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Simulations of quantitative shift in bio-climatic indices in the viticultural areas of Trentino (Italian Alps) by an open source R package

Emanuele Eccel[a,*], Alessandra Lucia Zollo[b,c], Paola Mercogliano[b,c], Roberto Zorer[d]

[a] Department of Sustainable Agro-ecosystems and Bioresources, Research and Innovation Centre, Fondazione Edmund Mach (FEM), Via E. Mach 1, 38010 San Michele all'Adige, Italy
[b] Meteorology Laboratory, Centro Italiano Ricerche Aerospaziali (CIRA), Via Maiorise s.n.c., 81043 Capua, Italy
[c] Regional Models and Geo-Hydrogeological Impacts Division, Centro Euro-Mediterraneo sui Cambiamenti Climatici, Via Maiorise s.n.c., 81043 Capua, Italy
[d] Department of Biodiversity and Molecular Ecology, Research and Innovation Centre, Fondazione Edmund Mach, Via E. Mach 1, 38010 San Michele all'Adige, Italy

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ABSTRACT

In consideration of the steady entanglements of viticulture with the environmental features – including climate – it is of concern to project which climatic conditions an area is expected to face in a changing climate scenario. A quantitative approach helps in assessing class shift in climate classification; both "generic" climatic and bioclimatic indices were considered in this study, namely: Köppen – Geiger types and subtypes, aridity (6 indices), and "International vine and wine organization" (OIV) classification (10 indices). All indices were easily calculated by an open source R library (ClimClass), which also includes tools for base pre-processing of weather series. Future climate scenarios for this study were obtained using the Regional Climate Model (RCM) COSMO-CLM, employing two IPCC's greenhouse gas concentrations (RCP 4.5 and RCP 8.5), statistically downscaled to 39 weather stations in Trentino, a region in the Italian Alps. The simulations envisage the new climatic profile of the area, with a shift towards warmer and somewhat drier conditions. While no limitation to wine growing is expected in the lower altitude areas, new climatic suitability is projected for mountain areas, presently devoted to other soil uses. The latter analysis was the result of a calibration of a thermal requirement index to the present soil use condition in the region.

1. Introduction

Among all crops, grapevine is one of those which inspired the highest number of bioclimatic analysis related to climate change (Hall and Jones, 2009; Anderson et al., 2012; Molitor et al., 2014; Koufos et al., 2014; Dunn et al., 2015). The term "*terroir*" itself stems from the idea that wine production is steadily entangled with the environmental features – including climate – which characterize origin and growing of a variety. Climate change obviously poses urgent questions about the future of premium wine production in many wine-growing regions. More than for most crops, the maintenance of the link of many wines with their typical production areas is an added value which impacts on the cultural and – ultimately – market value of the products. Hence, it is of concern for wine growers – as well as for all the wine production spin-offs – to know which climatic conditions an area is going to face in a changing climate scenario.

Generally speaking, warmer and drier conditions have mostly contributed to an increase of wine quality in many regions of the world (Jones et al., 2005; Dalu et al., 2013). If the latter authors highlighted above all the improvements of wine quality in the last 50 years, attributing an important role to warmer climate conditions, on the other hand, the same authors claimed that a further increase could take the bioclimatic physical driver beyond the optimum, leading to a worsening of ratings. For warm vine-growing regions, a temperature increase would probably bring with itself the undesired effect of a dramatic restriction of the suitable viticultural areas (White et al., 2006; Hall and Jones, 2009). Moriondo et al. (2011) suggested possible negative effects of temperature increase on wine quality in the Mediterranean area (particularly Italy). The recorded advance in phenological timing (Caffarra and Eccel, 2011; Tomasi et al., 2011; Fraga et al., 2015) is a clear warning against a change in the match between a variety and its long-lived growing context, questioning the subsistence of the balance between the ripening process and the meteorological conditions occurring in the relevant period (Mullins et al., 1992). The action of meteorological drivers on physiological development may also affect yield (Bindi et al., 1996; Duchêne and Schneider, 2005;

* Corresponding author.
E-mail address: emanuele.eccel@fmach.it (E. Eccel).

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Webb et al., 2008), due to an expected higher, unsatisfied water demand in summer, and to a shorter ripening period.

Spreading viticultural areas northward entails the shortcoming of a shift of production areas to regions which may be new to either specific varieties or even to vine growing (Fraga et al., 2016; Jones, 2006). Moriondo et al. (2011) suggested possible negative effects of temperature increase on wine quality in the Mediterranean area, highlighting that spreading the cultivation areas to higher altitudes within the same geographic context offers the chance to meet better conditions than the ones expected in the traditional production areas at lower elevations, according to the climatic scenarios. Trentino, a temperate wine-producing area in the Italian Alps, can benefit of the altitudinal range of mountain regions to face a progressive warming of climatic conditions.

This work aims at providing an in-depth analysis of the projected change in the quantitative bioclimatic indices that have been developed to assess the landscape suitability for viticulture. The model chain for this analysis was built by applying a code which calculates climate indices to the output of climate simulations.

2. Materials and methods

2.1. Geographical, climatological and viticultural features

Trentino is a 6212 km^2 region in the central-eastern Italian Alps (Fig. 1). Altitude ranges between 70 m a.s.l. (lower Sarca Valley) to 3769 m (Cevedale peak). Trentino climate is mostly oceanic, with some areas showing features of transition to a more continental-alpine climate, cooler and often drier, more typical of the inner mountain valleys. Precipitation is mostly distributed over two maxima, in the autumn (main) and in the spring (secondary).

The current viticultural areas in Trentino consist of about 10,000 ha, distributed from 70 to 850 m a.s.l. The list of the cultivated grapevines (*Vitis vinifera* ssp. *vinifera*) includes both red and white varieties, mainly from France (white: Pinot gris, Chardonnay, Sauvignon; rosé: Gewürztraminer; red: Pinot noir, Merlot, Cabernet Sauvignon) in addition to some local cultivars (white: Nosiola; rosé: Schiava gentile; red: Teroldego, Marzemino, Lagrein) and the Swiss Müller Thurgau, which is successfully cultivated up to the highest elevations.

The most updated land use map (August 2003), including viticulture, has been drawn and it is provided by the urban planning service of the Autonomous Province of Trento. The map is available as Esri shapefile at the Trentino OPENdata website (http://dati.trentino.it/) under Creative Commons Zero – CC0 v1.0 Universal terms of use.

2.2. Observational dataset

39 daily meteorological series of precipitation and temperature were made available from Meteotrentino, the meteorological service of the Autonomous Province of Trento (Fig. 1). The series covered all the altitudinal range of the region, from the 90 m a.s.l. of Torbole, in the proximity of Lake Garda, to 2600 m a.s.l. of Careser dam, an artificial reservoir in the heart of central Alps. These series were chosen according to their length and quality to bias-correct and downscale the model output in Orientgate project (http://www.orientgateproject.org/) – see further.

2.3. Climate simulations

Climate data for this study were obtained using the Regional Climate Model (RCM) COSMO-CLM (Rockel et al., 2008), the cli-

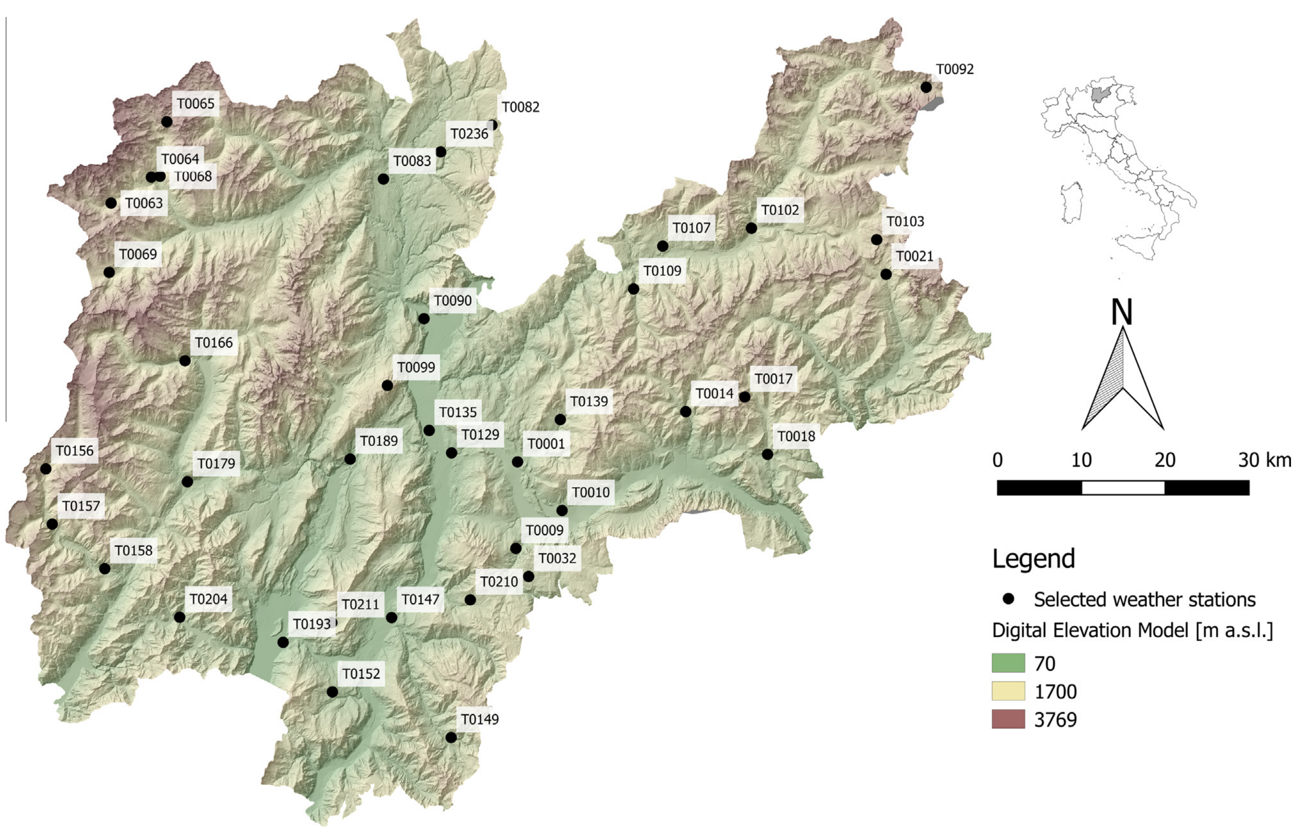

Fig. 1. Map of the 39 selected weather stations (PAT MeteoTrentino).