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# Modern viticulture in southern Europe: Vulnerabilities and strategies for adaptation to water scarcity

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ABSTRACT

Water is now considered the most important but vulnerable resource in the Mediterranean region. Nevertheless, irrigation expanded fast in the region (e.g. South Portugal and Spain) to mitigate environmental stress and to guarantee stable grape yield and quality. Sustainable wine production depends on sustainable water use in the wine's supply chain, from the vine to the bottle. Better understanding of grapevine stress physiology (e.g. water relations, temperature regulation, water use efficiency), more robust crop monitoring/phenotyping and implementation of best water management practices will help to mitigate climate effects and will enable significant water savings in the vineyard and winery. In this paper, we focused on the major vulnerabilities and opportunities of South European Mediterranean viticulture (e.g. in Portugal and Spain) and present a multi-level strategy (from plant to the consumer) to overcome region's weaknesses and support strategies for adaptation to water scarcity, promote sustainable water use and minimize the environmental impact of the sector.



## 1. The wine grape industry in south Mediterranean Europe

World's wine production sites are located in a wide geographical and climatic range, often in mid-latitude regions characterized by climate variability and stressful environments, such as the Mediterranean region (Fraga et al., 2013; Lionello et al., 2014). The European Union (EU-28), is the world's leader in wine production with about 50% of world's vine-growing area and about 60% of total volume of production (USDA, 2014). France, Italy, Spain, Germany and Portugal are the five leading EU wine producers and altogether they represent 90% of EU production (USDA, 2014). Spain has the largest vineyard area in the world (950,541 ha in 2014) with an increasing irrigated area (36% of the total, in 2014) (MAGRAMA, 2014) (Fig. 1). Portugal is the EU's 5th largest wine producer with a total of 6.7 Mhl in 2013 and it has a cultivated area estimated to be about 224,000 ha (IVV, 2015). In 2010, the irrigated area was estimated in 15% of the total area of vineyards (INE, 2010). However, irrigation continued expanding in the recent years in Portugal, in particular in the Alentejo region, and presently, the percentage of irrigated vines should be higher and around 20%. Mediterranean fresh water resources are under high pressure due to fast-growing population, increased water scarcity, extreme climate variability and intensive water use in agriculture, industry and tourism activities (Lange et al., 2005; Costa et al., 2007; EEA, 2012a,b; Lereboullet et al., 2013a,b; Blum, 2014). Water is now considered by EU experts as the most important but vulnerable resource in the Mediterranean region (EU-ERANETMED, 2014). In addition, climate scenarios for South Mediterranean Europe are not favourable for agriculture. The predicted lower precipitation, higher air and soil temperatures, more frequent and longer extreme climate events (e.g. heat waves, extreme drought) (IPCC, 2013) will negatively affect viticulture in the region (Chaves et al., 2010; Rogiers and Clarke, 2013; Teskey et al., 2014; Lionello et al., 2014).

In Europe, irrigation of vineyards is below 10% of the total area, but the tendency towards irrigation is increasing to mitigate the effects of climate change and more stressful environment. Irrigation has therefore expanded in dry regions of France, Spain, Portugal and Italy (Intrigliolo and Castel, 2008; Seguin, 2010; USDA, 2013; Fraga et al., 2013; Barisan et al., 2014; De Leo et al., 2015). Meanwhile, agriculture in South Mediterranean Europe is increasingly subjected to more restrictive legislation at both EU and individual country levels namely in terms of water use regulation and water conservation. Next we present some of the major constrains

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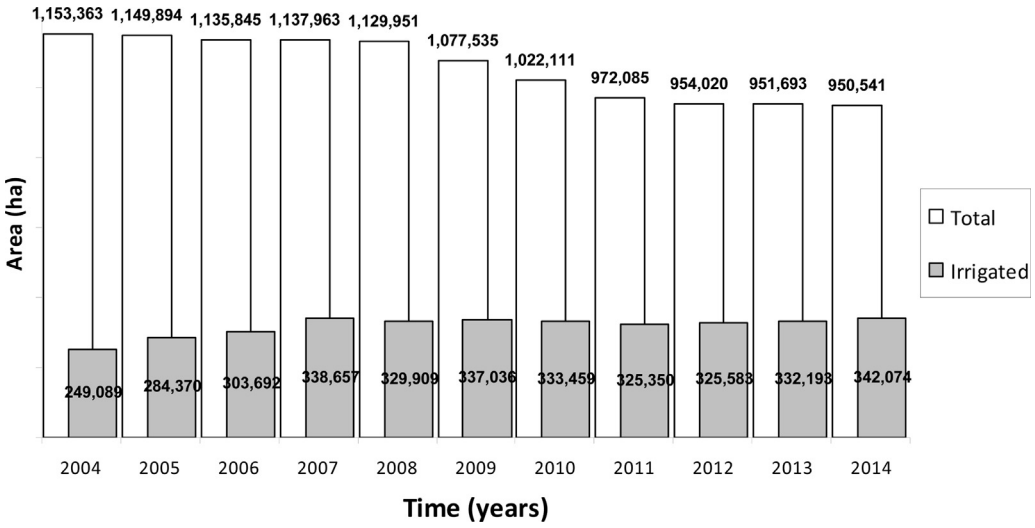


**Fig. 1.** Total cultivated area (ha) and irrigated area (ha) of Spanish vineyards from 2004 to 2014.
Source: "Encuesta sobre Superficies y Rendimientos de cultivos en España, ESYRCE, Spanish Agriculture Ministry 2014.

and opportunities experienced by South European wine industry, focusing on Spain and Portugal.

### 1.1. Constraints (environment and socio-economic)

An important vulnerability of rainfed agriculture in the Mediterranean is the combination of high air temperature and water deficit coupled to marked inter-annual and intra-annual climate variability and scarce water resources (Costa et al., 2007; Lopes et al., 2014; Rogiers and Clarke, 2013; Valverde et al., 2015). In the case of *Vitis vinifera*, Mediterranean climate may limit yield and berry quality because most of the berry growth and ripening period occurs under conditions of high air temperature and soil water deficit (Medrano et al., 2003; Chaves et al., 2007, 2010; Lereboullet et al., 2013a,b; 2014). In rainfed Mediterranean viticulture, water stress can be particularly severe during summer mainly if previous winter and spring seasons are dry. This situation is often reported for the Mediterranean zones of the Iberian Peninsula (e.g. Alentejo wine region in years 2003 and 2005). Moreover, Mediterranean viticulture is increasingly exposed to climate extremes (e.g. maximum temperatures and heat waves) (EASAC, 2013; Fraga et al., 2013; Hannah et al., 2013; Lereboullet et al., 2013a,b; Lionello et al., 2014). Not only extreme air temperatures but also high soil temperatures can be potentially negative for berry and leaf/canopy physiology. In fact, soil temperature ($T_s$) in Southern European countries can easily reach values above 50 °C along the day (Fig. 2). High soil temperature not only influences root activity and root growth but may also negatively impacts leaf/canopy photosynthesis, as well as diurnal and nocturnal stomatal conductance (Rogiers and Clarke, 2013). Temperature determines berry composition and quality by influencing the ripening process, berry biochemistry and synthesis/degradation of certain compounds such as anthocyanins or polyphenols (Mori et al., 2007; Teixeira et al., 2013; Zarrouk et al., 2015). High berry temperatures (>35 °C) may inhibit anthocyanins synthesis and induce their degradation (Bergqvist et al., 2001; Spayd et al., 2002).

Portugal is relatively well endowed in terms of water resources. However, these resources are unevenly distributed with marked difference between the rainy and cooler North and central Atlantic regions of the country and the dry and warmer South, inland regions (e.g. Alentejo). The same occurs with Spain which presents large differences in terms of water reserves and precipitation between the Atlantic and Northern regions and the southern Mediterranean regions. In Portugal, irrigated viticulture expanded mostly in the southern part of the country (Península de Setúbal, Alentejo, Algarve) but now other wine regions (e.g. Tejo, Douro Superior) are also now being punctually irrigated to face more stressful summer conditions (Fraga et al., 2013; Lopes et al., 2014). Spanish vineyards have been traditionally dry-farmed because irrigation was forbidden by law until 1996. Nowadays, irrigation is still not permitted in most of the "Denominaciones de Origen (DO)", and just like in Portugal, irrigation is only allowed under specific circumstances and after the technical allowance from Regional wine Commissions. However, vineyards in areas out of the DO control can be irrigated without any restriction. Although irrigation has increased dramatically in Spanish viticulture (Fig. 1), there are still authors questioning whether this is an environmentally sustainable trend in semi-arid areas such as regions of central and southern Spain (Intrigliolo and Castel, 2008; Romero et al., 2010; Medrano et al., 2015).

Ground water resources in the Mediterranean also deserve more attention. Indeed, they contribute to 20–100% of the water used in European irrigated farms, depending on the region and country. Besides the ongoing climate change is expected to limit recharge of aquifers due to reduced precipitation and to increased water abstraction to support larger irrigation needs and to minimize the problem of lower quality surface waters (Costa et al., 2007; Goderniaux et al., 2009; Stigter, 2012; Baudron et al., 2014; Carreira et al., 2014). Also, in most of the EU countries, groundwater users pay no tariff to water authorities and only few countries (France, Netherlands, Denmark, England and Wales) do charge a water abstraction fee (OECD, 2010).

Vulnerability and adaptive capacity of the Mediterranean viticulture is also linked to socio-economical aspects (Strano et al., 2013; Lereboullet et al., 2012; 2013a,b). For example, the small size of most of the companies results in limited budgets and restricted innovation with limited capacity to accommodate new legislation requirements for environment or new market trends related to quality (ECOPROWINE, 2014). In addition, fluctuations in the wine markets poses a limitation to Mediterranean viticulture and affect mostly smaller companies. Another limitation is the lack of information and perception of risks by growers and managers of smaller companies which restrict changes in terms of adoption of novel agronomic strategies or technologies to mitigate climate change and respond to changes in consumer demand and to more restrictive legislation on water use.

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