EVALUATION OF THE ENVIRONMENTAL COMPONENTS OF THE TAGGIASCA "TERROIR" OLIVE (IMPERIA, ITALY)

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ABSTRACT

The acknowledgement of the territory vocation is founded on the research of its peculiarities which determine the uniqueness of that production area. In this paper, results concerning the first contributions to characterize *terroir* environment components of Taggiasca olive in Imperia province are presented and discussed. GIS was used to improve the process of landscape characterization. Several profiles from distinct production olive groves were selected for full pedological description and analysis. The analysis showed that the olive groves were mainly located in areas characterized by the following aspects: average annual rainfall between 800 and 1200 mm/y, average annual temperature between 11° and 17°C, altitude between 0 and 400 m a.s.l., acclivity between 5° and 15° and exposure on west slope. Moreover, the research highlighted a number of distinctive features of soils which were characterized by properties rather homogeneous, e.g. moderate depth, good drainage, sub-alkaline reaction, good organic carbon, phosphorus and total nitrogen contents. Finally, we suggested an update of the official PDO EVO production protocols regarding the environment of Taggiasca olive.

KEYWORDS: Territory vocation, PDO EVO, Terraced soils, GIS.

INTRODUCTION

Territorial products have been subject of study since a long time, because of their environmental characteristics, cultivation, manufacturing techniques and territorial historical context, or in a word their *terroir*. The term – originating from "terre" in the French language meaning "land" – describes how the soil, place, and climate of a region influence the taste of food and wine, producing a unique flavor. *Terroir* also reflects the potential ability of a place to express its capabilities, under certain contexts, and to evoke a sense of "somewhere" in creating a unique combination of characteristics.

Therefore, the word *terroir* refers to environmental and cultural characteristics, in addition to the products, representing the symbols of identity of a place and an expression of material culture. Regarding the connection between agriculture and local culture, the term found an unheard-of support in the advancement of geomorphological, pedological and climatological research. These last have provided new handholds to the building process of local identities, allowing to outline the processes connecting environmental characteristics of any agropastoral space to specific features of their productions. However, it was shortly evident that mere environmental properties could not provide the definition of features related to specific territorial product by themselves; thus, cultivation and manufacture techniques and, through them, the entire historical-cultural context were considered (Pioletti, 2003).

Soil and climate are the main elements of the French notion of *terroir*. The application of this concept requires a scientific approach of the ''*terroir* climatic and pedoclimatic components'' to achieve a rigorous zoning of product. Often considered in wine, *terroir* is just as significant in extra virgin olive oil. Olive oils from certain territories generally portray distinct flavors, and olive oil tastings are just as serious (and certainly as delicious) as wine tastings, where the bottles are analyzed for a wide array of factors.

The present study has been focused on a particular Extra virgin olive oil (thereafter EVO) production from Taggiasca variety of olives. The Taggiasca cultivar is certainly the best known among the olive cultivars in Liguria and the EVO oils obtained from these olives are highly valued all over the world (The world's best olive oils, 2019). Several studies (Boggia et al., 2005; Casale et al., 2007; Mannina et al., 2010; Aceto et al., 2019) showed that specific trace elements found in EVO made from Taggiasca olives were good markers of particular production area, limited to the province of Imperia (Liguria, North-Western Italy).

In this paper, results concerning the first contributions to characterize environment components (climate and soil) of the Taggiasca *terroir* olive in the province of Imperia are presented and discussed. Finally, we suggest an update of the official PDO EVO production protocols regarding the environment of Taggiasca olive.

STUDY AREA

Environmental setting

The study area is located along the coastal zone of Western Liguria (NW Italy) and borders of the Tyrrhenian basin in the Western sector of the Ligurian Alps (Fig. 1), at the junction of the Maritime Alps.

From a geological point of view (Fig. 2), the study area is characterized by tectonic units involved in the front of Ligurian Alps, which belong to the Piedmontese continental margin Domain, the Piedmontese–Ligurian oceanic Domain and the Dauphinois Domains. This main geological complex testifies to the Europa-verging movement of the Ligurian Alps nappes and includes the Helmintoid Flysch Nappe, which is a detached non-metamorphic sedimentary cover belonging to the Piedmontese Oceanic (Vanossi et al., 1984; Schmid et al., 2004; Giammarino et al., 2010 a, b). The Helmintoid Flysch Nappe, also known as the Western Liguria Flysch complex, includes the Sanremo-Monte Saccarello, Moglio-Testico, Alassio-Borghetto and Colla Domenica-Leverone tectonic Units, which are largely composed of turbidite deposits (Vanossi et al., 1984). The Sanremo-Monte Saccarello Unit occupies most of the study area and includes the following three formations (bottom to top): San Bartolomeo Formation, Bordighera Sandstone and Sanremo flysch. This Unit is mainly constituted by anchimetamorphic upper Campanian-Maastrichtian turbidites, resting on upper Hauterivian-upper Campanian basin plane varicoloured pelites, which is, the San Bartolomeo Fm., up to 300 m thick (Cobianchi et al., 1991; Sagri, 1980, 1984). The turbiditic sequence begins with coarse to fine grained quartz-feldspatic sandstones and it is interlayered with thin beds of marls or dark pelites (Bordighera Sandstones Fm.), reaching 250 m of thickness.

The studied area comprises also a small part of the southeasternmost outcrops of the Dauphinois domain (Roia valley) which consist of thick succession of Cretaceous marly limestones and flysch (Vannossi, 1991). Moreover, along this sector of the coast, it is also possible to identify marine late and post-orogenic Pliocene deposits, resulting from a transgression of the Tyrrhenian basin (Gianmarino and Tedeschi,1983). In addition, the coast is characterized by the presence of relict-terraced landforms of marine origin at various elevations and ages, which are generally related to the repeated transgression/regression cycles caused by Quaternary tectonics and climatic fluctuations. The coast is generally high and abrupt with promontories, alternating with plains of limited amplitude, while the hydrographic network primarily follows the tectonic lineation.

The watercourses are primarily of torrential type, consisting of valleys incised with V-shaped cross-sections. The steep slopes are strongly influenced by running-water erosion processes that have been amplified by human activities and include mass movements and frequent rejuvenation phenomena, producing considerable accumulations of debris on the lower slopes.

The climatic features of Liguria are primarily determined by the relief configuration of its hilly or mountainous terrain and by its extensive contact with the coast. Liguria marks the transition between Mediterranean and sublittoral climates and subcontinental climate; the latter being characteristic of the south-western region of the Po Plain. The Western coast of Liguria is characterized by subarid climate, in contrast with the subhumid and humid climates of Eastern coastal sites (Csa-type, sensu Köppen, 1936). The present-day pedoclimate (*sensu* Soil Survey Staff, 2010) is distinguished by xeric to ustic soil moisture regime, associated with thermic soil temperature regime (Costantini et al., 2012).

The vegetation cover is primarily composed of maquis and holm oak woods with frequent areas of cultivated terraced areas.

According to the WRB (FAO and Food and Agricultural Organization of the United Nations 2014), soils occurring in this landscape are primarily Dystric or Calcaric Cambisols.

Historic background

The first documentation of olive cultivation dated back to Roman period (116-27 BC) in Valle del Magra and Piana di Albenga; although seems possible that the introduction of olive trees in the Western Liguria was earlier induced by the Phoenician colony of Marseille (Angelini, 2009, p. 294). The diffusion of olive growing continued until the Early Middle Ages on the interior hilly slopes and expanding to Piemonte and Eastern Emilia, favored by the activity of monks and warm climate (Angelini, 2009, p. 294; Quaini, 2010, p. 186). From XIV century a contraction of this area occurred, caused by the climatic change with worsening of temperatures: olive trees were limited to coastal areas, valleys and crests, where the microclimate was mitigated by the sea effect. During the XVI century, olive cultivation increased again because of the commercial activities of Pisa, Livorno and Genova, which exported the olive oil to the coasts of Italy, France and Spain, using the derived assets to invest in land properties and olives related activities in the countryside. The olive growing became more specialized and diffused, with consequent transformation of the landscape and construction of terraces, especially in the Western area of Liguria. Several olive types (Taggiasca, Lavagnina, Rizzola, Pignole, Mortine, Olivastri e Lantesca), which are still characteristic of Liguria, were documented in trading records (Angelini

2009, p. 294). In the XVIII century new theories for the innovation of the agriculture were developed and first studies concerning the Ligurian olive growing began (Angelini, 2009, p. 294).

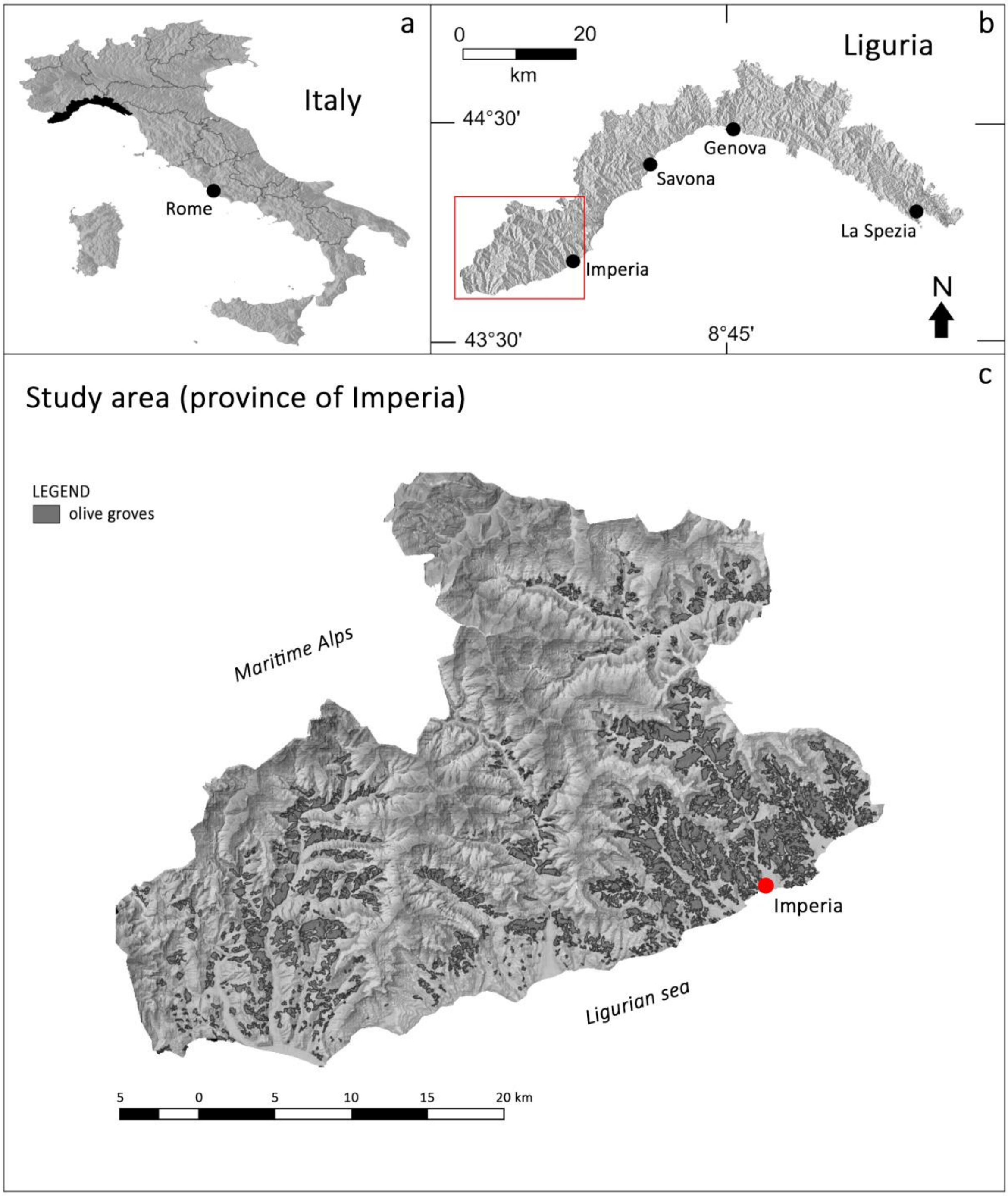

Figure 1. a) Location of Ligurian region in Italy; b) Location of the study area within the Ligurian region (red rectangle); c) Map of the study area in the province of Imperia, with selection of the olive groves present in the territory.

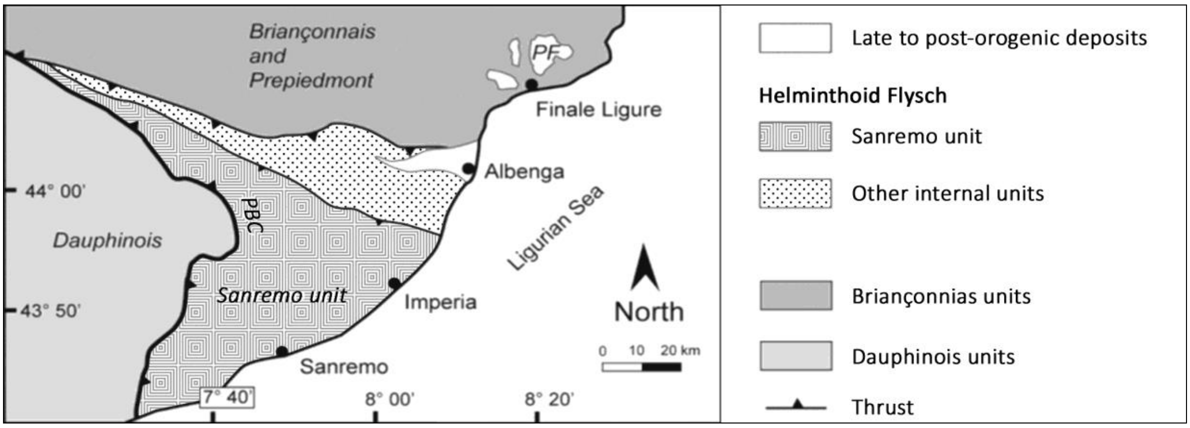

Figure 2. Tectonic setting of the study area (Imperia province) showing the main paleogeographic domains (Piedmont–Ligurian, Prepiedmont, Briançonnais and Dauphinois). The Helminthoid Flysch nappes rest above the Briançonnais–Dauphinois boundary through the Penninic Basal Contact (PBC). PF: Miocene-age Pietra di Finale deposits.

A case study regarding the hamlets of Caramagna, Cantalupo and Ricci, situated at NNW of Porto Maurizio in the province of Imperia, investigated the landscape evolution in relation to the olive cultivation and land use during the XVIII-XX centuries (Ribò 1991). During the XVIII century the olive tree were diffused from the plain to the upper hills, while the arable (vine, vegetables and rushes) was present in the valley floor (Fig. 3). In the XIX century the cultivation system was the wood-like olive orchards ("oliveto a bosco"), characterized by large trees, with irregular patterns, where terraces were used also for plants (Quaini, 2010, p. 186). At the end of XX century the olive growing decreased at 50% in this area, as well as the cultivation of oat, grain, fig and almond trees, in favor of fruit trees, vines, vegetables and uncultivated. Another case study is represented by the village of Lucinasco, where the high production of the Taggiasca olive was combined with pastoral activities, shaping the landscape and limiting the shepherd nomadism in the XIX century (Quaini, 2010, p. 188). This situation reflected the more general situation of Liguria, where the olive cultivation contracted in favor of more profitable cultivation and urbanistic and touristic demands. Finally, the olive growing rarefied in the plain and coastal areas, while it progressively disappeared from the internal areas on hills (Ribò, 1991). Since the end of XX century, a renovated interest for the cultivation of olives started in Liguria and Imperia is nowadays the province where the olive cultivation is mostly diffuse (Angelini, 2009, p. 295).

Olive cultivation

Olive tree *Olea europaea* requests specific climatic conditions: sun and light exposure, temperature above 3-4°C, absence or limitation of strong wind, excessive rain, and air humidity. It prefers loose or medium mixture soils, cool and well drained. It also grows in coarse or less deep soils, with emerging bedrock or in calcareous and acid soils, tolerating pH till 8.5-9, but it suffers in heavy soils and waterlogging conditions. Olive tree tolerates salinity and proximity to coasts. It can resist to long periods of drought, assuming a xerophytic habitus; however, the hydric stress compromises the olive production (Angelini, 2009, p. 296).

Figure 3. Perspective view of the Ligurian city of Oneglia and Porto Maurizio, one of the two main settlements of the city of Imperia, showing the diffusion of terraced olive cultivation and arable in the valley floor. Original etching on copper matrix impressed for the first time in Amsterdam, by the heirs of I. Blaeu, in 1682, under the title of Theatrum Statuum Regiæ Celsitudinis Sabaudiæ Ducis. Cfr.KOEMAN C., "Atlantes Neerlandici [...]", Amsterdam 1967-71, vol. I, pp. 376-377, record Bl 109- Bl 110. (www.cartiglio.it)

Olive cultivation in Liguria has created a peculiar agricultural landscape, worldly unique. The distinctive characters include diffusion on high slope soils and terraces made with dry walls, fragmentation of the firm surfaces, high density of plantation (1 hectare can contain till 500 trees), advanced age of the orchard and considerable height of the trees. High productivity and substantial index of covering of the soil are the main characteristics since the olive growing is considered a specialized cultivation for income. The construction of terraces has deeply modified the landscape, excavating flat portions of hills and creating steps of sediment, which are delimited and hold by dry stone walls on the rock surface (Fig. 4). The internal structure covered with permeable layer of sediment and pebbles has the function of controlling the hydric capacity of the sediment and reducing the erosive action. Therefore, even the steepest hills have become usable for cultivation. Nowadays terraces in Liguria are protected by restriction (*vincolo*) and they accommodate most of the olive cultivation (Angelini, 2009, p. 304-305). However, industrialization and tourism activities have caused important socioeconomic changes in rural areas, leading to the abandonment of marginal terraced hillslopes. Because of this, the anthropic hydrological infrastructures which were protecting the soil and preserving the land cover in the recent past are progressively collapsing. The structures in ruin lead to the rapid removal of the soil, hence, causing important land degradation problems.

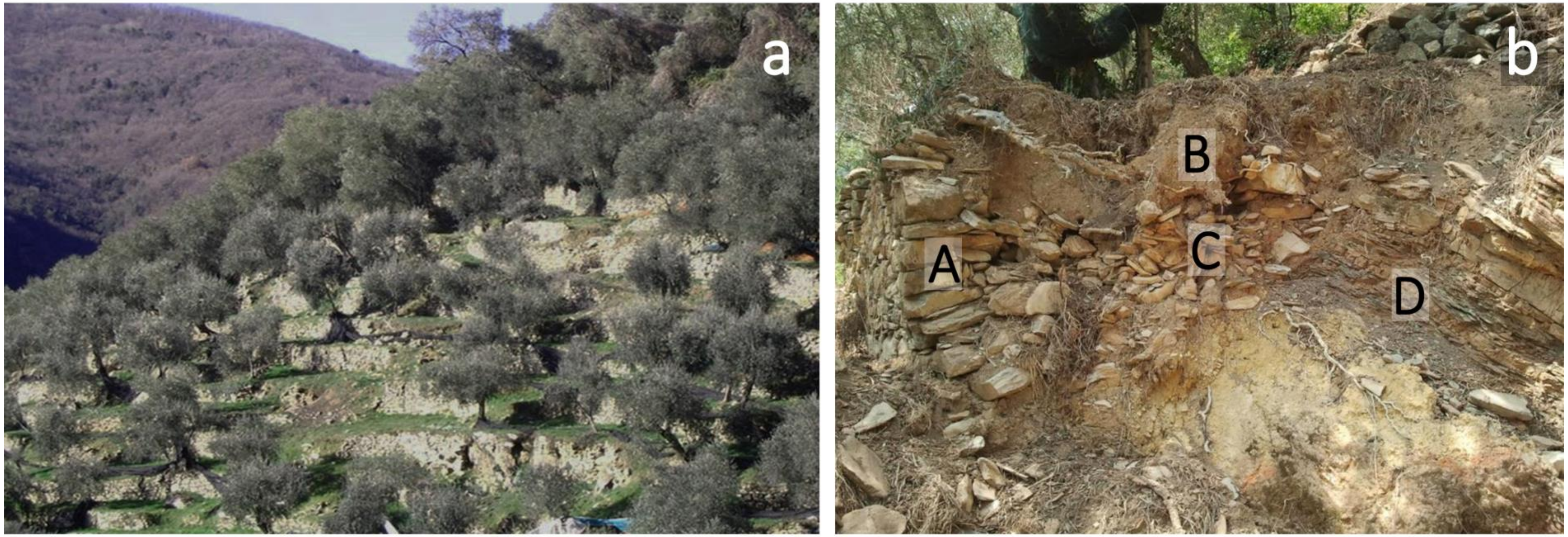

Figure 4. a) terraced hillslopes nowadays in the province of Imperia (https://hotcore.info/babki/news-liguria-ponente-ligure.htm); b) section of a terrace, exposed by its partial collapse: A- dry retaining wall; B- filling sediment; C- layer of pebbles to control the hydric capacity; D- bedrock excavated for the construction of the terrace.

Protected Designation of Origin (PDO) Disciplinary

The Taggiasca olive derives from Taggia, where it was brough by the monks of San Colombano from the monastery isle of Lerino. It is one of the most renowned to produce EVO, harmonized to the Ligurian climate over the centuries. This olive is typic of the Western Liguria “Riviera dei Fiori”, limited to the province of Imperia where 90% of the trees are from this quality. Taggiasca olive is one of the best for consumption because, despite of the small dimension, it is very savory and the oil has low acidity and sweet flavour; characteristics which are highly and worldwide appreciated (Casale et al., 2007; Angelini, 2009, pp. 303-304).

Since January 1997 the registered name of Protected Designation of Origin (thereafter PDO) for “Riviera Ligure Extra Virgin Olive Oil” (EC Regulation 123/97) has been instituted for this type of cultivation (Angelini, 2009, pp. 303-304). However, this PDO label includes different varieties, such as “Riviera dei Fiori”, “Riviera del Ponente Savonese” and “Riviera di Levante” obtained from the olives Lavagnina, Razzola and Pignola. Although these varieties are excellent products, the Taggiasca olives and EVO are considered superior. The producers, 340 farms cultivating over 2.600 ha on terracing and producing 1.2 million of bottles (500 ml – annual average) are hoping to obtain a specific PDO recognition of Taggiasca in the near future (Aceto et al., 2019).

This PDO label could guarantee for an important quality product and promote the development of an important sector of Ligurian economy (Casale et al., 2007).

MATERIALS AND METHODS

Geographical information systems (GIS)

GIS provide a powerful tool for the integration of large and complex environmental databases and models, improving the process of landscape characterization. ArcGIS 9.2 Desktop version (ESRI, Redmond, USA) was used to process the digital elevation model (DEM) data with 5 m resolution. The DEM was based on the interpolation of contour lines of a 1:5000 topographic map (Carta Tecnica Regionale Ligure, 2007 available at https://geoportal.regione.liguria.it) using a thin plate spline algorithm proposed by Hutchinson (1996). We performed a detailed Terrain Analysis on the DEM using GIS tools and extracted some topographic characteristics as slope, aspect, altitude.

Data concerning the areal distribution of the geological substrate was derived from GIS database stored in archived records by Regione Liguria (available at https://geoportal.regione.liguria.it).

These were successively overlaid with the map of the area registered in the olive groves of the PDO “Riviera dei Fiori” by Regione Liguria (available at https://geoportal.regione.liguria.it) to analyze the relationship between PDO olive groves and topographic or geological characteristics. Moreover, in the present study, high-temporal-resolution temperature and rainfall records were collected from 53 weather stations of the Regional Hydrographic Services and Regional Agencies for Environmental Protection (ARPAL). The selected stations were well distributed throughout the territory. The time-series were composed of continuous 10-year records for most of the stations (2002–2011).

The mean annual temperature and precipitation values of the last ten years calculated for the single stations were subsequently interpolated using a Co-Kriging method in GIS (Universal Kriging, Conrad, 2006) to obtain a spatial distribution of the precipitation and temperature. A digital elevation model with 5 meters resolution was utilized as co-variable. Consequently, the result has 5 meters resolution for the entire study area. These maps were successively overlaid with the map of the area registered in the olive groves of the PDO "Riviera dei Fiori" to analyze the relationship with temperature and precipitation

Soil

At present, the only informative soil maps of Liguria in Northern Italy include the following: a) soil regions at a scale of 1:5,000,000; b) soil sub-regions at a scale of 1,000,000 and c) soil systems at a scale of 1:500,000. The soil information was collected and harmonized from different sources (Costantini et al., 2004; Costantini and Dazzi, 2013). The scale of these maps was not adequate for local land planning strategies; nonetheless, it was useful for soil correlation at the national level. In addition, large amount of soil data, mostly stored in documents and not always freely available, were scattered among public offices. Therefore, several profiles from 8 distinct different agricultural holdings (i.e., pertaining to oil producer "Saguato", "Frantoio del Rundò", "Ramoino", "Euro", "Ernest", "Vis Amoris" and "Sciorato"), located on flysch and conglomerate (Pliocene) bedrock, were selected for full pedological description and sampling (Fig. 4b). Complete soil analyses were carried out for each horizon in the pits. The set of analyses was realized by the Regional Soil Analysis Laboratory in Sarzana (Spezia, Liguria) (ISO 9001 certified). Laboratory routine analyses were performed in compliance with the proposed official Italian methods for each horizon (MiPAF, 1999). Soils were defined on the base of their morphology, according to the criteria of the modern and international classification system of the WRB (World Reference Base; FAO, 2014). A two-tier system was used for the qualifier level, i.e., prefix and suffix, which are the formative elements for second-level WRB classification. The WRB system was well suited to our objectives and guaranteed the reproducibility and longevity of our interpretations.

RESULTS

GIS analyses

We have analyzed the relationships between PDO olive groves distribution and altitude, aspect, slope, and geology. The results of the analysis (Fig. 5-10) showed that maximum frequencies corresponded to the elevation class from 0 to 400 m (90%). The frequency tended to decrease from 400 m to 1000 m. All PDO olive groves were set on sedimentary rocks: the maximum frequency (90%) corresponded to turbiditic sandstone-marl (Helmintoid Flysch, Sanremo-Monte Saccarello Unit), while the minimum frequency (5%) of olive groves was found on debris and carbonates of Dauphinois domain. The relationship between PDO olive groves and slope showed that the maximum frequencies of PDO olive groves corresponded to the slope between 5° and 15° and only the 20% was cultivated in plains (0°-5°). Furthermore, the maximum density (69%) of PDO olive groves was observed on West and South facing slopes. Finally, we have analyzed the relationships between PDO olive groves distribution and the mean annual temperature and precipitation values registered for the study area. The results of the analysis showed that maximum frequencies corresponded to the precipitation classes from 800 to 1200 mm/y and to the temperature classes from 11° to 17°.

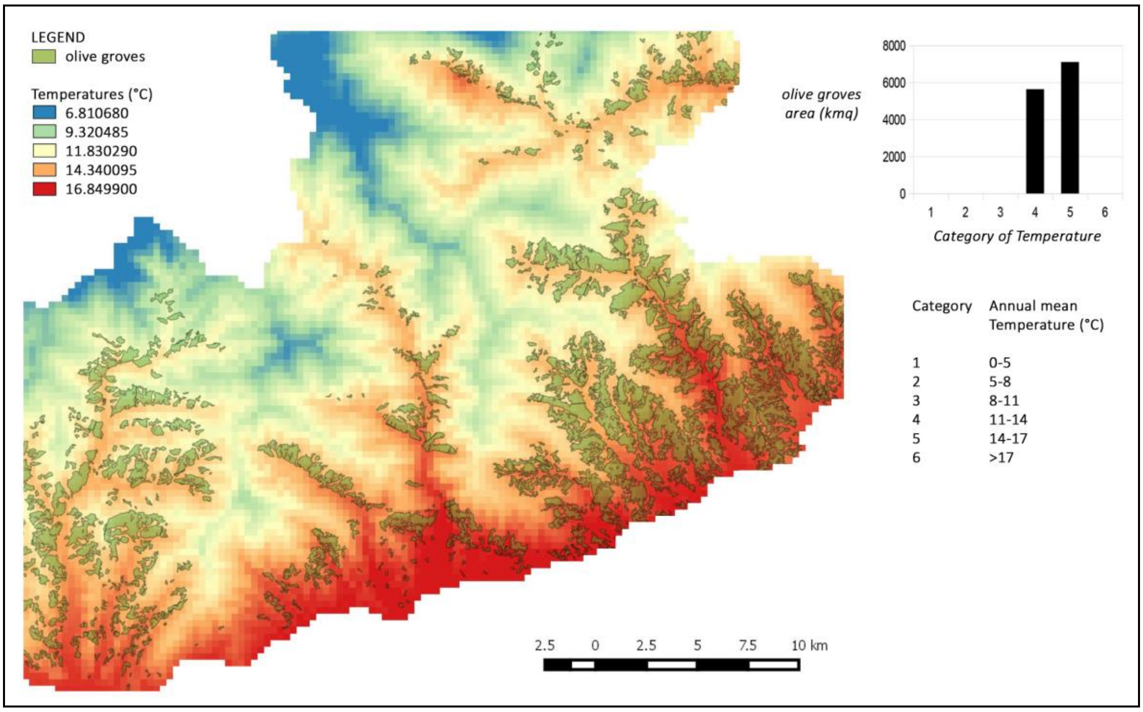

Figure 5. Overlapping between the map of average annual temperatures for the province of Imperia and the GIS layer regarding the PDO olive groves through the GIS Overlay Mapping function.

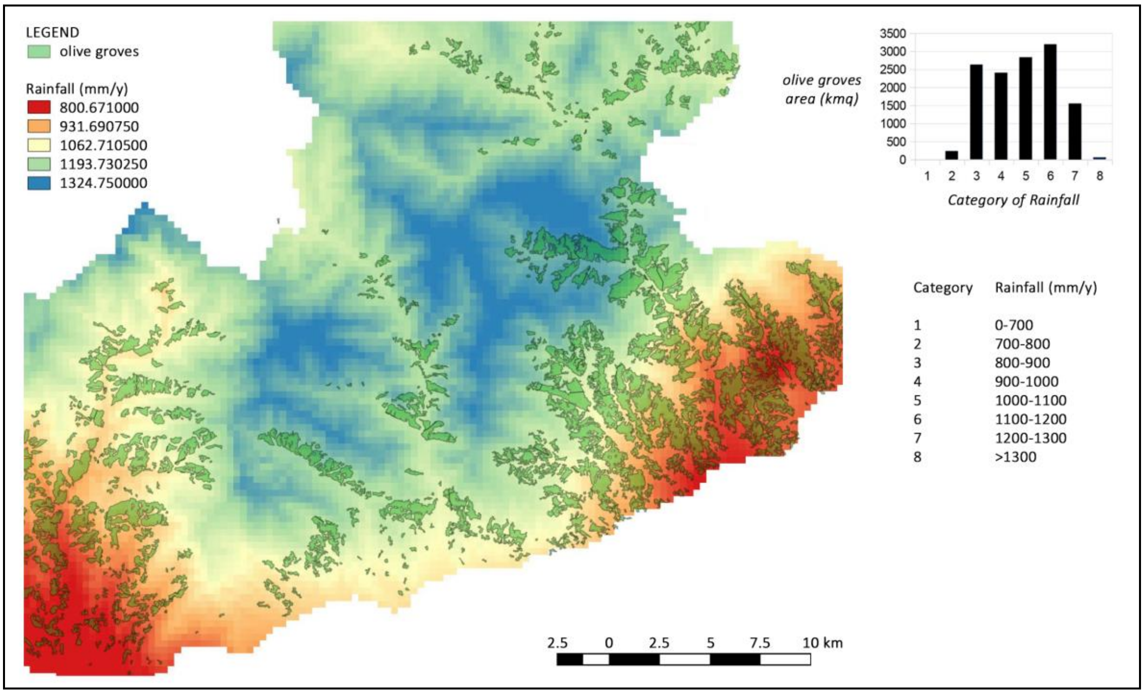

Figure 6. Overlapping between the map of average annual rainfalls for the province of Imperia and the GIS layer regarding the PDO olive groves through the GIS Overlay Mapping function.

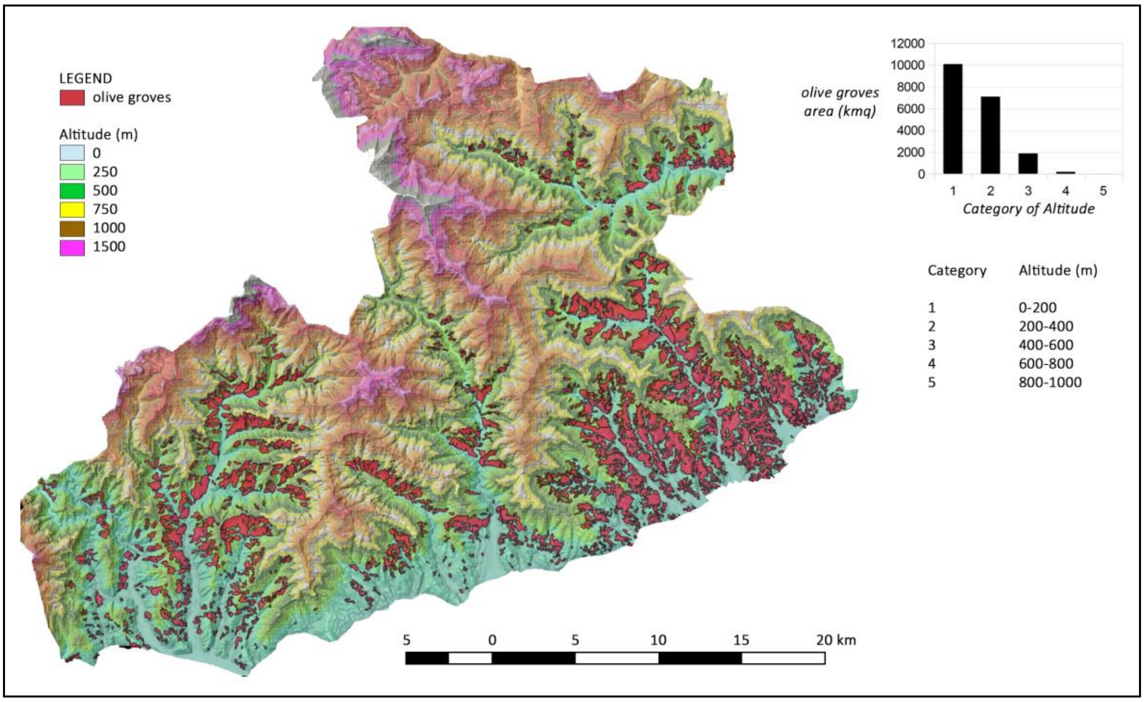

Figure 7. Overlapping between the map of altitude created with DEM (Digital Elevation Model) through Regional Technical Maps, 1:5.000 scale, 3D vector version and the GIS layer regarding the PDO olive groves through the GIS Overlay Mapping function.

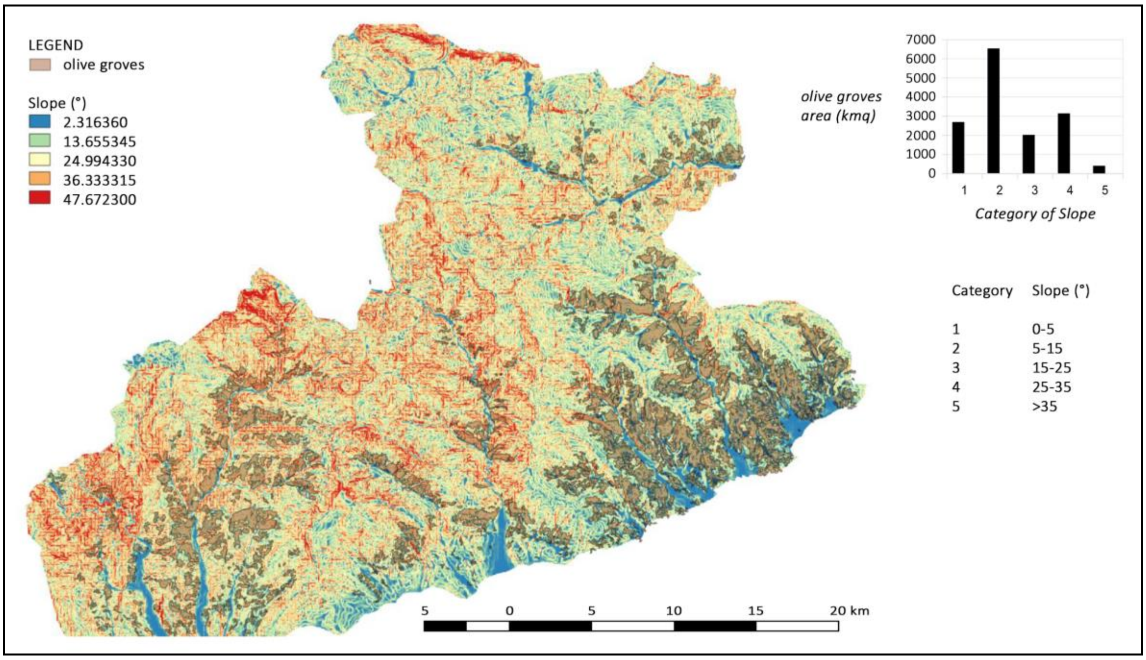

Figure 8. Overlapping between the map of slope created with DEM (Digital Elevation Model) through Regional Technical Maps, 1:5.000 scale, 3D vector version and the GIS layer regarding the PDO olive groves through the GIS Overlay Mapping function.

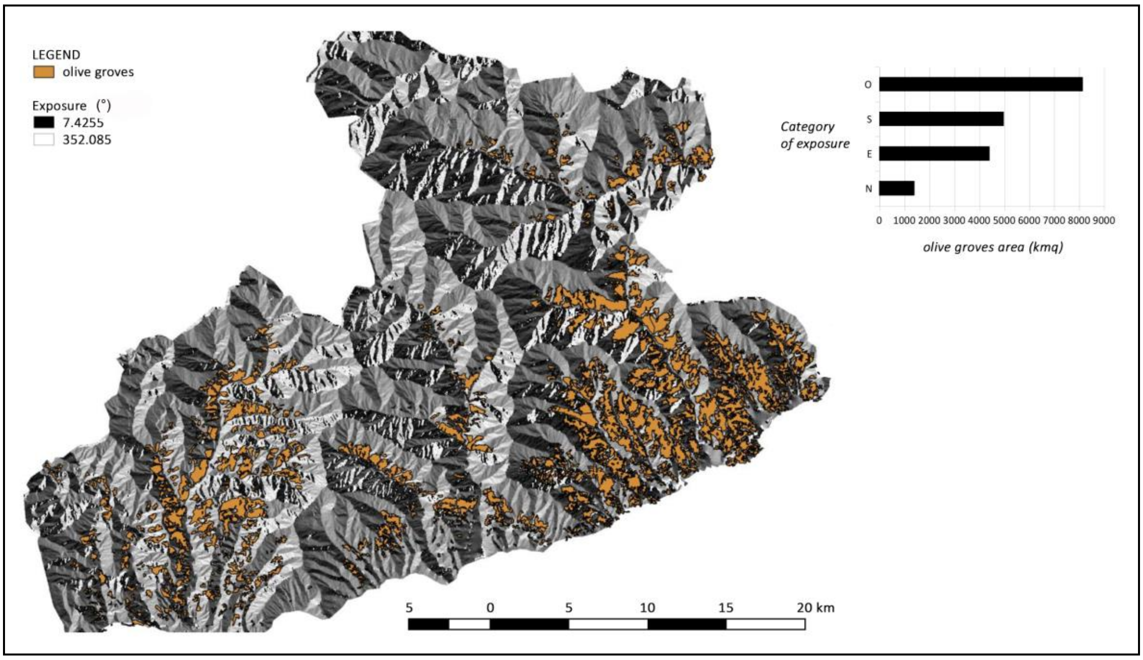

Figure 9. Overlapping between the map of exposure created with DEM (Digital Elevation Model) through Regional Technical Maps, 1:5.000 scale, 3D vector version and the GIS layer regarding the PDO olive groves through the GIS Overlay Mapping function.

Soil

Three Reference Soil Groups (RSGs) were identified among the 8 soil profiles, i.e., Cambisol, Calcisol and Lixisol, with detailed descriptions based on the WRB classification (FAO, 2014). The main morphological, physical and chemical data are reported in Table 1.

- Cambisols (five profiles) include soils with at least incipient subsurface soil formation. They were characterized by moderate weathering of parent material, early stages of horizon differentiation and evident changes in soil structure, colour and clay content. Cambisols were the dominant soils on most of terraced slopes (escalic) and marly-sandstone flysch. They were often moderately deep (leptic, 50-100 cm) and they featured loam and clay loam textures with common stones. The pH was slightly alkaline in the surficial horizon and moderately alkaline (pH > 8.2) within the deeper horizons. These soils were rich of basic components and characterized by incomplete carbonate leaching (sometimes calcaric), with total $CaCO_3$ content varying from 1 to 14%, probably due to limestone dissolution of parent material or interactions with groundwater, which contained dissolved carbonates. Organic carbon was primary concentrated in the surface horizons (A), despite the significant amount of it even in the underlying horizon (> 1%). The CEC values of these soils were the highest within the study area. Topsoils generally had high available P and N content values, whereas the subsoils featured lower values.

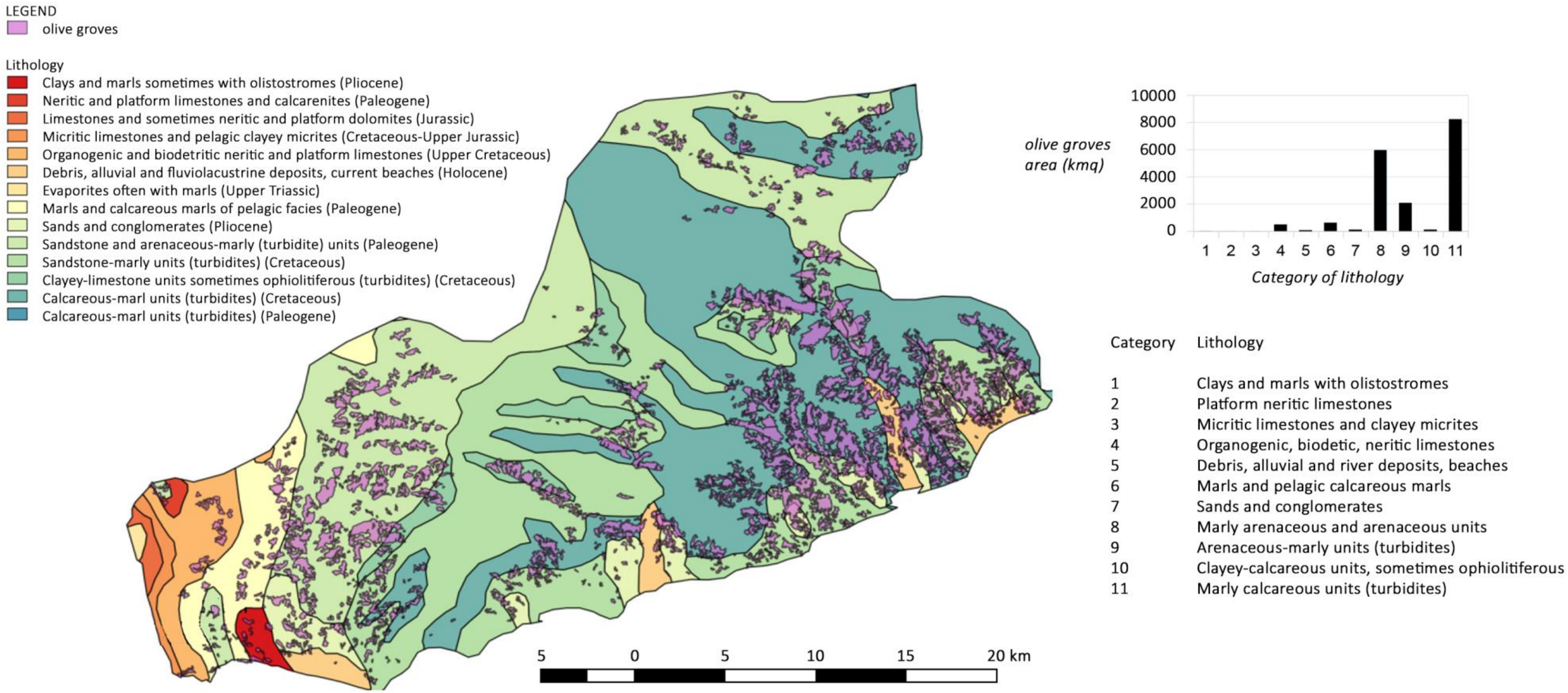

Figure 10. Overlapping between the map of lithology from archives of Regione Liguria and the GIS layer regarding the PDO olive groves through the GIS Overlay Mapping function.

- Calcisols (two profiles) were relatively common in the study area and appeared predominantly on Pliocenic conglomerate (marine terraces) and marly-limestones in the terraced slopes. Calcisols accommodated soils in which there was substantial secondary accumulation of lime (calcic horizon) within 100 cm of the soil surface, as evidenced by high values of $CaCO_3$, base saturation (equal or close to 100%), alkaline pH values and by common presence of soft powdery lime or nodules in deeper horizons. In particular, the soils on parent material consisting of Pliocene marine deposit (P8) showed very high values of $CaCO_3$ ranging from 30 to 40%. The texture of these soils varied from silty loam to clay loam with increasing stones content with depth. The analysis results (Table 1) confirmed that soils of this group had high available P and N content values in the surficial horizon; these values naturally decreased with depth. The CEC values were mostly due to higher OC contents in the enclosures, except for the very deep horizons, where values were had medium.

- Lixisol were less common (one profile) and were located in the summit areas of the sandstone-marly flysch. They seemed to be restricted to the development and preservation of ancient erosional surfaces (palaeosurfaces) that enabled rates of weathering to exceed those of erosion and favoured clay illuviation. They were shallow and characterized by with continuous rocks close to the surface (leptic), silty loam texture at the surface and increasing clay content with depth. The pH values were slightly alkaline and the soils showed very low values of $CaCO_3$ (<1%).
  The soils in this group had high available P, organic matter and N contents. The CEC was high, whereas the base saturation was medium.

Generally, the C/N ratios of all soils were close to 10 values, indicating Mull humus form, characterized by well-humified organic matter rich in stable mineral-organic complexes.

DISCUSSION

The geomorphological analyses documented an overall similar environment of the soils examined, belonging to terraced olive groves with low-medium altitude, west-facing and moderately steep slopes (strongly dissected topography), influenced by a semiarid climate on parent rock rich in carbonates and clay, often modified profoundly through human activities. In fact, terraced soils are artificially constructed by humans and are often manually filled with soil collected from the surrounding area. However, the filling could be composed by transported material to improve soil properties or nutrient status to enhance the cultivation of olives.

For all these reasons, terrace soils are considered as constructed pedoenvironments with typifying characteristics (Stanchi et al., 2012). The geomorphic processes resulting from terracing and the consequent management practices induce metapedogenetic changes in soil properties and evolution (Dudal, 2005), i.e. human-directed changes that do not depend directly on pedogenetic processes (Yaalon and Yaron, 1966). Terrace building could be regarded as an artificial “entisolization” process (Dazzi, 1995) with the restarting of the pedogenesis (Stanchi et al., 2012).

Table 1. The main chemical and physical features of the 8 soil profiles of the studied olive groves. [d] O.M.: organic matter; [e] Cond.: electrical conductivity; [f] C.E.C.: cation exchange capacity; [g] B.S.: base saturation.

Horiz.	**Depth** (cm)	**Grain size**			**pH**	**$CaCO_3$** (%)	**O.M.**[d] (%)	**N** (g/kg)	**P** (mg/kg)	**C/N**	**Cond.** e (dS/m)	**C.E.C.**[f] (meq/100 g)	**Exchangeable bases** (meq/100 g)				**B.S.**[g] %
		sand	**silt**	**clay**	**H_20**								**Ca**	**Mg**	**K**	**Na**	
P1 – SAGUATO: Leptic Cambisol Calcaric Escalic (Terraced Slope on Nelmintoid Flysch)																	
AB	0-10	18,1	52,4	29,5	8,0	11,61	4,80	3,45	10	8,1	0,68	22,90	20,7	0,8	1,22	0,25	100,61
BC	10-60	17,1	48,5	34,4	8,3	13,9	2,80	2,16	4	7,5	0,51	23,90	18,8	0,6	0,49	0,11	83,81
C	60-140	6,8	49,0	44,2	8,3	15,19	1,90	1,8	3	6,1	0,47	21,40	19,2	0,6	0,64	0,1	96,36
P2 – RUNDÒ: Leptic Calcisol Escalic (Terraced Slope on Nelmintoid Flysch)																	
A	0-10	27,8	51,7	20,5	7,8	18,71	7,30	4,49	6	9,5	0,74	24,80	21,4	0,6	1,52	0,17	95,28
B	10-40	31,9	39,7	28,4	8,5	24,3	2,00	1,56	3	7,5	0,52	22,50	16,6	0,3	0,24	0,12	76,67
P3 – SCIORATO: Leptic Cambisol Humic Escalic (Terraced Slope on Nelmintoid Flysch)																	
A	0-15	23,7	45,7	30,6	7,7	0,85	3,90	3,43	6	6,6	0,53	24,70	25,5	0,5	0,3	0,13	106,96
B1	15-55	25,0	35,1	39,9	8,2	1,01	1,80	2,16	3	4,8	0,5	24,90	29,9	0,9	0,75	0,15	127,31
B2	55-80	35,4	31,1	33,5	8,2	0,82	1,40	1,92	3	4,2	0,5	25,70	22,8	0,2	0,22	0,12	91,09
P4 – ACQUASANTA: Leptic Cambisol Humic Escalic (Terraced Slope on Nelmintoid Flysch)																	
A	0-5	26,6	48,3	25,1	7,4	1,18	9,40	5,92	27	9,2	0,72	28,60	26,4	0,8	27,18	0,15	99,90
BC	5-60	16,1	47,9	36,0	8,2	0,86	2,70	2,48	5	6,3	0,5	24,10	23,5	0,4	23,94	0,13	101,20
P5 – EURO: Leptic Cambisol Calcaric Escalic (Terraced Slope on Nelmintoid Flysch)																	
A	0-5	19,2	58,8	22,0	7,7	11,03	11,30	6,44	33	10,2	0,73	30,30	27,5	0,8	1,26	0,16	98,15
AB	5-35	16,2	49,6	34,2	8,2	14,94	2,70	2,37	5	6,6	0,53	26,80	24,9	0,4	0,32	0,14	96,19
2BC	35-50	17,0	45,1	37,9	8,4	15,15	1,60	1,88	3	4,9	0,51	28,70	26,4	0,5	0,3	0,13	95,37
P6 – RAMOINO: Cutanic Leptic Lixisol Hypereutic Skeletic (Summit Area on Helmintoid Flysch)																	
A	0-10	23,8	55,3	20,8	7,4	0,68	8,90	4,96	13	10,4	0,62	26,20	20,4	1,3	1,06	0,13	87,25
B1	10-30	27,9	47,9	24,2	7,9	0,69	2,10	2	3	6,1	0,52	20,80	16,0	0,4	0,25	0,11	80,72
B2	30-75	17,7	44,7	37,6	8,1	0,73	1,20	1,41	3	48,2	0,47	20,50	17,3	0,3	0,24	0,11	87,76
P7 – ERNEST: Leptic Cambisol Calcaric Escalic (Terraced Slope on Nelmintoid Flysch)																	
A	0-10	34,8	47,7	17,5	7,3	1,23	12,20	7,6	7	9,3	0,84	36,30	31,3	0,9	0,77	0,15	91,16
B	10-60	21,6	39,1	34,8	8,2	2,28	1,70	1,84	2	5,4	0,52	27,90	23,6	0,3	0,22	0,13	86,85
P8 – TERRE BIANCHE: Haplic Calcisol Skeletic (Marine Terrace on Pliocenic Conglomerate)																	
A	0-10	32,6	51,8	15,6	7,8	30,75	7,50	4,12	10	10,6	0,68	25,90	24,8	1,0	0,57	0,17	102,20
B	10-40	32,2	42,3	25,5	8,1	34,7	3,60	2,18	5	9,6	0,61	22,90	19,8	0,5	0,28	0,15	90,57
BC	40-60	22,4	46,0	31,6	8,2	34,68	2,40	1,87	3	7,5	0,57	21,40	18,8	0,4	0,25	0,17	91,64
BCk	60-90	18,8	45,9	35,3	8,5	37,87	1,30	1,06	2	7,1	0,52	19,30	16,6	0,3	0,19	0,16	89,33
Ck	90-150	23,4	45,3	31,3	8,4	40,87	1,20	0,85	3	8,2	0,52	17,90	14,3	0,3	0,19	0,11	83,02

Nevertheless, the terraced soils analysed during this study were mainly moderately developed (cambisols) as the origins and management history of terraces were quite ancient or the surrounding natural soil material already weathered (pre-altered).

Some soils in the summit position or on ancient marine terraces (Lixisol and Calcisol) were mostly considerably older than the soils on the slopes. These were relict soils marked by distinct argillic and calcic horizons. The low mean slope gradient decreased the erosion of the soil and increased clay and carbonate translocation. The group of those soils was less common, occurring only in few olive groves of the study area.

Despite these genetic differences, many of the soil properties analyzed during this research were rather homogeneous, e.g. moderately deep soil, good drainage, sub-alkaline reaction, good organic carbon, phosphorus and total nitrogen contents in the A horizons and in depth and loam texture.

As far as the aptitude of these soils for the cultivation of olive trees is concerned, in general, no limiting factors have been highlighted. In fact, although olive trees could grow up within several soil types, they better grow and produce in medium textured soils within wide range of pH from moderately acid (5.6) to moderately alkaline (8.5) and well drained calcareous soils. Problems could occur on very clay soils (clay > 40-45%), in plain soil, due to water stagnation, to which the olive tree is very sensitive. Moreover, olive is more salt and drought tolerant than other temperate fruit trees (Costantini, 2006).

According to the climatic requirements of the species proposed by Proietti and Regni (2019), the study area is suitable for the development of olive production and no limiting factors have been highlighted. Proper olive cultivation areas have mean annual temperature between 15–20 ◦C, with minimum of 4 ◦C and maximum of 40 ◦C. Usually, the optimum temperature for olive vegetative growth ranges between 10 ◦C and 30 ◦C, while carbohydrate synthesis occurs at higher rates at temperatures ranging from 20 ◦C to 30 ◦C. Olive trees require a period of low temperatures (0–7 ◦C) for flowering bud differentiation. On the other hand, temperatures constantly above 16 ◦C prevent bud differentiation. However, the minimum temperature should not drop below −7 ◦C, which can seriously damage trees, and if the temperature reaches −12 ◦C, the tree could die. High altitudes (>800 m) are not appropriate for olive cultivation, due to the incidences of frost and the short vegetative period in those locals. Although in some cases olive trees can grow with a rainfall of 200 mm year−1, the quantity of water above 400/ 500 mm year−1 should be considered sufficient.

In the study area, olive trees were grown mainly on the wide strip between 400 meters above sea level and the coastline characterized by average annual temperature varying from 11°C in the Alpine slopes to 17° along the coast or valley bottom and rainfall ranging from 800 to 1200 mm/y. On the Alpine slopes the number of olive tree decreased, due to the increase of elevation and the limitation of continentality.

CONCLUSION

The present research aimed to defined parameters and environmental factors useful for the definition of the *terroir* of the PDO EVO oil “Riviera dei Fiori”. The analysis showed that the olive groves were mainly located in areas characterized by the following aspects:

- average annual rainfall between 800 and 1200 mm/y;

- average annual temperature between 11° and 17°C;
- altitude between 0 and 400 m a.s.l.;
- acclivity between 5° and 15°;
- exposure on west slope;
- moderately developed and shallow terraced soils with sub-alkaline and good reaction content of organic carbon, carbonates and nutrients also in depth (Leptic Cambisol Calcaric/Humic Escalic) and loam texture.

The results could lead to an implementation of the PDO specification "Riviera dei Fiori", which currently quotes:
"For the production of controlled denomination of origin extra virgin olive oil "Riviera Ligure", accompanied by the additional geographical mention "Riviera dei Fiori", are from the olive groves included in the production area described in point 2 of the art. 3, from which lands, of more or less accentuated sloping position with terraced arrangement, derive from the mechanical disintegration of the parent rock of calcareous origin (Eocene) with the formation of stratifications which over time have given rise to medium-textured soils with a tendency to dissolved in the higher quotas". [Original quote: "*Per la produzione dell'olio extravergine di oliva a denominazione di origine controllata "Riviera Ligure", accompagnata dalla menzione geografica aggiuntiva "Riviera dei Fiori", sono da considerarsi idonei gli oliveti compresi nella zona di produzione descritta al punto 2 dell'art. 3, i cui terreni, di giacitura in pendenza più o meno accentuata con disposizione a terrazze, derivano dalla disgregazione meccanica della roccia madre di origine calcarea (Eocene) con la formazione di stratificazioni che nel tempo hanno dato origine a terreni di medio impasto con tendenza allo sciolto nelle quote più elevate."*]

The definition could be updated as follows:
"For the production of controlled denomination of origin extra virgin olive oil "Riviera Ligure", accompanied by the additional geographical mention "Riviera dei Fiori", are from the olive groves included in the production area described in point 2 of the art. 3, whose terraced soils, on slopes with moderate slope and prevalently western exposure, derived from the alteration of calcareous or arenaceous-marly rocks which over time have given rise to soils of loam texture and slightly alkaline reaction". [*"Per la produzione dell'olio extravergine di oliva a denominazione di origine controllata "Riviera Ligure", accompagnata dalla menzione geografica aggiuntiva "Riviera dei Fiori", sono da considerarsi idonei gli oliveti compresi nella zona di produzione descritta al punto 2 dell'art. 3, i cui suoli terrazzati, su versanti a moderata pendenza e prevalente esposizione ovest, derivano dall'alterazione di rocce calcaree o arenaceo-marnose che nel tempo hanno dato origine a suoli di tessitura franca e reazione debolmente alcalina."*]

Finally, this soil characterization could have two practical applications: being used by local companies to improve their productivity and implementing the regional pedological cartography (scale 1,250,000) providing punctual data.

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