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Adapting viticulture to climate change in the Mediterranean region: Evaluations accounting for spatial differences in the producers-climate interactions

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Abstract. Effective adaptation of viticulture to climate change requires impact and response scenarios. Although climate and production impact scenarios are based on the evaluation of a spatially heterogeneous system, conventional response scenarios do not take into account the variation of the producers-climate interactions. These interactions are often extremely heterogeneous and unevenly distributed in space, leading to errors in the needs and adaptation plans, especially in large areas. Here we develop a novel framework for adaptation that considers the heterogeneity of the responses given by producers to climate, and applies the concept to adaptation of viticulture to climate change in the Mediterranean region. We use future climate scenarios at 0.5° resolution to estimate the adaptation of viticulture by the end of the 21st century. Results suggest that most of the Mediterranean region may urgently need adaptation plans, leading to potential opportunities. By incorporating spatially explicit information on the diversity of viticulture systems, management practices, and climate vulnerability, this approach may contribute to adaptation policy.

1. Introduction

Mediterranean vineyards represent 40% of world area, providing livelihoods to millions of farmers and wine industry workers. The sector needs to look into the future with a range of agronomic and market-based strategies. However, the sector is linked to very old traditions and the industry has adjusted to the growing conditions imposed by the challenging environment.

The grapevine production is especially sensitive to lack of water, since it is raditionally placed in vulnerable areas, due to the effort to prioritise staple-food production in the most fertile lands with access to water. Grapevine production is sensitive not only to annual changes but to the seasonal distribution of precipitation. Climate change affecting Mediterranean grapevine production will have an effect globally, because a large fraction of Mediterranean wine production is exported and thus affect the international markets.

The concern is that grapevine growers and the wine industry demand stable production in order to make long term investments, but there is great uncertainty about how climate change may affect the sector. To address this concern, we have studied the impact of climate change in the production of grapevine in the Mediterranean region, recognising and building from the very important knowledge of previous studies (e.g., Jones et al., 2005; van Leeuwen, Darriet, 2016; Wolkovich et al., 2018; Cook, Wolkovich, 2016; De Oruña, 2010; Duchêne et al., 2010; Ferrise et al., 2016; Hannah et al., 2013; Schultz, 2016). In order to contribute to the characterisation of adaptation needs, our study includes three new elements: (a) Mediterraenan wide analysis using uniform high resolution datasets and common methodology, allowing to compare the limitations and oportunities across regions; (b) Probabilistic evaluation of the shift in production and quality indices and drought episodes; and (c) quantification of the adaptation efforts at the regional level, allowing to define policy strategies.

2. Methods and data

We develop an analytical framework based on Santillan et al. (2018a, 2018b) to link climate change risks to a set of indicators that inform on the main variables affecting grapevine production, that is, quantity and quality of the product.

We assess risks of climate change in the main Mediterranean grapevine producing regions (Fig. 1) by estimating the effect of projected climate on the agronomic performance of the vineyards and the adaptation choices available at each site. We estimate future impacts by assessing changes in climatic indices using future climatic scenarios. In the following subsections, we describe the climatic indices, the climatic projections, and the methodology used to assess the change in indices and estimate adaptation needs.

We compute changes induced by climate change in three representative bioclimatic indices: Huglin Index (HI) (Huglin, 1978), Cool Night Index (CNI), and Standardized Precipitation Evaporation Index (SPEI). The changes in these three indices have been recognized as the most adequate approach by previous studies (Tonietto and Carbonneau, 2004; Moriondo et al., 2011) to assess the

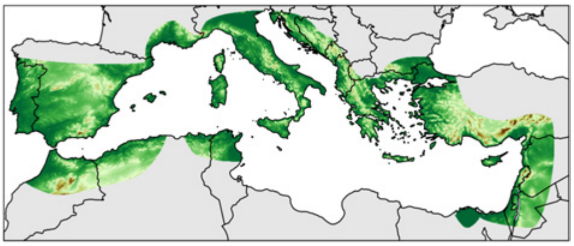

Figure 1. Mediterranean wine production regions.

impacts on climate change on vineyards and provide information about the adaption needs and applied globally and in the Mediterraean region with great detail (Sanatillan et al., 2018a; 2018b).

Both, the HI and CNI indices, are thermal indicators. The HI measures the thermal suitability for wine production at a given location. It characterizes the suitability of viticulture in general and particular grapevine crops at a given location (Huglin, 1978). The CI accounts for the minimum night temperature during the ripening period and provides insights about the quality of the wine, in terms of aroma and color of grapes and wine (Kliewer and Torres, 1972; Kliewer, 1973; Tonietto and Carbonneau, 2004). The SPEI is a drought indicator based on the precipitation and the potential evapotranspiration (Beguería et al., 2010; Vicente-Serrano et al., 2010). It provides information about water stress, and consequently, insights regarding the grape ripening, and wine quality and yield (Seguin 1983; Jackson and Lombard, 1993; Carbonneau, 1998).

3. Results and discussion

We assess the effects of climate change on vineyards by estimating changes in the bioclimatic indices from the climate in 1950 to the scenario in 2099. In the following subsections, we describe the evolution of the indices in the eight wine producing regions, the probabilistic projections of the changes, as well as the expected adaptation needs.

The estimated impact results can be used to optimise the policy choices as an adaptation response to climate change. Given the spatial and inter-annual resolution of the study, the study provides information for altering decisions during the growing season (e.g., the level of inputs, irrigation regimens, or insurance planning) and in the long term (e.g., varieties, water infrastructure and policy). The results highlight the critical need for alternative strategies to manage grapevine production in areas with future water stress, especially when water for irrigation competes with other uses of water of where current adaptation choices to market conditions have not considered future climate.

In the Mediterranean area, there are many wine-producing regions that have acquired renown for the adequate adaptation of their vineyards to their particular conditions: grape varieties, climate and soil (the "terroir" effect). This is a result of the reasonable predictability of their local climates in the short and middle term, in spite of their annual variabilities, kept within terms acceptable both for producers and consumers (the "vintage" effect). Wine typicity and maintenance of designation of origin can be strongly affected by grape maturation conditions.

Responding to changes in consumers' preferences and the demands for a less labour-intensive cultivation,

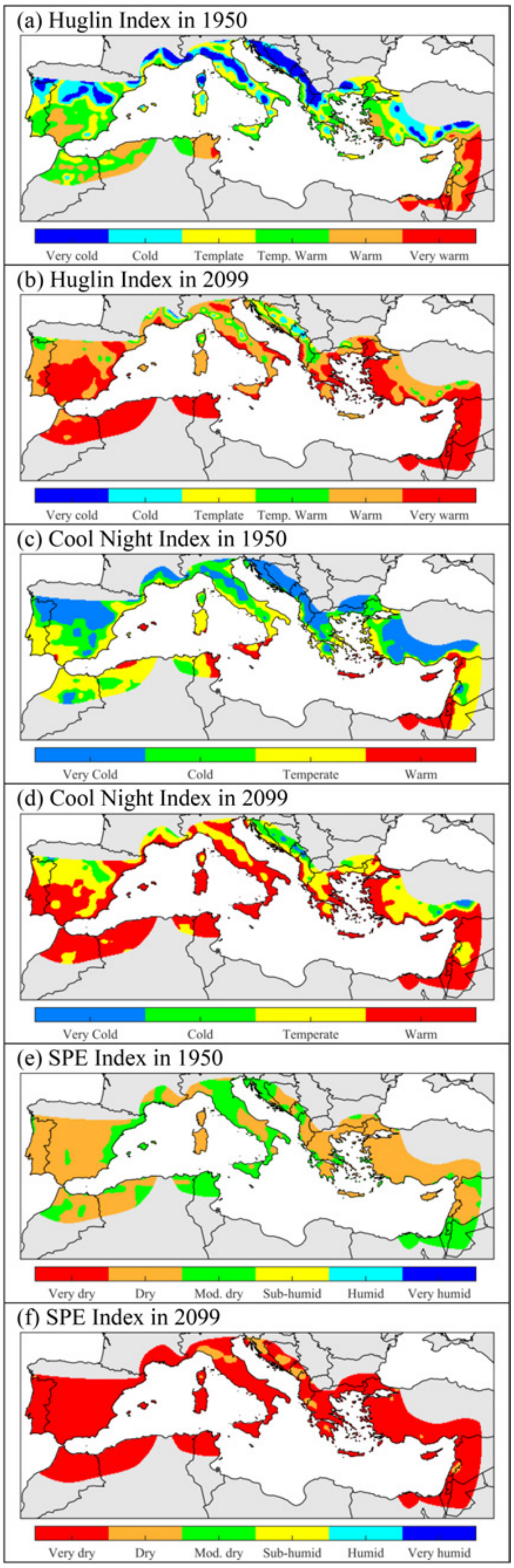

Figure 2. Magnitude of the climatic indices for the climate in 1950 and the projected scenario in 2099.

over the last three decades, traditional Mediterranean grapevine varieties (Grenache, Airen) are being substituted for Atlantic varieties (Cabernet Sauvignon, Merlot) and VSP pruning systems that are more water demanding, and have larger leaf area exposed to sun and heat which dramatically increases transpiration. Unfortunately, the investments have not considered climate change and are examples of not-informed adaptation that has transformed grapevine production in a more water-demanding system.

Our study has shown that, while climate change impacts are an important motivation factor to support for adaptation in grapevine production, the different effects in production and quality indices may play a key role on the regional disparities, which indirectly influence on individuals' support for adaptation choices.

In this work, the main adaptation needs which affect grapevine choices in the future are derived from the lack of water to support recently established plantations. Future work may consider a deeper assessment of producers views on varieties more adapted to less water well as the role of current normative.

Our study in the Mediterraena region show that the most widely needed adptation is to adjust to increased water scarcity. These results hold true under all climate scenarios analysed. The probabilistic analysis suggests that about half of the area will be mal-adapted in the future. However, the current transformation of very large grapewine production areas moves the production model towards a more water demanding one. Vineyard re-structuring plans are particularly important. For instance, 355,316 ha (equivalent to the total vineyard area of Australia and Chile combined) have been re-structured in Spain during the period 2001–2015, with subsidies amounting to 2 billion €. And there are plans for further re-structuring. This investment may have produced mal-adaptation in some areas in view of future climate. Irrigation systems have been developed for a large fraction of the re-structured area, mainly drip irrigation. In Castilla-La Mancha, which includes 50% of the Spanish vineyard area and the majority of irrigated vineyard, this has led to environmental problems in aquifers, because large water amounts are used in search of high productivities that help achieve profitability under low grape price conditions. In France irrigation has recently been authorized for vineyards because average precipitations were not enough to achieve the required production. Consequently, our results would be particularly relevant for increasing knowledge in support to more informed adaptation choices.

Since the wine sector is the most regulated in the European Union, there is hope that policy may be informed by sicence to deliver the most approapriate adaptation normative.

4. Further work

A multitude of solutions are available that can anticipate climate change damage to grape growing regions. However, the success depends on transforming the current morel of production. The literature on adoption of agricultural innovation helps understand the challenges and limitation to implement adaptation strategies. Many if the greatest barriers to adoption are beyond the producer and even the industry and in many cases, only the transformations that are supported by institutions will be effective.

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References

S. Beguería, S.M. Vicente-Serrano, M. Angulo, Am. Meteorol. Soc. **91**, 1351 (2010)

A. Carbonneau, Irrigation, vignoble et produits de la vigne. In *Traité d'irrigation, Aspects qualitatifs*, (Lavoisier, Paris, France, 1998) ISBN: 2743009101, p. 257

K.H. Hamed, A.R. Rao, J. Hydrol. **204**, 182 (1998)

S. Hempel, K. Frieler, L. Warszawski, J. Schewe, F. Piontek, Earth System Dynamics **4**, 219, doi: 10.5194/esd-4-219-2013 (2013)

P. Huglin, Nouveau mode d'évaluation des possibilités héliothermiques d'un milieu viticole. C.R. Academy of Agriculture in France **64**, 1117–1126. `http://prodinra.inra.fr/record/116105` (1978)

W.M. Kliewer, J. Am. Soc. Hort. Sci. **2**, 153 (1973)

Z.W. Kundzewicz, A.J. Robson, Hydrolog. Sci. J. **49**, 7 (2004)

D.I. Jackson, P.B. Lombard, J. Enol. Vitic. **44**, 409 (1993). `http://ajevonline.org/content/44/4/409.abstract`

W.M. Kliewer, R.E. Torres, Am. J. Enol. Vitic. **2**, 71 (1972)

P. Resco, A. Iglesias, I. Bardají, V. Sotés, Reg. Environ. Change **16**, 979 (2016)

K. Frieler, R. Betts, E. Burke, P. Ciais, S. Denvil, D. Deryng, K. Ebi, T. Eddy, K. Emanuel, J. Elliott, E. Galbraith, S.N. Gosling, K. Halladay, F. Hattermann, T. Hickler, J. Hinkel, V. Huber, C. Jones, V. Krysanova, S. Lange, H.K. Lotze, H. Lotze-Campen, M. Mengel, I. Mouratiadou, H. Müller Schmied, S. Ostberg, F. Piontek, A. Popp, C.P.O. Reyer, J. Schewe, M. Stevanovic, T. Suzuki, K. Thonicke, H. Tian, D.P. Tittensor, R. Vautard, M. van Vliet, L. Warszawski, F. Zhao, Assessing the impacts of 1.5 °C global warming – simulation protocol of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b). Geoscientific Model Development Discussions, 1–59, `https://doi.org/10.5194/gmd-2016-229` (2016)

S. Lange, Earth Syst. Dynam. Discuss. (2018), `https://doi.org/10.5194/esd-2017-81`, in review

C. Monfreda, N. Ramankutty, J.A. Foley, Glob. Biogeochemical Cycles **22**, GB1022 (2008), doi:10.1029/2007GB002947

M. Moriondo, M. Bindi, C. Fagarazzi, R. Ferrise, G. Trombi, Reg. Environ. Change **11**, 553 (2011), doi:10.1007/s10113-010-0171-z

D. Santillan, A. Iglesias, M.C. Llasat, L1. Garrote, V. Sotes, Reg. Env. Change (under review) (2018a)

D. Santillán, A. Iglesias, I. La Jeunesse, L. Garrote, V. Sotes, Sci. Total Environ. (STOTEN) (under review) (2018b)

G. Seguin, Influence des terroirs viticoles sur la constitution et la qualité des vendanges. Bulletin de la

Organisation Internationale de la Vigne et le Vin **623**, 3 (1983) ISSN 0029-7127
P.K. Sen, Tau. J. Am. Stat. Assoc. **63**, 1379 (1968)
C.W. Thornthwaite, Geograph. Rev. **38**, 55 (1948), doi: 10.2307/210739
J. Tonietto, A. Carbonneau, Agr. Forest Meteorol. **124**, 81–97 (2004), doi: 10.1016/j.agrformet.2003.06.001
C. Van Leeuwen, P. Frian, X. Chone, O. Tregoat, S. Koundouras, D. Dubourdieu, Amer. J. Enol. Vitic. **55**, 207 (2004)
S.M. Vicente-Serrano, S. Beguería, J.I. López-Moreno, J. Clim. **23**, 1696 (2010)
S. Yue, C.Y. Wang, Int. J. Climatol. **22**, 933 (2002)