OBSERVED AND EXPECTED SHIFT IN CLIMATIC AND BIO-CLIMATIC INDICES IN AN ALPINE REGION

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Introduction

Climate change poses urgent questions about the future of premium wine production in many wine-growing regions, and there is a wide interest in predicting the landscape suitability for viticulture, according to climate change scenarios.

Warmer and drier conditions have mostly contributed to an increase of wine quality in many regions of the world, but a further increase of temperature and dryness could take the bioclimatic driver beyond the optimum, leading to a worsening of ratings.

For temperate wine-producing areas, like the vineyards of Trentino, a mountain region in the Italian Alps, the expected effects of warmer and drier conditions would consist in a better ripening and sanitary status of the grapes of red varieties, earlier harvest of white varieties, particularly for sparkling wine production, and a possible enlargement of the viticulture area to higher elevation. Some varieties are particularly affected by the warm conditions (i.e. Müller Thurgau) and new planting are recommended right now in cooler areas (above 450 m a.s.l.).

Methods

In order to characterize the past and current climate in Trentino, time-series of meteorological data were used from 39 weather stations, ranging from the 90 m a.s.l. of Torbole, in the proximity of Lake Garda, to 2600 m a.s.l. (PAT MeteoTrentino, FEM CTT-SIG; Fig. 1). For the observed past, the change was assessed by comparing the early reference period 1961-1990 with the most recent one, 1981-2010.

Furthermore, future conditions have been investigated considering numerical simulations obtained using the regional climate model COSMO-CLM (Rockel et al., 2008) with a horizontal resolution of 0.0715° (about 8 km). Specifically, two IPCC "Representative Concentration Pathways" were used: RCP 4.5 and RCP 8.5, where the former is characterized by a stabilization in GHG emissions, and the latter by a rapidly increasing GHG concentrations. Simulated data have been bias corrected considering a quantile mapping approach (Zollo et al., 2015) and have been made available in the framework of the OrientGate project (http://www.orientgateproject.org/). Present conditions were set as the means of period 1976-2005, and two time windows for the future were chosen in the 30-year periods 2021-2050 and 2041-2070.

An R library ClimClass (Eccel et al., 2015), available from R-cran repository (http://cran.r-project.org/), was used to calculate climatic indices:

- Köppen – Geiger's climatic classification;
- aridity indices (De Martonne, Thornthwaite, Emberger, Lang, Rivas-Martinez);
- bioclimatic indices according to OIV (2012) guidelines.

The potential enlargement of the viticultural areas, with respect to climate change scenarios and geo-morphological features, has been assessed using open source GIS software (QGIS Geographic Information System ver. 2.8.2, QGIS Development Team), a high resolution digital elevation model, and finally a land-use map, both provided by the "P.A.T. Sistema Informativo Ambiente e Territorio" service of the Province of Trento.

Results

According to most indices, the area below 1000 m can be classified as suitable for wine growing in Trentino, especially for future conditions, even if grapevine is not currently grown above 850 m.

A change in viticultural classification is **already observable** from recorded instrumental weather series (Table 1).

	Warmer (HI, CI) or drier (DI)	Stable	Cooler (HI, CI) or more humid (DI)
Huglin Helioth. Index HI	4	8	0
Cool Night Index CI	1	11	0
Riou Drought Index DI	1	10	1

Table 1 – Transitions of viticultural bioclimatic classes after Tonietto and Carbonneau (2004), nr. of stations (below 1000 m): 1981 – 2010 compared to 1961 – 1990. Orange: transitions to warmer or drier classes. Blue: transition to more humid classes.

Period & RCP scenario		'76-'05	'21-'50		'41-'70	
			4.5	8.5	4.5	8.5
Climate types & subtypes	C f a	6	11	11	15	17
	C f b	24	21	21	19	20
	C f c	1	0	3	1	0
	D f b	1	0	1	3	1
	D f c	6	6	2	1	1
	E T	1	1	1	0	0

Table 2 – Predicted change in Köppen – Geiger climate classification: number of stations for any class (total of 39 stations from 93 m to 2600 m). Key: "C": mild temperate climate; "D" cold snow-forest climate, "E T" polar climate (tundra); "f" no distinct rainy season; "a" hot summer; "b" cool summer; "c" cool short summer. Orange marks outstanding transitions to warmer classes.

If an elevation threshold is set at 1000 m, the synthetic bioclimatic indices proposed by Tonietto and Carbonneau (2004) show a general shift to warmer classes, not necessarily to the drier ones. A limited change in Köppen – Geiger's classification (2 sites out of 12) was assessed.

Future simulations highlight the continuous trend to the general warming of climate. Table 2 summons up the shift in climatic classes from present to the two time windows and scenarios considered, for all stations. The colder classes ET and Dfc empty out in the second half of the century (the highest station considered was at 2600 m), while the warmest ones grow more populated.

Simulations also predict a shift of a number of sites toward **drier classes**, from the generally humid or very humid categories to generally sub-humid classes, with even some cases of dry classes in the farthest time window, mostly limited to scenario RCP 8.5.

The outlook of bioclimatic indices for present century confirms the general **further shift to warmer classes** (Table 3); Huglin classification even assumes the attainment of the highest temperature class for wine growing at one site.

A simulation of the **potential expansion** of viticultural area (Fig. 1) was carried out by using the best estimator index for present conditions (BEDD, Biologically Effective Degree Days) and geo-morphological constraints (gently slope, favourable orientation, large availability of potential mean sun-hours and cumulated global solar radiation during the vegetative period). A minimum contiguous surface of 1 ha was also set as a condition.

The real expansion should also consider the current land use and exclude unsuitable soil (i.e. urban and industrial areas, parks and protected areas, touristic places) from calculation. Moreover, it is unlikely that perennial crops (i.e. in the apple producing area of Non Valley) and high quality productions (horticulture, berries, and soft fruits) will be replaced due to climate change, if not driven by a decrease of production and quality. No restriction is expected to take place at the lower valley bottom due to the predicted warming or drying.

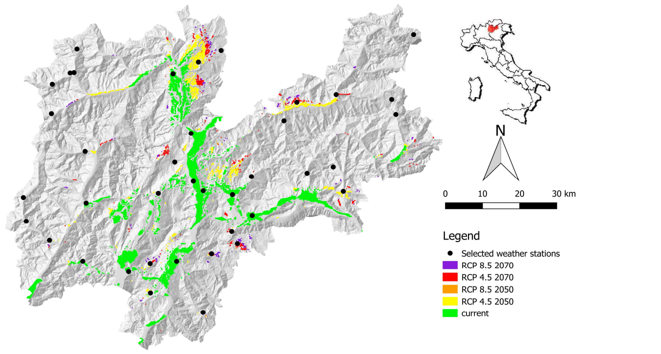

Figure 1 – Stations and potential expansion of viticultural area according to climate change scenarios.

Period & RCP scenario		'76-'05	'21 - '50		'41 - '70	
			4.5	8.5	4.5	8.5
Bioclimatic indices	CI -2	0	0	0	0	0
	CI -1	1	1	3	4	6
	CI +1	4	5	4	5	8
	CI +2	34	33	32	30	25
	DI -2	24	10	19	14	9
	DI -1	15	19	19	20	15
	DI +1	0	10	1	5	15
	DI +2	0	0	0	0	0

Period & RCP scenario		'76-'05	'21 - '50		'41 - '70	
			4.5	8.5	4.5	8.5
Bioclimatic indices	HI -3	24	13	13	10	9
	HI -2	4	11	11	9	4
	HI -1	5	4	4	8	11
	HI +1	6	5	5	3	4
	HI +2	0	6	6	9	10
	HI +3	0	0	0	0	1

Table 3 – Change in Tonietto and Carbonneau's synthetic bioclimatic classification. See table 1 for index keys. Orange highlights the outstanding transitions from cooler to warmer classes.

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Work co-funded by Climate Change Funds of Provincia Autonoma di Trento, 2013, project IndiClima, and by SEE Transnational Cooperation Programme of EU, 2012, project OrientGate.