, on the other hand, costs, suitable spaces, working hours and consultancy dedicated to the flock are to be added to those of vineyard management.

2.6. Woodlands surrounding vineyards

How diverse the vegetation is within and around a farm, how many cover crops are grown, how close a vineyard is to a forest, hedgerow, meadow, or other natural vegetation, are all factors that contribute to a vineyard's level of biodiversity [45].

If the presence of isolated trees or alley-trees in vineyards is of current interest for research on vitiforestry, the presence of woodlands surrounding the vineyards is slightly considered, although of relevance for the study-case traditional wine-landscape. It is thus necessary to consider other studies not specifically centered on the vineyard-woodland system.

Generally, forests are known for providing important ecosystem services including local climate regulation [50]. Particular interest is the issue addressed by recent research

showing that the presence of wooded areas surrounding the vineyard can increase the quantity of yeast communities on the grapes due to vector insects [51].

In the study area, the proximity of the not-grafted chestnut woods to the vineyard is historically planned to have easy access to a source of timber for the pergolas. In the area, there are numerous attestations of sales in which vineyards were sold together with the adjoining forest of not-grafted chestnuts [52]. Valuable chestnuts groves have therefore also an *identity* value, beyond their usefulness. Nowadays, woodlands can be evaluated also for the *sense of discovery* offered to visitors being spaces to enjoy wilder environments adjacent to the cultivated ones along the European Via Francigena crossing the area.

In Figliej's plots, the woodlands surrounding the vineyards are of different origins: chestnut groves grown for fruits, not-grafted chestnut trees used for pergola timber, mixed woods of secondary succession on terraces previously cutlivated. The hedge between vineyard and forest is particularly dynamic as it depends on the balance between two opposing dynamics: abandonment of former cultivated lands (thus forest grows) and terrace recover to agriculture. The adjacency between vineyard and woodland implies both positive and negative interconnections for the vineyard, in the experience of the Winery.

In Figliej's vineyards we observed that the proximity to forest ecosystems (in addition to the sustainable management of the vineyard soil) favors the establishment in the vineyard of some plant species characteristic of forest environments, including *Phyteuma* spp and species of protected wild orchids (*Dactylorhiza maculata* Neck., *Neotinea tridentata* Scop.), suggesting that the woodlands impact both as source area for the diffusion of plant germplasm and on the presence of beneficial fungal hyphae (associated to wild orchids) and organic substance in the soil.

Among observed unfavorable aspects the following can be listed: predation of the grapes by wildlife (avifauna, mammals such as *Glis glis*, *Meles meles*, *Capreolus capreolus*); potential shading and humidity in unsuitable areas of the vineyards, risk of tree crashing into the vineyard. Furthermore, in secondary succession forests, wild *Vitis vinifera* plants may persist and become hostbeds of transmission of plant deseases to the vineyards.

3. Conclusions and outlook: connecting vitiforestry innovation and landscape conservation in a global changing scenario

The present study only poses the basis for further interdisciplinar research based on the collection of data series in the field and on the wines. As a result the suggestion that vitiforestry has to be considered far from solely introduction of trees in vineyards arises. Considering vitiforestry a more complex dimension than a set of agronomic techniques, it should be interpreted also a landscaping action, therefore intervention on new and old vitiforestry projects should be planned also following historical site-specific patterns, in worth-of protection landscapes, thus being a means to conserve traditional landscapes.

In the wine-growing landscape of Settimo Vittone and Carema and in the site specific case of Figliej Winery, many features are historically present which are currently considered of interest for vitiforestation. In the literature, the most studied vitiforestry systems are the newly designed ones, where rows of trees are inserted within the row-trained vines. However, implications of the pergola in agroforestry systems should be further studied. In fact, if on the one hand the pergola characterizes some increasingly rare historical wine-landscapes, on the other hand the pergola is being re-evaluated even for newly planted vineyards as a response to the pressures imposed by climate change. However years with high levels of precipitation suggest to monitor pergola performance, and the proximity of wooded and scattered trees also regarding the maintenance of excessive humidity conditions.

Vityforestry could benefit traditional landscape conservation as it encompasses also complex considerations about grass cover under the vineyard and around them. The mix of plot dedicated to different land uses among others meadows has to be considered. Grazing could have a role both to fertilize the vineyards but also, on a landscape scale, to maintain extensive and diversified rural landscapes in which the vineyards do not overwhelm traditional polyculture.

The study of traditional vitiforestry in consolidated (traditional) landscapes gives new insights into modern agroforestry issues as suggested by Oller et al. [53]: the scientific parametrization of traditional vitiforestry systems could advantage research on agroforestry offering more consolidated systems where trees associated to vines present yet evolved structure such as heigh and canopy, beyond well rooted socio-cultural practices and know-how about the management of vines associated with trees.

Studying such traditional landscapes could be like having some hints about the future of those we are creating today.

4. References

1. P.J. Burgess, A. Rosati, Advances in European agroforestry: results from the AGFORWARD project, Agroforest Syst, **92**: 801-810 (2018)
2. Cassatella C., Spaziante A., Murano C., Carbone M., Consumo di suolo, consumo di paesaggio? Prospettive di ricerca sulla misura delle ricadute dei Programmi di Sviluppo Rurale, VA. Valutazione Ambientale, **16**, pp. 12-17 (2009)
3. C. Rega, Pursuing integration between rural development policies and landscape planning: towards a territorial governance approach, C. Rega (Ed), Landscape planning and rural development. Key issues and options towards integration, Springer: 13-40 (2014)

4. M. Mackay, H.C. Perkins, Making space for community in super-productivist rural settings, Journal of Rural Studies, **68**: 1-12 (2019)
5. F. Del Zozzo, S. Poni, Climate change affects choice and management of training systems in the grapevine, Australian Journal of Grape and Wine Research, Article ID 7834357 (2024)
6. L.M. Irimia, C.V Patriche, T. Petitjean, C. Tissot, L.G. Santesteban, E.Neethling, C. Foss, R. Le Roux, H. Quénol, Structural and Spatial Shifts in the Viticulture Potential of Main EuropeanWine Regions as an Effect of Climate Change. Horticulturae **10**, 413 (2024)
7. R.Z. Melnick, Deciphering cultural landscape heritage in the time of climate change, Landscape Journal, **35**: 2-16 (2016)
8. Garnett T, Appleby MC, Balmford A, Bateman IJ, Benton TG, Bloomer P, Burlingame B, Dawkins M, Dolan L, Fraser D, Herrero M, Hoffmann I, Smith P, Thornton PK, Toulmin C, Vermeulen SJ, Godfray HCJ, Sustainable intensification in agriculture: premises and policies. Science **341(6141)**: 33–34 (2013)
9. FAO, Agroforestry for landscape restoration: Exploring the potential of agroforestry to enhance the sustainability and resilience of degraded landscapes (2017)
10. M.L. Augère-Granier, Agroforestry in the European Union, PE 651.982 European Parliament Research Service (2020)
11. J.H. McAdam, P.J. Burgess, A.R. Graves, A. Rigueiro-Rodríguez, M.R. Mosquera-Losada, Classification and Functions of Agroforestry Systems in Europe, Agroforestry in Europe. Current Status and Future Prospects, A. Rigueiro Rodríguez, J. McAdam, M.R. Mosquera-Losada Eds., Springer (2009)
12. R. Joffre, J.J. Vacher, C. de los Llanos, G. Long, The dehesa: an agrosilvopastoral system of the Mediterranean region with special reference to the Sierra Morena area of Spain, Agroforestry Systems **6(1)**: 71-96 (1988)
13. Herzog F., Streuobst: a traditional agroforestry system as a model for agroforestry development in temperate Europe, Agroforestry Systems **42**: 61-80 (1998)
14. Zomer RJ, Trabucco A, Coe R, Place F, van Noordwijk M, Xu JC. *Trees on farms: an update and reanalysis of agroforestry's global extent and socio-ecological characteristics.* Working Paper 179. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program (2014)
15. M. den Herder, G. Moreno, RM. Mosquera-Losada, JHN Palma, A. Sidiropoulou, J.J.Santiago Freijanes, J. Crous-Duran, J.A. Paulo, M. Tome´, A. Pantera, V.P. Papanastasis, K. Mantzanas, P. Pachana, A. Papadopoulos, T. Plieninger, P.J. Burgess, Current extent and stratification of agroforestry in the European Union, Agr Ecosyst Environ **241**:121–132 (2017)
16. M.R. Mosquera-Losada, J.J. Santiago-Freijanes, M. Rois-Díaz, G. Moreno, M. Den Herder, J.A. Aldrey-Vázques, N. Ferreiro-Domínguez, A. Pantera, A. Pisanelli, A. Rigueiro-Rodríguez, Agroforestry in Europe: A land management policy tool to combat climate change, Land Use Policy **7**: 603-613 (2018)
17. B.M. Seardo, Non è (solo) un paesaggio del vino. Forme della viticoltura promiscua fra specializzazione e abbandono: il Canavese, in: Il paesaggio agrario italiano. Sessant'anni di trasformazioni da Emilio Sereni a oggi (1961-2021), C. Tosco, G. Bonomi (Eds.), Viella, Roma, Italy: 307-317 (2023)
18. *Council of Europe, European Landscape Convention*, Florence 20. 10. 2000. European Treaty Series, No. 176. 7 p. (2000)
19. F. Graham, I. Sarlv Herlin, C. Swanwick (Eds.), Routledge handbook of Landscape Character Assessment. Current approaches to characterisation and assessment. Routledge (2018)
20. C. Cassatella, R. Gambino, Il territorio. Conoscenza, interpretazione, rappresentazione, Celid, Torino (2005)
21. B.M. Seardo, C. Cassatella, F. Bonavero, Studio di azioni paesaggistiche per la conservazione e il recupero dei paesaggi viticoli alpini - Parte I: Atlante dei paesaggi viticoli alpini della Città metropolitana di Torino, Report di ricerca, research financed under the agreement between Città Metropolitana di Torini and DIST Politecnico e Università di Torino, for the implementation of activities of common interest within the Interreg ALCOTRA project Vi.A Routes des Vignobles Alpins – Strada dei Vigneti Alpini". Activity 3.1 "Studio di azioni paesaggistiche per la conservazione e il recupero dei paesaggi viticoli", Caludia Cassatella scientific manager (2018)
22. S. Gou, 2016, Growing degree hours-a simple, accurate, and precise protocol to approximate growing heat summation for grapevines, *International Journal of Biometeorology*, **60(8)**: 1123-1134
23. L. De Rességuier, P. Pieri, S. Mary, R. Pons, T. Petitjean, C. Van Leeuwen, Characterisazion of the vertical temperature gradient in the canopy reveals increased trunk heighr to be a potential adaptation to climate change, Oeno One, **57(1)**: 41-53 (2023)
24. C. Amiel, Les fruit de la vigne. Représentations de l'environnement naturel en Languedoc, Éditions

de la maison des sciences de l'homme, Paris (1985)

25. J.A. Paulo, A. Tomás, J.S. Guedes, Vinha do enforcado: produção de vinho num sistema agroforestal ancestral e ameaçado no Norte de Portugal, AFINET on-line publication (no year)
26. P. Paris, F. Camilli, A. Rosati et al., What is the future for agroforestry in Italy?, *Agroforest Syst* **93**, 2243–2256 (2019)
27. H. Desplanques, Il paesaggio della coltura promiscua in Italia, Rivista Geografica Italiana LXVI: 29-64 (1959)
28. E. Bougarde, A. Alonso Ugaglia, V. Bustillo, T. Dufourcq, J. Grimaldi, J. Guenser, V. Montagne, L. Ranjard, A. Ugaglia, VITIFOREST: Evaluation de l'impact de l'arbre agroforestier en contexte viticole, Innovations Agronomiques 79: 471-497 (2020)
29. J. Grimaldi, Impacts microclimatique de l'agroforesterie en viticulture: étude de cas dans le Sud de la France, Thèse de Doctorat de l'Université de Toulouse, Unité de recherche CESBIO, (2018)
30. G. Lawson, C. Dupraz, J. Watté, Can silvoarable systems maintain yield, resilience and diversity in the face of changing environments?, G. Lemaire, P. C. De Faccio Carvalho, S. Kronberg, S. Recous (Eds.), Agroecosystem diversity. Reconciling contemporary agriculture and environmental quality, Academic Press: 145-168 (2019)
31. W. Trambouze, N. Goma-Fortin, Agroforesterie viticole: résultats de 11 ans d'étude sur la production et la vigueur des vignes, Ciência e técnica vitivinicola: journal of Viticulture and Enology **28**: 510-513 (2013)
32. C.P. Lang, N. Merkt, C.M. Geilfus, S. Graeff-Hönniger, J. Simon, H. Rennenberg, C. Zörb, Interaction between grapevines and trees: effects on water relations, nitrogen nutrition and wine, Archives of Agronomy and Soil Science **65(2)**: 224
33. J. Grimaldi, J.P. Gastellu-Etchgorry, What are the impacts of tree shade on the absorption of light by grapevine in alley-cropped vineyards?, presentation (2019)
34. K. Steenwerth, K.M. Belina, Cover Crops Enhance Soil Organic Matter, Carbon Dynamics and Microbiological Function in a Vineyard Agroecosystem. Appl. Soil Ecol. **40**, 359–369 (2008)
35. F. Peregrina, F., E.P. Pérez-Álvarez, E. García-Escudero, Soil Microbiological Properties and Its Stratification Ratios for Soil Quality Assessment under Different Cover Crop Management Systems in a Semiarid Vineyard. J. Plant Nutr. Soil Sci. **177:** 548–559 (2014)
36. L. Mercenaro, G. Nieddu, P. Pulina, C. Porqueddu, Sustainable Management of an Intercropped Mediterranean Vineyard. Agric. Ecosyst. Environ. **192**: 95–104 (2014)
37. B. Guerra, K. Steenwerth, Influence of Floor Management Technique on Grapevine Growth, Disease Pressure, and Juice and Wine Composition: A Review. Am. J. Enol. Vitic. **63**: 149–164 (2012)
38. R. Smith, L. Bettiga, M. Cahn, K. Baumgartner, L.E. Jackson, T. Bensen, Vineyard Floor Management Affects Soil, Plant Nutrition, and Grape Yield and Quality. Calif. Agric. **62**: 184–190 (2008)
39. F. Dittrich, T. Iserloh, C.Treseler, R. Hüppi, S. Ogan, M. Seeger, S. Thiele-Bruhn, Crop Diversification in Viticulture with Aromatic Plants: Effects of Intercropping on Grapevine Productivity in a Steep-Slope Vineyard in the Mosel Area, Germany. Agriculture **11**, 95 (2021)
40. B.E.A. Belal, M.A. El-kenawy, S.I.I. Ismail, A.M. Abd El-Hameed, effect of intercropping of Thompson seedless grapevines with some medicinal plants on vine nutritional status, yield, berry quality and the microbiological activity of the soil, J. Plant Production, **8(4)**: 495-501 (2017)
41. F.S. Mohsen, R.M. El-Ashry, H.G. Zyada, Evaluating the effect of intercropping garlic with grapevines on productivity, phytoremediation, competitive indices and plant parasitic nematode community, J. Of Plant Production, **12(4)**: 407-414 (2021)
42. J. Grimaldi, R. Fieuzal, C. Pelletier, V. Bustillo, T. Houet, D. Sheeren, Microclimate patterns in an agroforestry intercropped vineyard: first results, Proceedings of the 3rd European Agroforestry Conference – Montpellier, 23-25 May (2016)
43. A. Pou, J. Gulias, M. Moreno, Cover cropping in Vitis vinifera L. cv. Manto Negro vineyards under Mediterranean conditions: effects on plant vigour, yiela and grape quality, J. Int. Sci. Vigne Vin, **45(4)**: 223-234 (2011)
44. K. Ball, J.A. Baldock, C.M. Penfold, S.A. Power, S.J. Woodin, P- Smith, Pendall E., Soil organic carbon and nitrogen pools are icreased by mixed grass and legume cover crops in vineyard agroecosystems: detecting short-term management effects using infrared spectroscopy, Geoderma **379(2)**, 114619 (2020)
45. M.A. Altieri, C. Nicholls, L. Ponti L., A. York, Designing biodiverse, pest-resilient vineyards through habitat management, Practical Winery & Vineyard, May-June: 1-6 (2005)
46. J.C. Dodd, C.L. Boddington, A. Rodriguez, C. Gonzalez-Chavez, I. Mansur, Mycelium of arbuscular mycorrhizal fungi (AMF) from

different genera: form, function and detection. Plant and Soil **226**: 131-151 (2000)

47. P. Cesaro, N. Massa, E. Bona, G. Novello, V. Todeschini, L. Boatti, F. Mignone, E. Gamalero, G. Berta, G. Lingua, Native AMF Communities in an Italian Vineyard at Two Different Phenological Stages of *Vitis vinifera*. Front Microbiol. **12**: 676610 (2021)
48. P. Török, M. Janisová, A. Kuzemko, S. Rusina., Z. Dajic-Stevanovic, Grasslands, their threats and management in Eastern Europe. V.R. Squires, J. Dengler, H. Feng, L. Hua (Eds.) Grasslands of the world: diversity, management and conservation. CRC Press, Boca Raton, USA, 64–88 (2018)
49. J. Dengler, S. Tischew, Grasslands of western and northern Europe – between intensification and abandonment. In: V.R. Squires,J. Dengler, H. Feng, L. Hua, L. (Eds.) Grasslands of the world: diversity, management and conservation. CRC Press, Boca Raton, USA, 27–63 (2018)
50. K. Gregor, C. P. O. Reyer, T. A. Nagel, A. Mäkela, A. Krause, T. Knoke, A. Ramming, Reconciling the EU forest, biodiversity and climate strategies, Glob Change Biol **30**:e17431 (2024)
51. B. Valentini, F. Barbero, L.P. Casacci, A. Luganini, I. Stefanini, Forests influence yeast populations vectored by insects into vineyards. *Front. Microbiol.* **13**:1039939 (2022)
52. E. Erlicher, Donnas: I vini della Valle d'Aosta tra signorie alpine e dominio sabaudo, Kellermann Ed., Treviso, Italy (2022)
53. P. Oliva Oller, M. Notaro, E. Langer, C. Gary, Structure and management of traditional agroforestry vineyards in the high valleys of southern Bolivia. Agroforest Syst **96**: 375–386 (2022)

5. Appendix

Landscape feature worth of conservation	Values linked to the landscape feature	Services perceived/experienced by the Winery	Potential services provided in the vitiforestry system (from literature review)
Pergola training system	*Characterizing* factor for its *rarity*, creating an iconic texture which confers *recognisability* to this specific landscape Community *symbolic* value Outstanding national value officially protected	Positive impacts on clusters sheltering and ripening in the climate change Possibility og grazing under de vines (also near the trunk) without damaging the canopy/clusters Marketing lever Identity and affective value for the owners of the winery Creation of sheltered and aesthetically valuable spaces for cultural activities	Microclimate regulation (protection in case of frost and injury events) Protection of clusters from overheating, sunburn, frost and other injury events General high yield and better ripening potential
Vine intercropping with vegetables or ornamental plants	*Characterizing* factor that creates a specific landscape pattern *Identity value* of the traditional practice	Food resource Traditional practice to "nourish" the vines	Supply of nitrogen and organic carbon to vines if species are well balanced Pests control
Vine intercropped with other trees	*Characterizing* factor that creates a specific landscape pattern *Qualifying* factor that confers *visual diversity* and *sense of naturalness* *Identity value* of the traditional practice	Food resource Scattered trees of *Salix* spp. are used to secure the branches of the vines to the pergolas	Microclimate regulation and windbreak effect Change in radiation: sheltering effect Change of ground water availability in space and time improving infiltration and intercepting runoff Improving soil structure, permeability, fertility and modification of microorganisms communities
Natural grass cover under the pergola	*Qualifying* factor that satisfies the *sense of naturalness* especially in the flowering season	Total grass cover is a normal condition in the area: the vineyards grow on terraced meadows Food supplement for the sheep flock (vineyard-meadows cycle). On the other hand costs, suitable spaces, working hours and consultancy for the management of the flock have to be highlighted Human foraging resource (partial) Aesthetic value	Microclimate regulation if mowing is correctly managed Supply of nitrogen and organic carbon to vines if species are well balanced Source of beneficial biodiversity if species are well balanced
Meadows surrounding the vineyards	*Qualifying* factor that satisfies the *sense of naturalness* Socio-economic value linked to animal breeding	Main food resource for the sheep flock Diversification of the environments surrounding the vineyards (pest and beneficial insects) Human foraging resource	Increasing agroecosystem diversity at the landscape scale favors emergent ecological properties suitable of keeping pest population in check
Woodlands surrounding the vineyards	*Qualifying* factor that satisfies the *sense of naturalness* and *sense of discovery* when associated to spaces usabilty Identity value linked to chestnut groves	Diversification of the environments surrounding the vineyards (pest and beneficial insects) Human foraging resource Potential resource for timber The uncultivated woodland is source of many disservices (grape predation by wildlife, crashes, excessive shading on parts of the vineyards). Great management difficulties	Microclimate regulation Source of yeasts Shading and windbreak

Linking the traditional landscape features worth of conservation of the study area with their potential benefits for vitiforestry systems highlighted across literature