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Combining multi-source data to map vineyards in a specialized district of Basilicata (Southern Italy)

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ABSTRACT

In agriculture, the geography of specific crops can successfully support productivity monitoring and farming practices management. Vineyards particularly have a key role in modeling and protecting Mediterranean landscapes, representing a fundamental asset in the economies of inner areas. In this paper, we mapped the 2017 coverage of vineyards of the Vulture-Melfese, a specialized agricultural district of Basilicata (Southern Italy) renowned for hosting the Aglianico grapevine variety. To achieve this objective, we combined information extracted from free-accessible multisource data by leveraging the traditional photo-interpretation technique. Then, we characterized the mapped vineyards based on simple geo-environmental variables (size, elevation, climate). This detailed inventory can help public bodies and land managers to shape more specific local agricultural policies to strengthen the profitability of the agricultural sector, preserve agrobiodiversity and face climate change effects.

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Viticulture; agricultural landscapes; geospatial data; GIS; photo-interpretation

1. Introduction

Land cover maps contain spatial information on different classes of physical coverage populating the Earth (water areas, forest species, crop types, urban categories, and other physical classes). Mapping land cover and its changes over time is a piece of essential baseline information that can support human activities in different fields at global (see e.g. the Copernicus Land Monitoring Service – CLMS and the FAO Land Cover Classification System tool – LCCS) and local level (see, e.g. Du et al., 2016; Jia et al., 2018; Sturari et al., 2017; Tsai et al., 2018). In the agricultural sector, the correct geography of specific crops over large areas can effectively support the monitoring of health conditions and productivity levels, the adjustment of the timing of farming practices and the strengthening of the local sense of place, offering a precious service for land management and the enhancement of the overall agricultural value (Dougherty, 2012; Fraigneau, 2009). This also to comply with the European Green Deal, a set of EU initiatives for the transition to a greener economy (European Commission, 2019). Considering the increasing evidence of climate change impacts in Mediterranean regions, making vineyards more sustainable is of primary importance in terms of soil loss and nutrient leaching. In particular, among the major crop species in southern Europe regions, vineyards have had in the past and still have a key role in modeling and protecting landscapes. Furthermore, they take on great significance for the agricultural and economic sectors in the fragile Mediterranean agro-ecosystems affected by an excessive degree of fragmentation of land ownership, high production costs and low accessibility to markets (Beltramo et al., 2018), contributing, sometimes, to land abandonment and degradation phenomena (Incze & Novák, 2016; Nickayin et al., 2022; Quaranta et al., 2020), especially in peri-urban areas (Coluzzi et al., 2022). Therefore, vineyards mapping is crucial to provide public bodies and land managers with specific inventories useful for defining agricultural policies (Urretavizcaya et al., 2014) and facing climate change effects associated with this crop (Mozell & Thach, 2014).

The issue of mapping vineyards has been dealt with in the past and the difficulties of the time-consuming manual mapping over large areas have suggested taking alternative routes. In particular, the need for vineyard inventories at the European scale has stimulated the use of space technologies for vine area location and crop status through several EU-funded projects (e.g. Vinident Study and Bacchus project; Masson & Leo, 2002; Rabatel et al., 2006).

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From this perspective, the recent advancement in image processing and the possibility of managing a massive amount of remote sensing data has opened up new promising horizons.

Satellite/aerial data at different spatial resolutions have recently been adopted to map vineyards using different techniques (Gong et al., 2003; Merenlender, 2000; Pérez et al., 2008; Rabatel et al., 2008; Ranchin et al., 2001; Senturk et al., 2013).

Notably, satellite data, equipped with different multi/hyperspectral sensors with various spatial resolutions, have been profitably exploited at this point: Landsat and Sentinel 2 with multispectral sensors and medium-high resolution (Pérez et al., 2008; Zhao et al., 2019); commercial satellites, such as WorldView-2 and Pléiades, with very high–resolution (VHR) sensors (Alganci et al., 2018; Karakizi et al., 2016), UAV/LIDAR platforms with a finer resolution (Duarte et al., 2018; Tagarakis et al., 2018), and hyperspectral imaging which is limited to the local scale applications of precision agriculture rather than actual mapping (Pôças et al., 2015).

Despite this wealth of remote sensing data coexisting with other data sources (census, field, cadastral) having different features and levels of spatial detail, it is not immediate that all this can be translated into promptly usable information.

It is necessary to elaborate specific procedures aimed at transforming the available row data into useful insights by narrowing the gap between remote sensing observations (satellite, LIDAR, aerial, UAV) and cadastral data because both show intrinsic limitations. In fact, on the one side, automatic detection procedures, based on remote sensing data, are complex and may be affected by accuracy problems over large areas (Matese et al., 2015); on the other, cadastral data for their dynamic nature often do not provide up-to-date information on land parcel boundaries and relative crops requiring time-consuming and expensive field inspections.

Hence, the need for appropriately mixing these different data categories and adopting the traditional photo-interpretation techniques as the prevailing tool. This way, it is possible to manage and filter the available layers with their specific features 'to build' the final information content with the desired spatial/temporal/labeling level of detail.

This effort is somewhat burdensome because most activities are manually implemented in a GIS environment. However, this enables a user-friendly visualization of the distinctive pattern of land covers to be subsequently capitalized by farmers, land managers and researchers for different purposes.

This work aims to map the overall coverage of vineyards in a specialized area of southern Italy: the Vulture-Melfese district, located in Basilicata (Southern Italy). This area, with the highest density of rainfed vineyards, is characterized by the presence of the Aglianico, a late ripening grapevine cultivar (Carlucci, 1904). Wines of this cultivar produced in the Vulture-Melfese area are, since the 1971, under the 'Aglianico del Vulture' Denomination of Controlled Origin (DOC) and have obtained in 2010 the Denomination of Controlled and Guaranteed Origin (DOCG) as 'Aglianico del Vulture Superiore'. From the 2013 cadastral data provided by Basilicata Region, using a devised procedure combining multisource data, including orthophotos and free ancillary geodata, we obtained the extension of vineyards updated to 2017. We also provide a vineyard characterization of the district based on basic geo-environmental variables (plot size, elevation, climate).

2. Materials and methods

2.1. Study area

The study area (Figure 1) is known as the Vulture-Melfese district, located in the northern part of the Basilicata (Southern Italy). The DOC 'Aglianico del Vulture' and the DOCG 'Aglianico del Vulture Superiore' wines production area includes 15 municipalities (Rionero in Vulture, Barile, Rapolla, Ripacandida, Ginestra, Maschito, Forenza, Acerenza, Melfi, Atella, Venosa, Lavello, Palazzo San Gervasio, Banzi, Genzano di Lucania).

Overall, the study area is considered at increasing risk of land degradation because of soil loss, land use/cover changes, improper agricultural and forest practices, and climate variability (Bonfiglio et al., 2002; Canora et al., 2015; Imbrenda et al., 2022a; Lanfredi et al., 2020; Piccarreta et al., 2015; Samela et al., 2022).

The landscape is predominantly hilly (within the Southern Apennine chain), dominated by Mount Vulture (1326 m.a.s.l.), an extinct volcano sloping to the East towards Apulia plains (Figure 2(a)). Monte Vulture is a middle Pleistocene composite volcano with roughly 700 m-thick lavas and pyroclastic succession made of very undersaturated alkaline-potassic to ultrapotassic rocks from the Roman Magmatic Province (Giano et al., 2022; Schiattarella et al., 2005). It is a relatively small volcanic complex featuring a central vent, parasitic cones, and eccentric lava plugs (Giano et al., 2022; Schiattarella et al., 2005). It formed over a period of around 550,000 years on a deep-seated transfer fault (Vulture Line in Schiattarella et al., 2005; Trinitapoli-Paestum Line in Ciaranfi et al., 1983), which represents a breakoff of the Apulian plate during its subduction toward the W-WS (Giano et al., 2022; Schiattarella et al., 2005). The genesis and evolution of this volcanic complex have been significantly influenced by tectonics, which have also had an impact on the geochemistry composition of

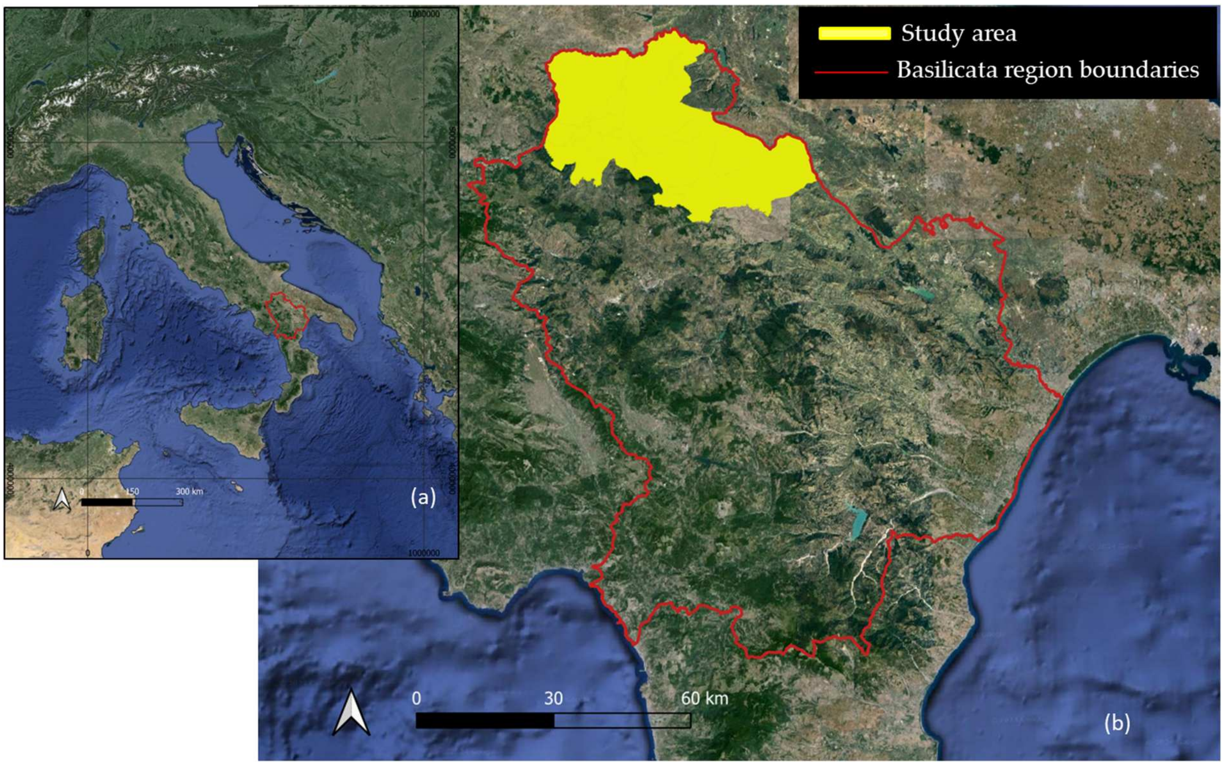

Figure 1. Study area: (a) geographical setting of the Basilicata region (Southern Italy); (b) zoom of the Basilicata and geographical setting of the study area: the Vulture-Melfese district (in yellow color). Layers of regional and district boundaries are available at the Italian National Institute of Statistics – ISTAT; https://www.istat.it/it/archivio/222527, last accessed on 29 June 2022.

the Vulture volcanites (Schiattarella et al., 2005). These volcanites do not exhibit a single evolutionary trend, instead they are the expression of various magmatic sources with distinct geochemical properties, genetically linked to changes in the tectonic regimes (De Fino et al., 1986; Schiattarella et al., 2005).

The volcanic products are interbedded with the nearby coeval fluvio-lacustrine deposits of the Ofanto, Venosa-Arcidiaconata, Atella, and Melfi basins (Giano et al., 2022; Schiattarella et al., 2005).

According to Giannandrea et al. (2006), two distinct Supersynthems units can be identified in this area, separated by a paleosoil that is also observable beyond the volcanic area (La Volpe & Principe, 1989), representing a hiatus in the volcanic activity. These supersynthems are named as the Monte Vulture and Monticchio Supersynthems and are composed of sedimentary deposits and volcanic products (Giannandrea et al., 2006).

The soils of the study area (Figure 2(c)) are andosols formed by the pedogenesis of effusive volcanic rocks, with high cation-exchange capacity and low apparent density (Lazzari & Piccarreta, 2023). The profiles are less evolved and differentiated at the greatest altitudes (Lazzari & Piccarreta, 2023). The soils of the vineyards within this area have a high concentration of organic matter in the surface horizons and are alkaline, highly permeable, and well-drained (Lazzari & Piccarreta, 2023).

The climate of the study area is classified as steppic and temperate (Beck et al., 2018) feeding a variegated natural vegetation, often included in protected sites of the European Natura 2000 network (Grotticelle di Monticchio and Vulture Regional Natural Park, see Imbrenda et al., 2022b). However, the eastern part of the investigated area is mostly flat, hosting large extents of cereal crops recently experiencing a continuous decline in terms of extent and workforce (Simoniello et al., 2022), whereas viticulture is largely spread in the whole study area, as the most economically valuable crop (Di Motta et al., 2016) also representing an iconic element epitomizing the idea of Mediterranean landscapes (Russo and Carella, 2012). Moreover, vineyards have a crucial role in this district because they model the landscapes, contributing to give them a peculiar configuration (Gabriele et al., 2023) and because specific efforts towards their sustainable management have a major impact due to the commonly adopted practice of continuous tillage, that produces the highest soil erosion rates, further exacerbated by the absence of grassland between the rows (Lazzari & Piccarreta, 2023; Romero et al., 2022). The role of these vineyard-dominated landscapes is equally important in terms of biodiversity conservation, since the sustainable practice of inter-row grassing is a key action for promoting biodiversity in vineyards with no adverse effects on the wine productivity, while intensive tillage and chemical weeding

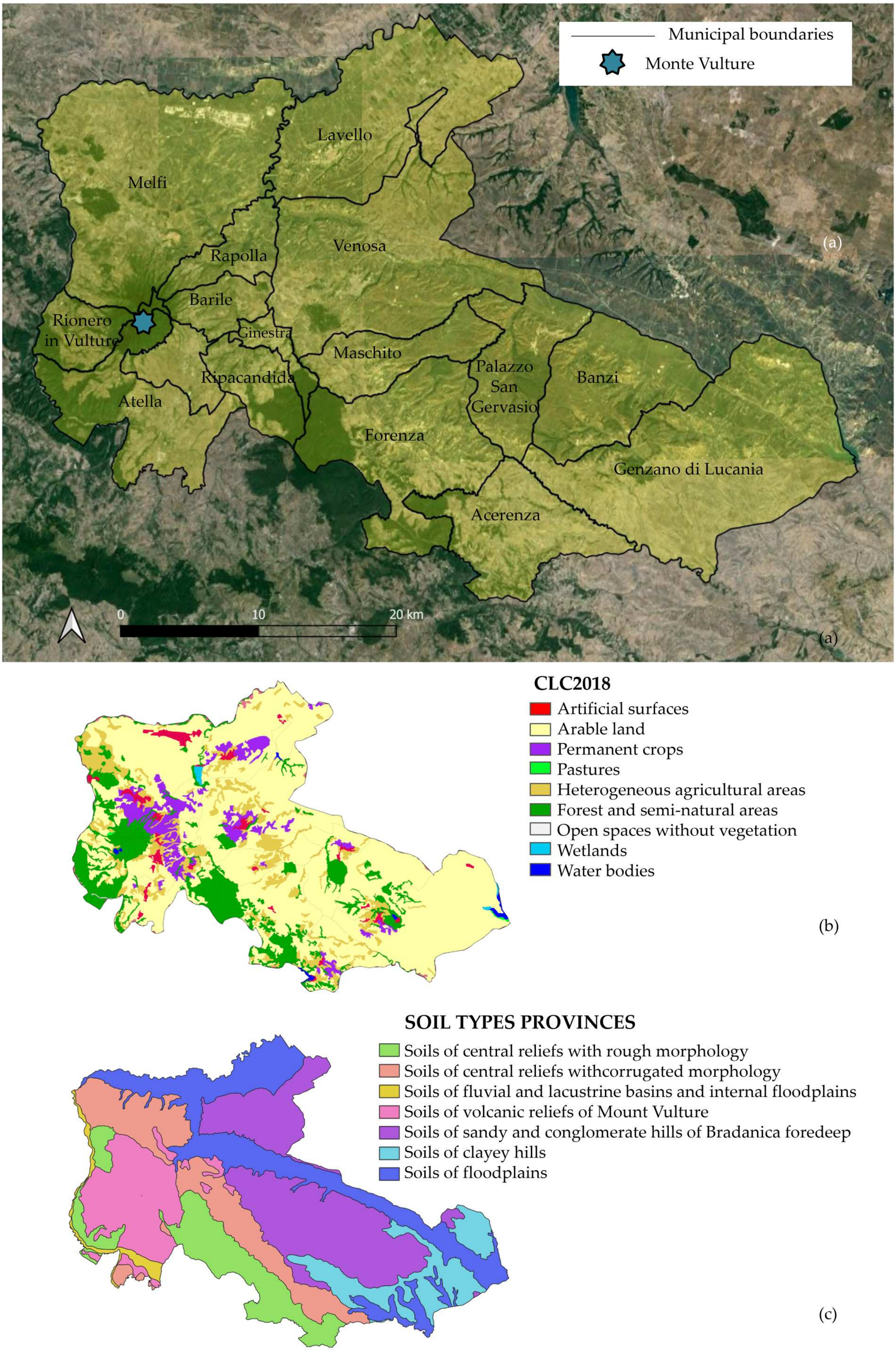

Figure 2. Study area: (a) municipalities of the Vulture-Melfese district. Layers of municipal boundaries are available at the Italian National Institute of Statistics – ISTAT; https://www.istat.it/it/archivio/222527, last accessed on 29 June 2022; (b) Corine Land Cover (CLC) 2018 – II Level; (c) pedological characterization: soil types provinces (open source data of the Region of Basilicata http://www.basilicatanet.it/suoli/index.htm).

have detrimental effects on the majority of taxa (Paiola et al., 2020).

In addition, vineyard products with other speciality foods of the area (olive oil, chestnuts, etc.) contribute to the development of the local sense of place and its associated cultural identity, strengthening the link among food products, culture and ecosystems in a specific geographical area of Southern Italy, as happens in other areas of southern Italy (Imeneo et al., 2022; Wilson et al., 2018). This is particularly important for most of the municipalities of the Vulture-Melfese district, classified as inner areas, i.e. fragile territories, located far away from main centers of supply of essential services for which Italy has promoted a specific strategy (the National Strategy for 'Inner Areas' – SNAI) to counteract marginalization and demographic decline (see https://www.agenziacoesione.gov.it/strategia-nazionale-aree-interne/?lang=en).

2.2. Data and methods

2.2.1. Building the 2017 update of the cadastral inventory of the Vulture-Melfese vineyards

With a GIS-based approach, we combined in a synergistic way various data sources, not temporally homogeneous, to build the Main Map and some thematic layers characterizing the vineyards of the Vulture-Melfese district.

Firstly, we started with the 2013 cadastral map, i.e. the most reliable, recent and detailed source of reference for vineyards in Italy. It was kindly provided by SIAN (Italian Agricultural Information System), a homogeneous and coherent system which collects information concerning the Italian agricultural sector to support rural policies. The base map included vineyard parcels related to the Vulture-Melfese district. Parcels were available in shape format and were processed in a GIS environment (Datum WGS84, Projection UTM – Zone 33).

For each parcel, we checked the presence of vineyards via photo interpretation. Thanks to a peculiar structure characterized by row patterns and regular spatial distributions, vineyards can be almost always recognizable on the orthophotos.

At this aim, we verified the geometries reported by the 2013 cadastral inventory through the following free remote data:

- 2016 Google Earth images;
- 2017 orthophoto (1:10,000) provided by AGEA (Italian Agency for the Delivery in Agriculture) and available as WMS layer at the Regional Space Data Infrastructure of the Basilicata Region (RSDI-Basilicata, see https://rsdi.regione.basilicata.it/, last accessed 29 October 2022). This orthophoto has a resolution of less than 1 m, facilitating land cover identification.

Only the vineyard parcels present in the two ancillary images were labeled as 'real'. To update the cadastral inventory, we searched for possible vineyards not reported in the starting map because of the time interval separating 2013 (cadastral reference) and 2017 (orthophoto). At this aim, we adopted the Corine Land Cover (CLC) 2018 (Figure 2(b)) as the most recent land cover map covering the study area. It represents the largest pan-European land cover/use database for non-commercial use, consisting of an inventory of 44 land cover classes (see Büttner et al., 2017, free available at https://land.copernicus.eu/pan-european/corine-land-cover/clc2018, last accessed on 29 June 2022). Specifically, we used all the CLC agricultural areas at level II except for class 21 (arable land), within which to search for other vineyards. We detected new vineyard 'profiles' not reported in the 2013 cadastral map within the classes 22 (permanent crops), 23 (pastures), and 24 (heterogeneous agricultural areas) by inspecting the 2017 orthophoto. This choice is justified by the overall accuracy of the CLC2018 reaching values of about 85% (GMES, 2021), meaning the real possibility to find vineyards within other land cover classes, except for arable land class that has higher accuracy (over 90%) and is arranged in compact patterns within the study area. In particular, due to the 25 hectares of the minimum mapping unit (MMU) and 100 meters minimum mapping width, CLC2018 does not capture land use categories occurring in small patches and can hardly identify the fine-grained nature of Mediterranean ecomosaics consisting of a variegated mix of juxtaposed land covers, often populated also by small vineyards.

When a new vineyard geometry, not reported in the original database but recognizable in the 2017 orthophoto, was found, it was digitized as a vector and then added to the cadastral database.

Google Street View, available in Google Earth, was adopted as an inexpensive auxiliary data source to examine doubtful cases when the only photo interpretation does not definitively discriminate the crop type.

In the final map, each vineyard parcel was labeled according to the following rules:

- Code 1 = Correct Vineyard (colored in green), present in the 2013 cadastral map and still visible in the examined 2016–2017 orthophotos;
- Code 2 = False Vineyard (colored in red), present in the 2013 cadastral map but corresponding to other land cover types in the examined 2016–2017 orthophotos;
- Code 3 = New Vineyard (colored in blue), not present in the 2013 cadastral map but populating the neighboring agricultural areas and captured thanks to the visual inspection of 2016–2017 orthophotos.

We successively removed the false vineyards (Code 2) and created the Main Map, including exclusively the correct and the new vineyards (Codes 1 and 3).

The scheme of the procedure is synthesized in Figure 3.

2.2.2. Characterization of the vineyard capital of the Vulture-Melfese district

Finally, this map representing the 2017 update of the cadastral inventory, was processed based on topographic factors (elevation, slope, and exposure), property (plot size) and climatic features (Winkler index and Koppen-Geiger classification) by using simple geospatial tools in a GIS environment to provide a characterization of the whole vineyard capital of the Vulture-Melfese district. The bioclimatic Winkler Index (WI) is a heat summation index proposed by Amerine and Winkler (1944) to segregate grape-producing areas with respect to the suitability to ripe a particular grapevine variety and to produce high-quality wines.

For this purpose, we used the following ancillary data:

- Municipal Boundaries of Basilicata (available from the ISTAT – Italian National Institute of Statistics, see https://www.istat.it/it/archivio/222527);
- Tinitaly DEM (Digital Elevation Model) at 10 m of spatial resolution (Tarquini & Nannipieri, 2017);

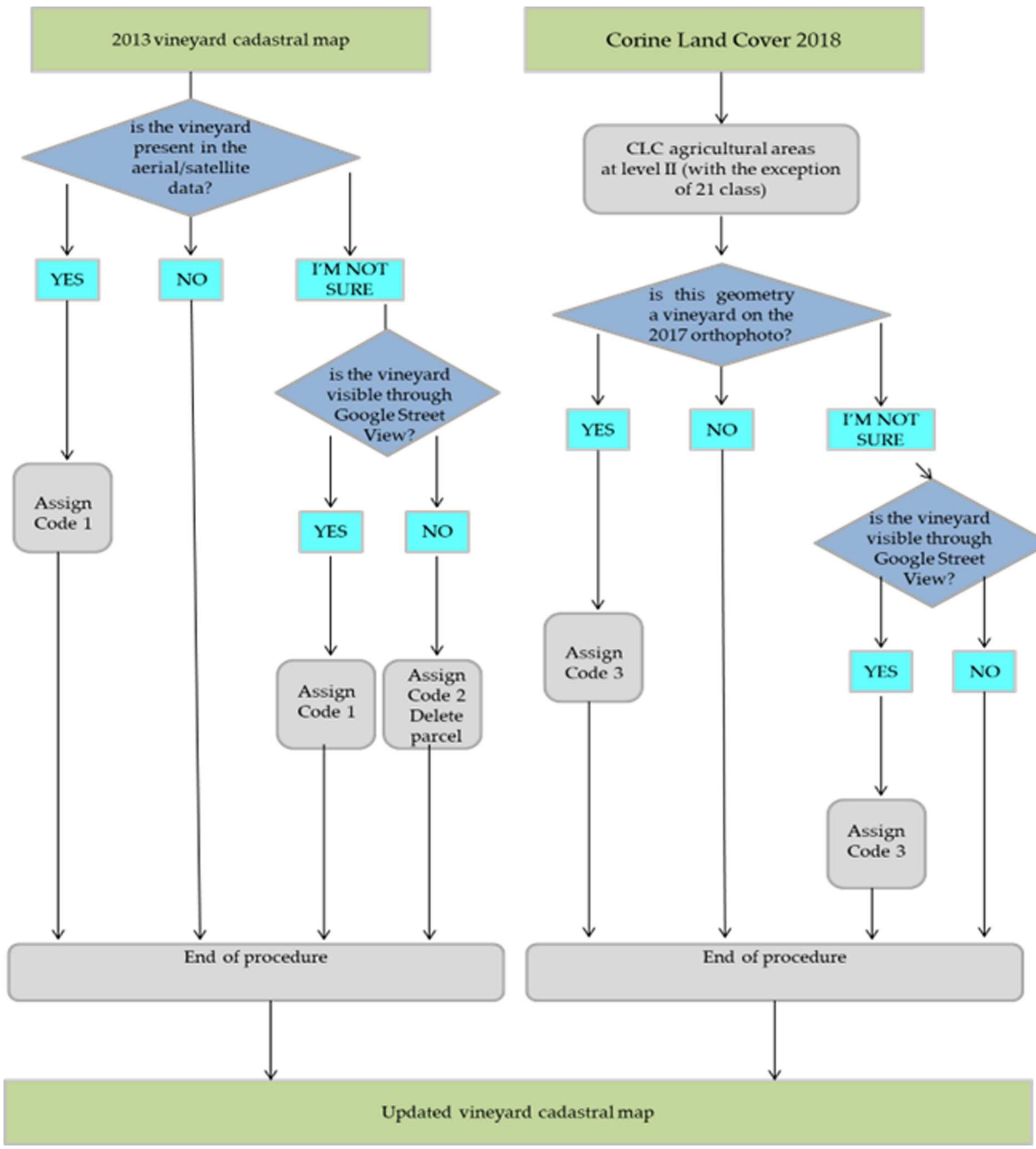

Figure 3. Flowchart illustrating the procedure implemented to update the vineyard cadastral map.

- Meteorological data (2000–2021) from 44 stations belonging to the Regional Agency for Development and Innovation in Agriculture of Basilicata Region (ALSIA) spread over the whole territory of Basilicata.

Winkler index was calculated with the equation:

$$\mathrm{WI} = \sum_{i=1\ \mathrm{April}}^{31\ \mathrm{October}} [(Tavg - 10)_i; 0] \quad [°\mathrm{C}]$$

where *Tavg* is the daily average of air temperature calculated from the hourly data measured from automatic weather stations of the Basilicata Agrometeorological Service (https://www.alsia.it/opencms/opencms/Servizi/dettaglio/Accedi-ai-dati-agrometeorologici/, accessed the 24/12/2022); The baseline of 10 °C is because there is almost no growth below this temperature; days with *Tavg* lower than 10°C were not considered in the summation.

This index, obtained for each station, was then spatialized following a linear regressive approach (Lanfredi et al., 2015) to model the dependence of temperature on elevation (lapse rate), which is the most important factor determining the temperature spatial distribution in the region. The regressive coefficients were estimated and then used to obtain monthly temperature maps useful to estimate the WI.

3. Results and discussion

The Main Map concerns exclusively the vineyards updated to 2017. However, taking into consideration the starting map from the 2013 cadastral inventory, about 66% of the vineyards are already present in this reference map, while more than 20,5% has been classified as false vineyard according to our method and so removed, while the new detected vineyards represent about 13,5% of the total.

Whoever uprooted or planted new vineyards probably did not notify the cadastre of the changes to land property. In addition to this, there are also some pockets of illegality linked to the constraints related to the stricter rules for viticulture under the umbrella of the DOCG. In any case, this information about previously existing vineyards can be useful to trace back their history over the territory of Basilicata.

3.1. Extension and fragmentation

We estimated the extension of the vineyards in absolute terms (in hectares) and percentage (area covered by vineyards on the total municipal area). In absolute terms, the municipality with the largest area of vineyards is Venosa, with 797.30 hectares. The municipality with the most significant percentage of vineyards with respect to its total cultivated surface is Maschito, with 6.17% of the entire municipal territory devoted to wine/grape production. In contrast, Venosa ranks second with 4.75% (see Figure 4).

The municipality with the largest area of vineyards is Venosa (797.30 ha); the most significant percentage of vineyards with respect to its total cultivated surface is Maschito (6.17% of the entire municipal territory devoted to wine/grape production).

The subsequent analysis relies on the extent of the single vineyard plots as a proxy indicator of fragmentation (Figure 5). About 57% of vineyards have a surface less than or equal to one hectare ($0 < \mathrm{ha} \le 1$), about 16% have an area ranging between one and two hectares ($1 < \mathrm{ha} \le 2$) and the remaining 27% of the vineyards falls in the class with surfaces greater than two hectares ($\mathrm{ha} > 2$). These results reflect the topographically complex nature of the analyzed landscapes, favoring the fragmented land property conditions in Basilicata. This implies a certain difficulty in activating partial or full mechanization of these areas that were found to be among the least favorable to the vineyard mechanisability in Italy (Cogato et al., 2020).

3.2. Climatic factors

Intersection of the Köppen-Geiger climate classification map (Beck et al., 2018) with the geometries of the identified vineyards shows that about 88.5% of them falls in the Bsk class (steppic climate, prevalently

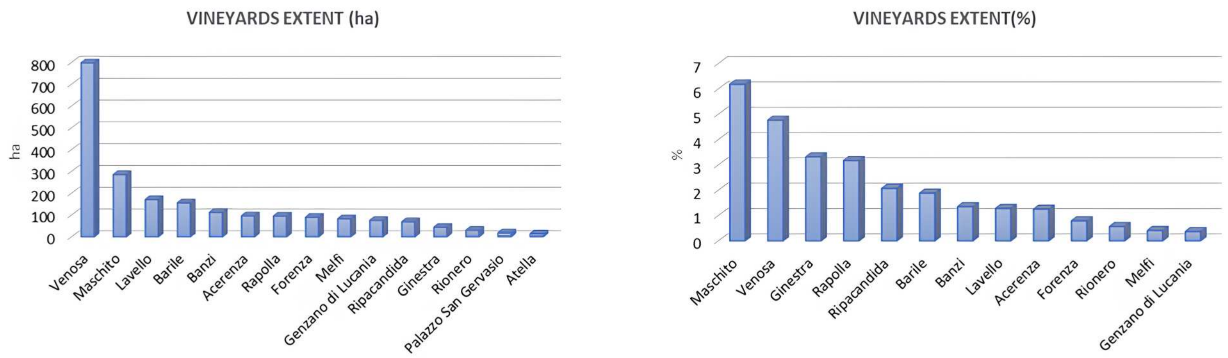

Figure 4. Absolute and relative extent of vineyards for each municipality of the Vulture-Melfese district.

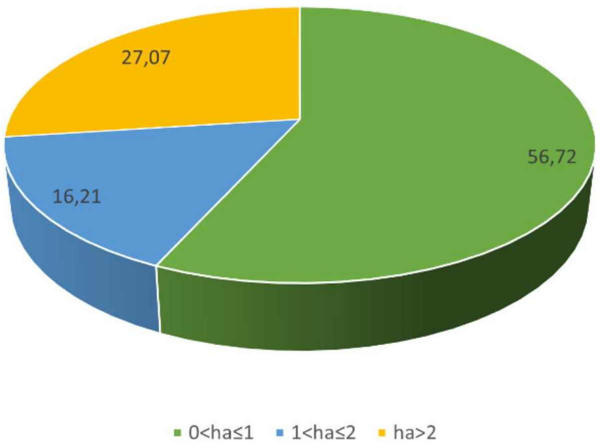

Figure 5. Plot size of the Vulture-Melfese vineyards. Over half of the vineyards have an area of one hectare or less.

arid and cold), about 11% falls in the Csa class (temperate climate with hot and dry summers) and about 0.5% falls in the Csb class (temperate climate with warm and dry summers). Taking into account the partition of the Winkler index into different Regions (according to the degree-day classification of Amerine & Winkler, 1944), vineyards of the Vulture-Melfese district belong prevalently to the Regions III and IV, whereas just about 1% belong to the Region II and a residual 0,35% falls within the range of the Region V (Figure 6).

Based on our results, areas of the Vulture-Melfese district are included in Region II, III, and IV (Amerine & Winkler, 1944; Winkler et al., 1974). Overall, about half of the investigated area falls within the Region II which is mostly suitable for premium-quality white and red wine, and Region III which is suitable for producing excellent red wine of late ripening grapevine variety, such as Aglianico, i.e. the main cultivar of the examined area (Carlucci, 1904; Corbo et al., 2012; Winkler et al., 1974).

3.3. Morphological factors

3.3.1. Elevation

Analyzing the altimetric distribution of the vineyards, it emerges that hilly areas largely dominate, being the favorite elevation belt for vineyards (about 83.5%), whereas about 10.5% is located in plain (altitudes ranging between 0 and 300 m), and about 6% populates areas with elevations greater than 600 m (mountains) as Figure 7(a) shows. Combining information about plot size and elevation of the existing vineyards, we observe that most of them (about 88%), having a size less than 1 ha, occupy high-hilly/mountainous areas (altitude >600 m), whereas largest vineyards (area >2 ha) are mainly located (about 45%) in lowland areas (0–300 m).

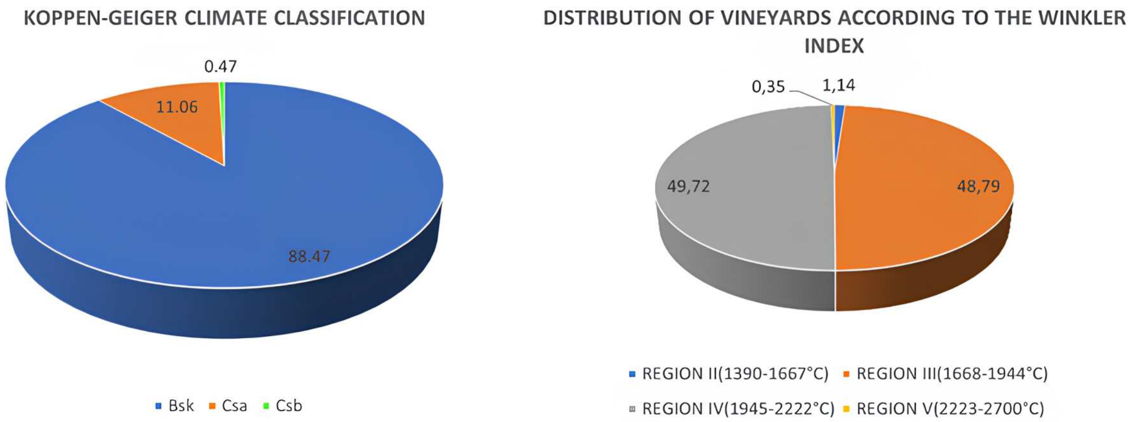

Figure 6. Vineyards distribution according to the Koppen-Geiger climate classification (on the left) and the degree-day classification of the Winkler Index (on the right).

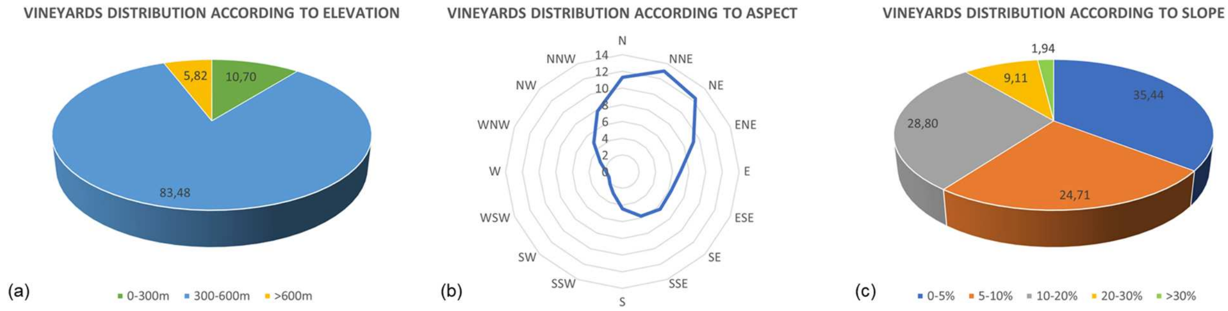

Figure 7. Results of the analysis of the vineyards distribution based on the morphological factors, respectively elevation, aspect and slope. Corresponding maps are in the Main Map.

3.3.2. Aspect

As for the aspect, a large part of the identified vineyards is north and east-facing, a percentage significantly higher than those of south and west-facing vineyards (see Figure 7(b)). From the point of view of viticulture, the greater presence of vineyards on the hillsides facing north or east could be attributed to the need to avoid direct exposure to solar radiation, especially during the afternoon hours when the maximum daily temperature is normally recorded (Naulleau et al., 2021).

3.3.3. Slope

Regarding the slope (expressed in percentage grade, see Figure 7(c)), about 90% of the vineyards falls in areas with slopes between 0% and 20%, with the largest part (about 35.5%) falling in the class with the lowest slopes (< 5%). About 9% of vineyards is located on steep slopes (between 20% and 30%), and only 2% is located on very steep slopes (>30%). Similarly to what was observed for the elevation, also for the slope marginal vineyards, with steep slopes (>20%), are mainly characterized (about 77%) by small sizes (< 1 ha). On the contrary, plot size does not seem to be a decisive factor for vineyards with gentle slopes (<5%), because the distribution is rather homogeneous in the different size classes, with a slight prevalence (about 43%) of the small vineyard (area less than 1 ha).

4. Conclusions

The viticultural agroecosystem of the Vulture Melfese district benefits of the structure of the soils and the availability of minerals absorbed by the plants here growing which positively affect the quality and productivity of grapes in the area (Lazcano et al., 2020).

Because of this, viticulture has an ancient tradition in Basilicata and represents an important asset for the agricultural economy of this region due to volumes of business generated, number of employees and extent of surfaces covered.

Mapping and characterizing the 2017 extension of vineyards of this district were performed using cadastral data (2013) and freely accessible geospatial data. This updated inventory can facilitate public bodies in optimizing policies designed to support and preserve vineyards and finding out inconsistencies in the current cadastral data.

Contextually, this should support the strategic orientation of the Basilicata wineries towards the adoption of a more sustainable viticulture in terms of environmental, energy and economic management so as to 'marry' European strategies (e.g. the European Green Deal), especially if this knowledge flows into interactive tools (e.g. WebGIS) enabling winegrowers to know the main features of their terroirs.

Mapping the status quo of vineyards in this district helps to identify areas where climate change projections are expected to have a greater impact on grape productivity. Furthermore, being Mediterranean Italy a climate change hot-spot (Lionello & Scarascia, 2018), the issue of preserving the productivity and quality of wines in the era of climate change is now inescapable (Chieco et al., 2023). The first countermeasures are the adoption of adaptation strategies encompassing primarily varietal selection, indicating a shift from traditional varieties to those exhibiting enhanced resistance to pests and drought (Venios et al., 2020).

Furthermore, being Southern Basilicata the heart of the third vine domestication center in the world (De Lorenzis et al., 2019; D'Onofrio et al., 2021), it is important to search for autochthonous grapevine varieties able to indicate origins and geography of major varieties. Thanks to such a pernickety procedure also local/family varieties can be identified as potential wealth of genetic diversity.

Lastly, the final vineyards map for the examined district can be considered an important knowledge basis as ground truth data for the training of specific algorithms of semi-automatic detection of this crop by using high-resolution remote sensing observations. This process can be then extended to other similar areas guaranteeing a timely and continuous maintenance process of cadastral records to support consortium agriculture and protect biodiversity in agroforestry Mediterranean areas where ownership parcelization and climate change make land management more difficult and economically disadvantageous.

Software

The Geographical Information System (GIS) environment adopted for the collection, management and analysis of all the layers is Quantum GIS (QGIS) 3.16.8 version (http://qgis.osgeo.org, last accessed 29 June 2023). Also Google Earth images and the Open Street Map layer have been integrated in QGIS using a specific plugin (i.e. QuickMapServices).

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The updated vineyard cadastral map is openly accessible via the WebGis VITIVINICOLO of the Geoportal of the Basilicata Region (RSDI) at https://rsdi.regione.basilicata.it/webgisvitivinicolo/. Orthophotos are openly available on the Basilicata Region Geoportal (https://rsdi.regione.basilicata.it/); the 2018 CLC (Corine Land Cover) from Copernicus at https://land.copernicus.eu/pan-european/corine-land-cover/clc2018; elevation data are freely accessible from https://tinitaly.pi.ingv.it/; municipal boundaries from ISTAT at https://www.istat.it/it/archivio/222527; whereas meteorological data are available from ALSIA at https://www.alsia.it/opencms/opencms/Servizi/dettaglio/Accedi-ai-dati-agrometeorologici/ Cadastral data of land parcels were provided by SIAN (Italian Agricultural Information System) and are available upon reasonable request. Shape of Europe was downloaded from http://www.efrainmaps.es, Carlos Efraín Porto Tapiquén. Geografía, SIG y Cartografía Digital. Valencia, Spain, 2020.

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