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Research Paper

Viticultural irrigation demands under climate change scenarios in Portugal

H. Fraga [a,*], I. García de Cortázar Atauri [b], J.A Santos [a]

[a] Centre for the Research and Technology of Agro-Environmental and Biological Sciences, CITAB, Universidade de Trás-os-Montes e Alto Douro, UTAD, 5000-801, Vila Real, Portugal
[b] French National Institute for Agricultural Research, INRA, US1116 AgroClim, F-84914, Avignon, France

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ABSTRACT

Climate change projections for Southern Europe reveal warming and drying trends for the upcoming decades, bringing important challenges to Portuguese viticulture in particular. The present study analyses irrigation as an adaptation measure to ensure the future sustainability of viticultural yields in Portugal. The STICS crop model was used to simulate baseline (1981–2005) and future (2041–2070) grapevine yields in Portugal. Future yield decreases (yields are 60% with respect to baseline) over some of the innermost and most renowned winemaking regions of the country are found, following the decrease of precipitation in the growing season. As an adaptation measure, grapevine irrigation was tested for future climates. STICS irrigation replicates a highly efficient water use strategy, only applied when a certain water stress level is reached. The results indicate higher yields with this irrigation strategy, thus largely alleviating the projected yield decreases. Nonetheless, in some warmer and dryer regions, such as inner Alentejo and Douro/Porto, yield levels are still projected to decrease with irrigation (70–80% of baseline yields), though to a lesser extent when compared to non-irrigated simulations. This decrease is attributed to the synergistic effect of severe heat and water stresses in the future. Although these simulations aim at achieving the same yields and alcohol level in future scenarios as in baseline, applying irrigation may modify the wine typicity of each region and threaten the currently scarce water resources. Outlining appropriate, timely and cost-effective adaptation measures is critical for the sustainability of both the environment and the national Portuguese winemaking sector.

1. Introduction

Grapevine growth and development is largely controlled by atmospheric conditions (Jones and Goodrich, 2008; Jones et al., 2005; Tonietto and Carbonneau, 2004; van Leeuwen et al., 2004). In fact, weather factors such as temperatures, solar radiation and water availability strongly influence vine growth and development, which ultimately impact yield and wine quality (Makra et al., 2009; van Leeuwen et al., 2008). Although grapevines show a strong adaptation to different environmental conditions, many of the renowned winemaking regions worldwide are located in areas with Mediterranean-type climates, characterized by stressful conditions for plant growth (Fraga et al., 2016a; Toth and Vegvari, 2016; van Leeuwen and Darriet, 2016). In Portugal (Fig. 1), grapevines are often exposed to severe heat and water stresses, in the most internal regions during summer. In the Douro/Porto wineregion (Fig. 1), world renowned for its Port Wine, total precipitation in the summer months (June-July-August) is usually around 100 mm (Fraga et al., 2015).

Water is essential for grapevine vegetative and reproductive growth, being a major forcing factor of crop yields (Hardie and Martin, 2000; Iglesias and Garrote, 2015). Water availability, while more critical at certain development stages, will define in most the case, the crop suitability (feasibility) in a specific area (Caubel et al., 2015). Severe water stress may result in a wide range of negative impacts, such as low flower- and berry-set, low leaf area, limited photosynthesis, flower abortion and cluster abscission (During, 1986; Hardie and Considine, 1976). Conversely, excessive humidity overstimulates growth, leading to denser canopies and higher risk of specific pests and diseases. Additionally, for the production of a high quality wine, a certain level of water stress at certain development stages may be required (Jones and Davis, 2000; Nemani et al., 2001; Ramos et al., 2008; Reynolds and Naylor, 1994; Storchi et al., 2005; Tonietto, 1999).

For the Portuguese viticulture, which is currently the European 5th largest wine producer, with a total of 6.7 Mhl (IVV, 2015; OIV,

* Corresponding author.
E-mail address: hfraga@utad.pt (H. Fraga).

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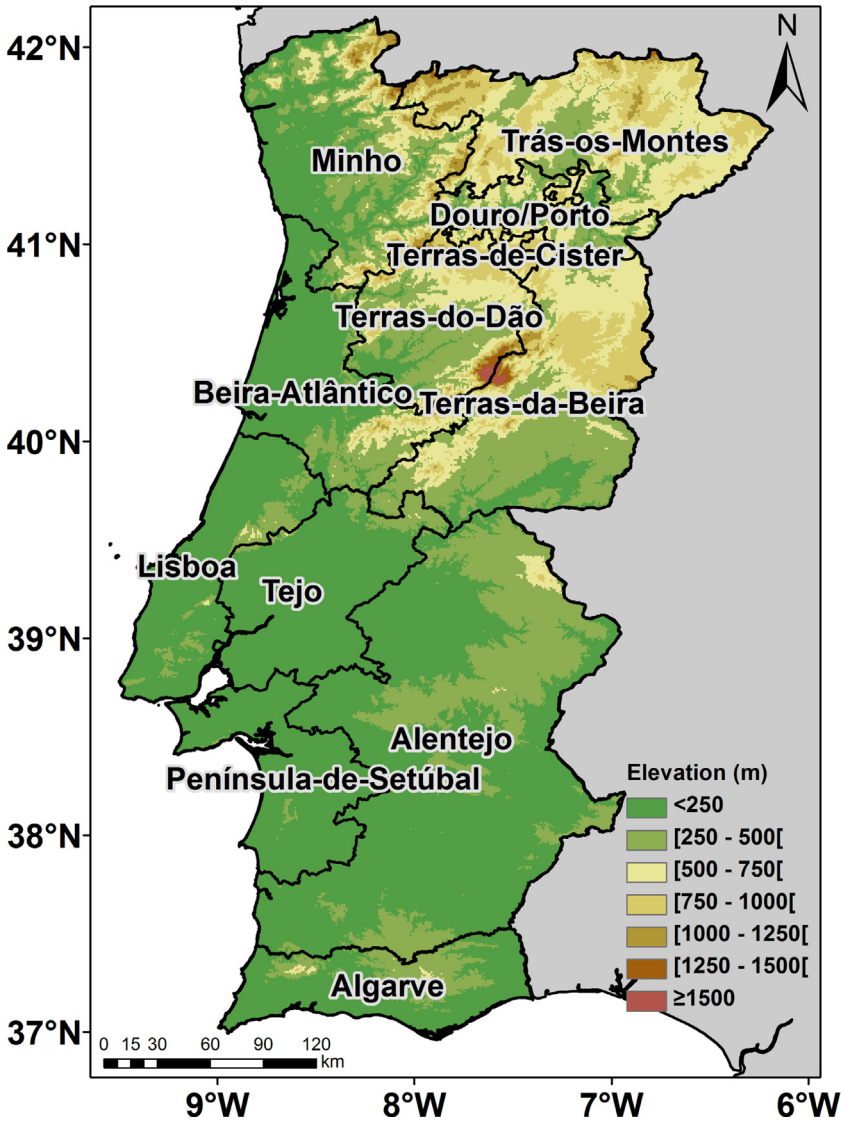

Fig. 1. Grapevine growing regions in mainland Portugal as defined by the *Instituto do Vinho e da Vinha (IVV)*.

2015), precipitation is, for most regions, traditionally considered the only source of available water for plant growth. In almost all of the 12 Portuguese mainland viticultural regions (Fig. 1), water stress levels can be severe, especially in the warm and dry summers. Irrigation application is often not advised, or even not allowed, as it can alter grape yield and quality attributes. In many European countries, this practice has indeed been historically forbidden by strict wine regulations, specifically established for each winemaking region. This is also the case of the Portuguese Douro Demarcated Region, where irrigation has been outlawed, except in very specific cases (e.g. experimental plots, vineyards endangered due to excessive water stress). Despite this limitation, viticultural irrigation in Portugal has been increasing, though still limited to the dryer inner-southern areas of the country, such as in Alentejo (Costa et al., 2016; Permanhani et al., 2016).

Climate change may challenge these traditional concepts (Fraga and Santos, 2017; Fraga et al., 2016b; Jones, 2005; Kenny and Harrison, 1992; Neethling et al., 2016; Nesbitt et al., 2016; Toth and Vegvari, 2016). In the future, the projected lower precipitations in Southern Europe, combined with higher temperatures and more frequent and longer extreme climate events, such as heat waves and extreme droughts (IPCC, 2013; Santos et al., 2017), may negatively affect final yields and quality attributes (Jones and Alves, 2012). A recent study clearly points to a decrease in yields over some areas of Portugal under climate change scenarios if no adaptation measures are adopted (Fraga et al., 2016a). These findings are encouraging the research and development of climate change adaptation measures, namely the implementation of irrigation systems (Costa et al., 2016; Permanhani et al., 2016). As a result, throughout Southern Europe, many winemaking countries have been loosening their regulations regarding irrigation (Permanhani et al., 2016). Still, the assessment of the potential positive effects of viticultural irrigation under climate change scenarios in Portugal was not previously performed, being of utmost importance for growers.

Under the increasingly dryer Portuguese climates, water is considered a threatened resource. Water scarcity is increasing, not only due to climate change, but also due to population growth, industrial use and intensive agriculture water demands, amongst other factors. Hence, applying irrigation to this historically rainfed crop brings additional economic, environmental and social costs. As adaptation to water scarcity is required under future climates (Costa et al., 2016), smart (e.g. deficit) irrigation strategies should be implemented (Permanhani et al., 2016; Romero and Martinez-Cutillas, 2012; Santos et al., 2003), both to reduce non-beneficial water consumption (Pereira et al., 2012; Perry, 2011) and to optimize grape composition (Junquera et al., 2012), providing a