The on-farm conservation of grapevine (Vitis vinifera L.) landraces assures the habitat diversity in the viticultural agro-ecosystem

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The on-farm conservation of grapevine (*Vitis vinifera* L.) landraces assures the habitat diversity in the viticultural agro-ecosystem

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Summary

A sustainable maintenance of grapevine biodiversity at risk of genetic erosion should involve farmers in the conservation process. Many local varieties of high biological significance are residually cultivated in traditional and marginal agricultural areas or in rural contests endangered by different factor of biodiversity erosion. The landrace-based orchards in the innate areas, *i.e.* the *in situ* conservation on farm, represent hotspots of biodiversity, while preserving at the same time natural resources like soil fertility, air and landscape quality owing to the optimal relationship genotype-environment that allows environmentally friendly agronomical practices. The study aims at highlighting the importance of grapevine on-farm conservation with special attention to the ecological and environmental implications derived from the maintenance of habitat diversity and complexity in the viticultural agro-ecosystem. To the aim, data on landscape pattern, configuration and composition at large and detailed scale were measured according to the methodology of landscape ecology in a landrace-based viticultural area in central Italy, and the landrace-based vineyard's patch structure, as well the surrounding vineyard landscape, were analysed for shape, complexity, heterogeneity of the margins. The results prove the ecosystem services provided by the landrace-based vineyards in their innate growing area. These services can be attributable to the conservation of a high natural capital within the vineyard agro-ecosystem. The re-functionalization of these productive spaces, particularly when relictual or abandoned, and the involvement of farmers in the conservation strategy by strengthening the perception of the multifunctional value of their productive contests could provide a valuable example of strategy for the on farm conservation of local germplasm, together with the preservation of environmental benefits.

K e y w o r d s : buffer zones; hedges; ecosystem services; landscape configuration; riparian vegetation; traditional viticulture.

Introduction

The *in situ* conservation on-farm of cultivated fruit species and vines is considered at first a strategy for preventing genetic erosion itself, generally complementary to the *ex situ* one (Jarvis *et al*. 2000, Maxted *et al*. 2011). Nonetheless, even in the most developed European countries, autochthonous landraces are still at the base of marginal economies of traditional agriculture and their maintenance allow typical productions that express the cultural value of small territories (Negri 2005) and traditional uses that preserve a high natural capital within the agricultural landscape (House *et al*. 2008, Smith and Sullivan 2014). Furthermore, recently the *in situ* conservation of food-producing crops has been defined as a resilient-based strategy of high social-ecological sustainability (Zimmerer 2014).

The traditional use of local genetic resources, *i.e.* planting, growing, transformation and consumption, at the base of a traditional way of life and a traditional socio-economic structure, represents sustainable productive models based on low outside-farm inputs employment (Alvarez *et al.* 2010) because it is dependent on autochthonous landraces that are, by definition (Zeven 1998), "varieties with high capacity to tolerated biotic and abiotic stress, resulting in a high yield stability, an intermediate yield level under a low input agricultural system".

Local genetic resources have a great importance for sustainable viticulture, being the possibility to rich high quality grape and oenological productions with minimal outside-farm input requirements based on an optimized genotype-environment relationship. Many local varieties of high biological significance are residually cultivated in traditional agricultural assets. In particular, relictual vineyards of marginal rural areas or areas endangered by a strong anthropogenic pressure represent hotspots for agro-biodiversity and land uses that prevent soil consumption and habitat richness depletion (Biasi *et al*. 2012). The cultivation of autochthonous landraces implies the preservation of traditional agricultural landscapes together with their provided ecosystem services, represented by habitat, species and genotype diversity, soil fertility maintenance, carbon sequestration, landscape quality, *i.e.* landscape complexity and heterogeneity (Barbera *et al.* 2014). Furthermore, it has been proved that simplification of landscape, *i.e.* adoption of regularly shaped orchards or arable fields owing to modern crop farming based on few modern cultivars, is negatively correlated to local biodiversity richness (Moser *et al*. 2002). On the contrary, the improvement of the ecosystem services represents the major task for the future modern agriculture. It has been recently stressed that viticulture can provide many ecosystem services like a rich biodiversity maintenance within the vineyard itself owing to proper soil management practices (Orre-Gordon *et al.* 2013). Furthermore, traditional viticulture that is based on

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the use of local genetic resources has been demonstrated to prevent soil erosion in hill slopes where vineyard management practices control slope steepness (Chevigny *et al*. 2014) and to exhibit ecological sustainability (Abbona *et al.* 2007). Nonetheless, the environmental value of the *in situ* conservation of agro-biodiversity is poorly documented and for grapevine cultivation information on the relationship between landraces conservation and derived ecosystem services is lacking. Many traditional grapewine growing areas in Italy can be considered as hotspots of agro-biodiversity and large assortments of differently endangered grapevine varieties and oenological products have been catalogued.

The study aim was to investigate the environmental value of the *in situ* conservation on farm through a study case based on an autochthonous grapevine landrace in a traditional grape-wine growing area in central Italy (Latium region). To the aim, some ecosystem services, *i.e.* the maintenance of landscape eco-mosaic complexity and of habitat diversity within the agro-ecosystem were quantified for the landrace-based vineyards through a GIS-based multiscale approach involving landscape ecology tools. Results prove that the *in situ* conservation on farm in viticulture may preserve an high natural capital in the agro-ecosystem.

Material and Methods

The grapevine landrace and the study area: Our investigation has considered the Italian grapevine landrace known as ‘Grechetto Rosso’ (GrR), an autochthonous residual and endangered genetic resource of a volcanic district of the central Italy, *i.e.* the Bolsena lake basin in the Latium region, that is an highly vocated region for grapevine cultivation extended from 11.86° west to 12.00° east, and from 42.53° south to 42.65° north (Fig. 1). The characterization of this cv. and of its growth environment has been reported in Brunori *et al.* (2015). The

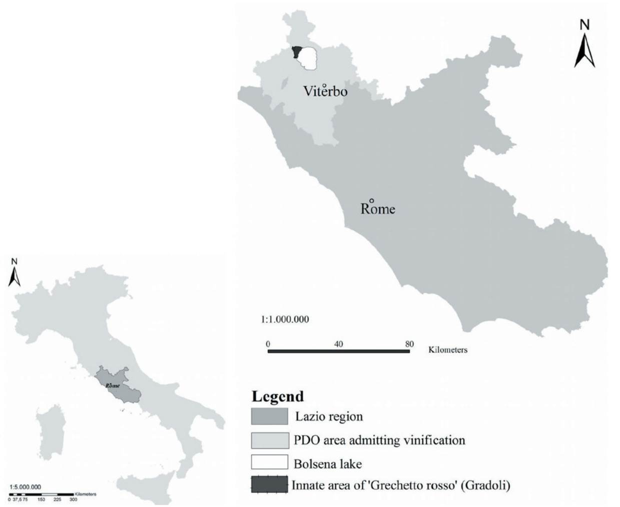

Fig. 1: Localization of the study area and delimitation of the innate growing area for the autochthonous landrace "Grechetto Rosso" (GrR), in witch the certified wine production is admitted. The whole PDO extension is also indicated.

surface of production is limited to a few ha concentrated in a spots areas (that cover about 0.4 km^2) in a large recognized PDO (Protected Designation of Origin), *i.e.* the “Colli Etruschi Viterbesi” PDO, that admits its vinification in the innate area. The whole innate area of production is restricted to a small municipality (Gradoli), historically growing this variety from witch a typical and certified local wine, named Greghetto, derived.

The landrace-based viticultural landscape structure: a high resolution analysis of the landscape based on aerial photograph interpretation was performed in the innate area of the studied cultivar. The landscape structure and configuration was analysed through GIS technology (ArcGis 9.3) at large and detail scales. At large scale, an objective-oriented land use/land cover map of selected classes of the territory including the innate areal of the cv. GrR was derived from CLC 2006 project (1:250.000). A patch analysis was performed at landscape scale for the quantification of the most pivotal landscape metrics indexes that measure the structure, shape and complexity of the landscape, *i.e.* patch number (NP), mean patch size (MPS), Shannon diversity index (SDI), Shannon evenness index (SEI) (Elkie *et al*. 1999). At detail scale (1:1000), through the integration of GIS technology, cadastral maps and data, aerial-photo (2008) interpretation, the spatial distribution of GrR vineyards was derived and the viticultural mapping units were also metrically analysed for landscape metrics indexes, *i.e*. the number of GrR landrace-based vineyards patches (NP), patch density (PD), mean patch size (MPS), mean shape index (MSI), edge density (ED) and mean patch edge (MPE). Vineyards with a traditional consociated asset (mainly grapevine-olive or grapevine-olive-herbaceous/horticultural crops) and with a modern asset (specialized) were analysed separately for structure and configuration indexes.

Margin analysis: For the characterization of the non productive areas surrounding the vineyards, *i.e.* the margins, a 25 m wide buffer strip was considered along each vineyard perimeter. All the cadastral viticultural parcels belonging to the GrR landrace, mapped on high resolution aerial photographs, were subjected to margin analysis and compared for margin composition. The segments of different land cover/land uses derived from direct photo-interpretation (1:1000) were quantified through GIS-based tools. The following classes were distinguished for percentage incidence in the margin structure: ecological infrastructures (*i.e.* agro-forest areas, riparian vegetation, hedges, wooded remnants, tree alleys), and olive groves, pastures, vineyards, consociated permanent crops and urban tissue.

Results and Discussion

Viticultural landscape structure: The landscape structure of the volcanic basin that includes the innate area of the autochthonous landrace GrR maintains the characters of complexity and heterogeneity of the landscape eco-mosaic, that are proper traits of a sustainable environment (Fig. 2), being well represented different

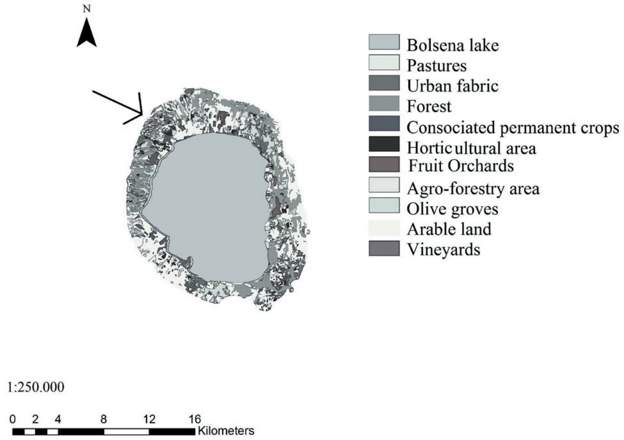

Fig. 2: Land use and land cover map of the area surrounding the study side. The growing area of the autochthonous landrace "Grechetto Rosso" is indicated (arrow). The objective-oriented land use map has been drown considering an homogenous area for physiographic characters (homogeneous phytoclimate) all around the Bolsena lake that is prevalently interested by agricultural uses.

natural and agro-ecosystems, *i.e.* forests (mainly of *Carpinus betulus, Corylus avellana, Fagus sylvatica, Prunus avium, Quercus ilex* and shrubs species of the Mediterranean maquis*),* olive groves, pastures, arable lands, fruit orchards and vineyards. The area surrounding the Bolsena lake caldera is highly and irregularly patched as demonstrated by the numerosity of the land parcels (PN = 1109) of small size (MPS = 11.10 ha) and by the high value of the shape index that indicate rather irregular and edged parcels (MSI = 2). Furthermore, the levels of the SDI that indicate the level of biodiversity (SDI = 2.21), and of the SEI, correlated to the uniformity of patches extension (SEI = 0.84), were consistent to an heterogeneous and equilibrated environment. In fact, the diversity of land use/land cover patches, the irregularity of their shape that implies many margin contacts can be interpreted as traits of a landscape of high environmental meaning (Forman and Godron 1986). This entire wine-grape-growing area present an highly patched landscape and a rather high landscape diversity (Fig. 2, arrow), as prove of a traditional rural environment of high ecological value for the ecosystem richness, being complexity positively related to resiliency and equilibrium (Cullotta and Barbera 2011, Farina 2000). At detail scale, the landscape metric analysis applied to the GrR-based vineyards, both the "modern" and the "traditional" ones, showed comparable value for all the main indexes (Tab. 1). In particular, vineyard patch size was very limited (0.19 and 0.22 ha, respectively), and this proved the fragmentation of viticultural parcels, therefore a major exposure to risk of biodiversity erosion. In both cases, high values for the MSI (irregularity of the vineyard shape) and MPE (numerosity of edges per patch) were measured and this can be related to the possibility to safeguard biodiversity and habitats owing to a margin effect. In fact, when margins are more curved they allow higher ecological benefits, like habitat and species diversity (Forman and Godron 1986, Elkie *et al*. 1999). In particular, the high value of ED measured for the landrace-based vineyard patches, also in the specialized vineyards, can be considered at the base of the preservation of an environment diversity and therefore of natural habitats, agro-biodiversity and landscape quality defence. It has been demonstrated a positive correlation between the complexity of landscape patches and the richness of species and biodiversity (Moser *et al*. 2002) and the respect of simple landscape ecology design principles assuring ecosystem services have been evocated also for new farm configuration (House *et al*. 2008).

Vineyard margin composition: The photointerpretation of high-resolution aerial photographs, overlaid with the viticultural cadastral data referring to the GrR surfaces, allowed to distinguish the spatial distribution of this genetic resource (Fig. 3A). This information is highly useful because it can address and focus conservation efforts. In particular, the presence of a limited number of vineyard patches concentrated on two-spotted area is to be considered as a further risk factor for the erosion of the landrace, actually considered as medium endangered. Erosion risk, in fact, is negatively correlated to the diffusion of the landrace presence (INEA, 2013). The results highlight also the comparable traits for the GrR-based vineyard consociated with other tree crops („traditional" asset) and those specialized („modern" asset) in terms of buffer composition diversity (Tab. 2; Fig. 3B and 3C-D, in comparison). The land use analysis of buffer strip composition alongside the vineyard perimeter proved a highly complex habitat composition (Tab. 2). The composition of habitat in the vineyard surrounding landscape was mainly represented by more natural ecosystems, like forest remnants, riparian vegetation and agroforestry systems, when GrR vineyards had the consociated asset (*i.e.*, the more traditional vineyard configuration), whereas for the specialized surfaces more represented were homogeneous arable and horticultural habitat or hedges of anthropogenic nature (Tab. 2 and Fig. 3C and D, in comparison).

Table 1

Landscape metric applied to the vineyard patches of the "Grechetto Rosso" (GrR) autochthonous landrace. Landscape indexes have been calculated for vineyard parcels consociated with other permanent tree crops (traditional asset) and for specialized parcels (modern asset)

Landrace-based vineyards (GrR)	Class area (ha)	Patch number	Patch density (n/100 ha)	Mean patch size (ha)	Mean shape index	Edge density	Mean patch edge
	CA	NP	PD	MPS	MSI	ED	MPE
Traditional asset	17.0	74	434.76	0.23 ± 0.2	1.31	423.58	214.36
Modern asset	17.5	89	509.68	0.20 ± 0.4	1.32	436.83	183.80

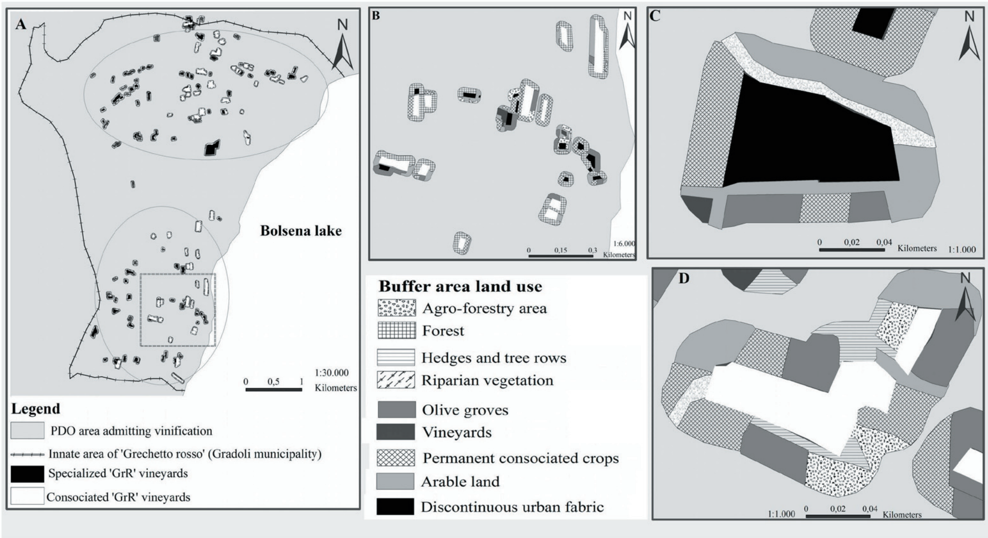

Fig. 3: Spatial distribution of "Grechetto Rosso" (GrR) vineyards in the innate growing areas and typology of ecosystems in the buffer strip (25 m width) alongside the GrR vineyard patches perimeter. **A**, localization in two spotted areas of the GrR specialized or consociated vineyard patches (aerial photographs (2008) interpretation and cadastral data comparison); **B**, detail of the buffer strip (25 m width) composition of an exemplary space (dotted square in A) of the innate GrR distribution area; **C**, detail of the buffer strip (25 m width) composition of GrR based specialized vineyard parcel (black background) (scale 1:1000); **D**, detail of the buffer strip (25 m width) composition of GrR based consociated vineyard parcel (white background) (scale 1:1000).

Table 2

Typology of habitats in the composition of the buffer strip alongside the perimeter of the parcels of "Grechetto Rosso" (GrR) vineyards. Buffer composition was assessed in a 25-width strip. Parcels consociated with other permanent tree crops (traditional asset) and specialized parcels (modern asset) have been analysed separately

Vineyard-associated buffer strip composition	Traditional GrR vineyards (%)	Specialized GrR vineyards (%)
Total ecological infrastructures	45.1	46.6
Agro-forestry areas	2.5	2.4
Forest remnants	35.1	35.4
Riparian vegetation	2.4	1.6
Hedges and tree rows	2.6	5.5
Arable land	25.4	34.3
Olive groves	14.4	9.8
Vineyards	3.4	4.8
Consociated permanent crops	12.3	5.2
Discontinuous urban fabric	1.3	0.9

In particular, almost half of the vineyard surrounding habitats (45.1 % and 46.6 % for the consociated and the specialized vineyards, respectively) were represented by ecological infrastructures, *i.e.* tree alley, hedges, riparian vegetation, forests remnants (Tab. 2). This buffer strip composition could be interpreted as an increase of the benefits deriving from a high presence of margins in the cv GrR-based vineyards. This land covers, both of natural and anthropogenic origin, besides representing hotspots of biodiversity, assure ecological landscape connectivity for plant and animals species (Weibull *et al.* 2003). It has been demonstrated that particularly vulnerable ecosystems of high ecological significance, like those represented in the riparian vegetation, are strongly affected by the proximity of agricultural areas (Fernandes *et al*. 2011). Our data demonstrate that small sized vineyards based on the use of local landraces maintain complex ecological infrastructures, *i.e.* treed riparian strips, as well as forest remnants, natural edges, out of forest trees. Forest areas in the surrounding landscape in apple orchards have been demonstrated to positively influence pollinator‘s presence (Watson *et al.* 2011). It has been reported that the pattern of treed habitats such as woodlots, hedgerows, riparian buffers, windbreaks and orchards are more complex and better conserved in smaller farms (Lovell *et al*. 2010), as those that depend on local landraces and wooded habitat remnants in the vineyard have been demonstrated to preserve also endemic animal biodiversity (Jedlicka *et al*. 2014). Our data demonstrate that GrR-based vineyards, as an example of *in situ* conservation on-farm of grapevine genetic resources, assure a habitat diversity within the viticultural agro-ecostystem, in accordance to the principle of agricultural sustainability and in particular that GrR vineyards are crucial eco-mosaic patches for maintaining landscape complexity, connectivity and to enhance the environmental resilience of the innate territory.

Conclusion

The eco-mosaic complexity is an intrinsic value of the rural landscape of traditional agricultural areas. To maintain this landscape complexity, and therefore biodiversity richness, accounts also the viticulture that is tightly linked to the local grapevine genetic resources. The structure of the vineyards, at the base of a traditional use of the local landraces, reflects the principle of landscape ecology. In particular, the respect of a high numerosity of ecological infrastructures and treed areas around side the viticultural surfaces that connect natural parts of the landscape prove the environmental meaning of the *in situ* conservation on farm, also thanks to environmentally friendly viticultural practices. Finally, the resulting agro-ecosystem can be considered a multifunctional agricultural landscape. Therefore, the erosion of grapevine genetic resources and the abandonment of their cultivation not only must be considered as a loss in biological values, but also in precious ecosystem services. The promotion of the on farm conservation, could represent a strategy for maintaining traits of sustainable landscape even in modern agricultural landscapes, beside the ethical, cultural and economic values of marginal rural areas. The significance of the on farm conservation should therefore be implemented with this environmental and ecological meaning and the reinforcement in the farmers of the concept of the ecosystem services linked to natural habitats could preserve landrace-based agro-ecosystems and, in general, assure agriculture sustainability in many agricultural threaded areas.

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