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Vineyard mulching as a climate change adaptation measure: Future simulations for Alentejo, Portugal

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A B S T R A C T

Climate change projections for the next decades are expected to bring important challenges to the Portuguese viticulture. More specifically, for the wine region of Alentejo, in Southern Portugal, the projected warming and drying are expected to have detrimental impacts on grapevine physiology and ultimately on yields. The present study assesses the adaptation potential of mulching for maintaining current grapevine yield levels in the region. For this purpose, the STICS process-based crop model was used to simulate future (2021–2080) grapevine yields in the 8 sub-regions of Alentejo (with Denomination of Origin). Several datasets for weather variables, soil characteristics, topographic features and management practices were defined independently for each sub-region. Simulations comprise both non-mulching and mulching experiments over the next 60 years, under the climate change scenario RCP8.5. Although both non-mulching and mulching simulations suggest a gradual yield decrease in the future, mulching mitigates these decreases by 10 to 25%. Furthermore, the results show that mulching can reduce the yield decreasing trend, from −0.75%/year to −0.66%/year. In effect, mulching is expected to provide yield gains over the full simulated time period, being the benefits particularly apparent towards the end of the target period (2061–2080; warmest years of simulation). Mulching is a cost-effective adaptation measure that may be easily adopted by growers on the short-term. Nonetheless, this strategy alone might not be enough to fully mitigate yield losses and additional / complementary measures should be envisioned to warrant the sustainability of the Alentejo winemaking sector under futures climates.

1. Introduction

Climate change brings important challenges to viticulture. Some of the major risks may be driven by the projected rise in air temperatures and the decrease in soil water availability (Fraga et al., 2016; Santos et al., 2017). Particularly in Southern European winemaking regions, the increasing intra- and inter-annual climatic variability are an emerging concern for the sector stakeholders (OIV, 2015). Additionally, the synergistic effects of warming and drying projected for these regions may further threaten this important socioeconomic sector (Fraga et al., 2018). The increasing frequency of occurrence of extreme weather events, such as droughts, prolonged rainfall periods (Cyr et al., 2010), heat waves (White et al., 2006), late frosts or cold spells (Menzel et al., 2011; Molitor et al., 2014; Yadollahi, 2011), hail and thunderstorms (Spellman, 1999), may cause negative effects on both grapevine yield and berry quality attributes and, in more extreme conditions, crop failure.

Several world winemaking regions are located in areas with typical Mediterranean-type climates (Jones et al., 2005). In effect, these regions are already under very stressful conditions for plant growth, characterized by warm and dry grapevine growing season (Jones et al., 2005; Kottek et al., 2006; Toth and Vegvari, 2016). It has been shown that these stresses can be relieved and even counteracted by certain management practices that can be applied by growers (Fraga et al., 2017; Keller, 2010a). Some of these practices include leaf area control (Harbertson and Keller, 2012; Keller et al., 2011), changes in the tillage systems and soil management (Bahar and Yasasin, 2010; Kvaternjak et al., 2008), or even the application of irrigation (Chaves et al., 2007; Chaves et al., 2010; dos Santos et al., 2003; Ferreira et al., 2012). Given the projected future warming and drying of climatic conditions in the Southern European winemaking regions, there is an increasing need for a better understanding of the potential benefits of these practices.

One potential adaptation measure that needs to be considered and further studied is the application of mulches or mulching (Chan et al., 2010). Mulches are organic or inorganic products that may be placed on the soil surface. Mulching reduces soil compaction and retains soil moisture, as it protects the soil surface, regulates soil temperature and reduces evaporation (Chen et al., 2007; Novak et al., 2000). In addition

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to saving water, mulching improves soil quality and increases its organic matter content. Mulches may also be beneficial for combatting pests and stopping weed development, thus reducing water competition. Moreover, vineyards with mulch tend suffer less heat and water stresses. Previous studies showed that mulching may help to maintain yield levels under adverse climatic conditions, while decreasing water requirements (DeVetter et al., 2015). Furthermore, mulching is an affordable agricultural technology for sustainable soil and land management, promoting a reduction of soil erosion, and can be easily adopted by most farmers. Although potential benefits of mulching have already been reported, no study has yet investigated the impacts of mulching application under climate change scenarios. Thus, a better understanding of the impact of mulching on future yields is required.

The present study will be focused on Alentejo, a large viticultural region in inner southern Portugal. This region has undergone a remarkable development over the recent decades and is currently the leading region in terms of non-fortified wine production. It is characterized by a dry sub-humid Mediterranean climate and is classified as a climate change hotspot, i.e. "*a region for which potential climate change impacts on the environment or different activity sectors can be particularly pronounced*" (Giorgi, 2006). In fact, it is highly vulnerable to climate change owing to the high risk of desertification under future semi-arid conditions, low quality of soils and high temperatures (Costa et al., 2017; Jones et al., 2011; Santos et al., 2017). Despite the growing irrigated areas, namely using water from the vast Alqueva dam and other important water reservoirs, the majority of the region is still not irrigated and viticulture is mostly rainfed. As a result, climate suitability for grapevine growth and development is threatened in Alentejo (Coelho et al., 2013) and suitable adaptation measures are thereby needed to ensure the future sustainability of this crop.

The present study aims at assessing the impacts of mulch application as a climate change adaptation measure in the viticultural region of Alentejo, Portugal. Therefore, the present study objectives are four-fold: 1) to simulate mulching application using a dynamic crop model, specifically adapted to viticulture in Alentejo; 2) to assess potential benefits of different mulch types, particularly regarding yields; 3) to analyze the impacts of mulch treatments on Alentejo spatial and temporal grapevine yield variability; and 4) to compare the range of these potential benefits regarding different bioclimatic indicators under future climate change scenarios.

2. Material and methods

2.1. Study region

Alentejo is a large viticultural region in southern Portugal characterized mostly by flatlands, with a relatively homogenous warm and dry climate. The Alentejo viticultural region is currently divided into 8 sub-regions (with Denomination of Origin: DO): Portalegre, Borba, Redondo, Reguengos, Vidigueira, Évora, Granja-Amareleja and Moura (Fig. 1). The vineyard land cover is mostly concentrated within these sub-regions. Vineyard area in this region has been increasing since the 1980s (Linear Trend; LT ~500 ha/year), despite some recent slight decreases, and it is currently around 23 thousand ha (IVV, 2015). This is one of the most productive wine regions in Portugal, with a wine production of around 1 million hl, which has also been increasing in the last years (LT ~38,000 hl/year) (IVV, 2015). Regarding the main cultivars, Aragonez (syn. Tempranillo), Trincadeira and Castelão are the most important red varieties, while Roupeiro, Antão-Vaz and Arinto are the main white varieties (IVV, 2015).

2.2. The STICS dynamical crop-model

Modelling was achieved using the STICS (*Simulateur mulTIdisciplinaire pour les Cultures Standard*) crop model (Brisson et al., 2008). This model is, presently, one of the few process-based crop

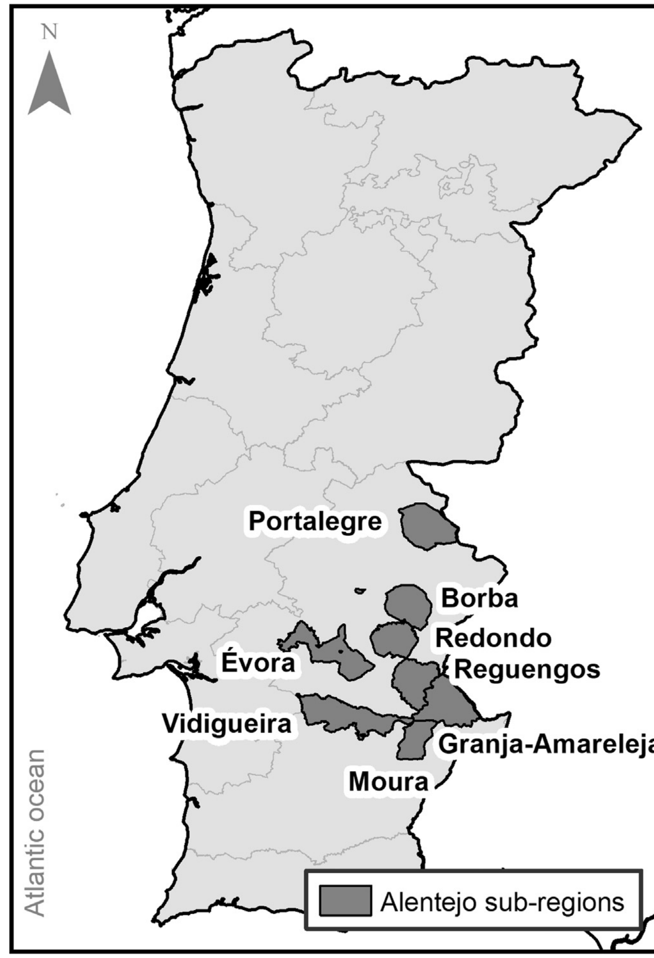

Fig. 1. Geographical boundaries of the viticultural regions in Portugal. The 8 viticultural sub-regions in Alentejo are highlighted (Portalegre, Borba, Redondo, Reguengos, Vidigueira, Évora, Granja-Amareleja and Moura).

models that may be applied to grapevine simulation (perennial crop). STICS requires a large number of input parameters, such as weather data, soil characteristics, terrain features, along with varietal information and management practices. All these inputs are then used to simulate grapevine growth, phenological development and yields (among other outputs). The model has been tested and validated for grapevines under different climates, management practices, soils and irrigation regimes (Coucheney et al., 2015; Fraga et al., 2015, 2018; Valdes-Gomez et al., 2009). Furthermore, this model has previously been used in assessing the impacts of climate change on European viticulture (Fraga et al., 2016). Given the model skillfulness in simulating grapevine yields (Fraga et al., 2015; García de Cortazar-Atauri, 2006; Valdes-Gomez et al., 2009), it was used herein to assess the benefits of mulching strategies as a climate change adaptation measure at regional level.

2.2.1. Crop model simulation inputs

Datasets for i) daily weather variables, ii) soils properties, iii) topographic features, iv) management practices and v) cultivar data were used as model inputs. These data were retrieved for each sub-region in Alentejo separately, using the centroid method (i.e. the value for the geographic centroid of each sub-region was extracted using a geographic information system).

2.2.2. Weather variables

The daily weather variables used were: minimum and maximum 2-m air temperature (°C), solar radiation (MJ m^{-2}), precipitation (mm),