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Socio-ecological adaptation to climate change: A comparative case study from the Mediterranean wine industry in France and Australia

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ABSTRACT

The article aims to present a systemic and comparative framework to study adaptation to climate change in agricultural systems. Mediterranean viticulture, projected to experience significant and rapid changes in climate, is used as a case study. We apply an international socio-ecological approach focusing on viticulture in Roussillon (France) and McLaren Vale (Australia). Mixed-methods, including analysis of meteorological data, semi-structured interviews and field observations, guide an analysis of the exposure, sensitivity and adaptation of the two viticultural systems to climate change. We found that the exposure to climate change is likely to become more acute in the two regions by 2060, and that the sensitivity and adaptive capacity of viticultural systems to such change depend strongly on the complex interaction of ecological and socio-economic factors. Most studies focusing on viticulture and climate change are either oriented towards plant physiology, phenological modelling or the economic future of the industry in one region. The research bridges discipline approaches to provide a holistic comparative analysis to guide adaptation, and argues that socio-ecological analyses will become increasingly important to support adaptation decision-making.

1. Introduction

Vitis vinifera is a traditional crop in the Mediterranean basin, and still today, almost two-thirds of global vineyards and wine production are within countries surrounding the Mediterranean Sea (OIV, 2007). Since the end of the Nineteenth century, however, wine production has developed in similar climates outside the Mediterranean basin, due to the capacities of *V. vinifera* to grow on poor, dry soils and generate a high value-added product. The opportunities to produce wine more cheaply and with fewer cultural and regulatory restrictions has led to increasing competition between the New World (particularly America, South Africa, Oceania) and the Old World (Europe). In recent years this traditional opposition has been transformed by environmental and socio-economic crises into a far more complex situation of global competition.

Climate change is now presenting new challenges for viticultural systems. As well as altering viticultural practices, climate change could extend or alter spatially potential wine producing areas and have important impacts on the quality and quantity of wines produced. Climate change may become particularly problematic this century for Mediterranean regions at the hotter and drier climatic margins of the productive growth range of *V. vinifera* (Jones et al., 2005). The increasing occurrence of extremes such as drought or heat waves in those areas threatens the plant's natural resilience and producers' plans for vineyard management. *V. vinifera* is a perennial plant with a commercial lifespan of at least several decades, so it is essential for producers to plan far ahead when taking vineyard management decisions.

The article focuses on two wine producing regions belonging to CSb climate type ("hot summer" or "typical" Mediterranean climate, characterized by irregular autumn or winter rain and dry summers) of Köppen–Geiger classification (Peel et al., 2007): Roussillon in France and McLaren Vale in Australia. These production regions, one in the Old World, the other in the New World, are facing rapid change, and we review their adaptation capacities in the face of future uncertainty. Recent and present exposure, sensitivity and adaptation to climate change are all examined. In climate change scholarship, *adaptive capacity* represents the potential to mobilize resources for anticipation or adaptation to perceived or current stresses (Engle, 2011). It is generally defined as the ability of a system to anticipate or adjust and respond to the effects caused by changes (Smit et al., 2001). It is conceptualized as a function of *vulnerability*, or the impact that cannot be managed by current levels of adaptation (Adger, 2006; Eakin and Luers, 2006) and

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resilience, or the capacity of a system to absorb changes without significant detrimental effects (Walker et al., 2004; Folke et al., 2005). Vulnerability is a function of physical *exposure* to change and *sensitivity*, or the extent to which a system is affected after being exposed. The Allen Consulting Group (2005) identified agricultural systems most vulnerable to climate change as those that are: (i) already stressed, (ii) at edge of their climatic conditions, and (iii) where large and long lived investments are made, such as with perennial crops, irrigation and processing facilities. Both Roussillon and McLaren Vale meet these three criteria. Therefore, it could be particularly important that planning and investment is undertaken now to adapt systems to predictable future change.

The aim of the present article is not to undertake vulnerability analyses, as such studies have already been completed by Bardsley and Sweeney (2010) for McLaren Vale, and by Maton et al. (2010) for Roussillon. Both conclude that the regional economies, including viticultural systems, are highly dependent on water resources, which will be threatened by projected climatic change. In fact, the capacity to manage present and future uses and pressures on water resources will be a key aspect of regional adaptive capacities. Clearly, both biophysical and human factors are at play in the strengthening of adaptive capacity of socio-ecological systems (Luers et al., 2003; Ivey et al., 2004; Adger, 2006; Eakin and Luers, 2006; Janssen and Ostrom, 2006; Fussel, 2007; Brown et al., 2010; Engle and Lemos, 2010; Engle, 2011). Socio-ecosystems dynamics are based on reciprocal feedbacks (Berkes et al., 2003; Waltner-Toews and Kay, 2005), therefore such systems are constantly adapting to changing conditions (Holling, 1978; Walker et al., 2004). However, when disturbance of one or several components of a system occurs abruptly and at the same time, often the experience is lacking to understand clearly the system dynamics and predict its evolution (Gunderson and Holling, 2002). That is why it is important to account for all socio-ecological interactions across spatial and temporal scales to better understand adaptive reactions of systems facing change (Arthur, 1999; Janssen and Jager, 2001; Folke et al., 2005). For those reasons, a comprehensive *socio-ecological approach* (Berkes and Folke, 1998) is particularly relevant as an analytical framework of current risks and practices, as well as to guide future adaptation planning. The socio-ecological approach is increasingly used to describe the evolution of community responses to change (e.g. Tschakert, 2007; Brondizio and Moran, 2008; Deressa et al., 2009; Meza and Silva, 2009; Djoudi et al., 2011). Even if, as Eakin and Patt (2011) note, studies on risk assessment are still dominant in industrialized countries, they can lack insights concerning the broader social and economical constraints of adaptation and thus may not facilitate a holistic understanding of adaptation processes (Bardsley and Rogers, 2011).

In viticulture, the socio-ecological approach has not been widely applied, although it is a growing analytical tool (Belliveau et al., 2006; Hadarits et al., 2010; Holland and Smit, 2010). A majority of studies on viticulture and climate change aim to warn the wine industry and facilitate its adaptation. To achieve these goals, different research approaches have been applied. First, a section of literature focuses on the future suitability of a region for viticulture by using bioclimatic indices and climate models (e.g. Kenny and Harrison, 1992; Jones et al., 2005; Beltrando and Briche, 2010; Bonnefoy et al., 2010). Secondly, a section examines the impacts of predicted future climate on *V. vinifera*'s physiology and yields. Results from this research suggest that impacts are likely to be generally negative in Mediterranean climatic regions in terms of harvest yields (Jones and Davis, 2000; Garcia de Cortazar, 2006 in France; Sadras and Soar, 2009; Cozzolino et al., 2010; Sadras and Petrie, 2011 in Australia) and wine quality (Chalmers et al., 2007; Webb et al., 2008; White et al., 2009). Thirdly, a phenological approach describes and models dates of growth stages in relationship with climate (Bellia et al., 2007; Duchêne et al., 2010 in France; Hayhoe et al., 2004; Sadras et al., 2007; Petrie and Sadras, 2008; Webb et al., 2008, 2011; Parker et al., 2011 in Australia). This approach is sometimes complemented with associated modelled economic impacts for the wine industry (Webb et al., 2007; White et al., 2006; Gatto et al., 2009). However, despite recognition of an important "human factor" in viticultural systems worldwide (e.g. Shaw, 1999; Bisson et al., 2002; Pincus, 2003; Vaudour and Shaw, 2005; Lobell et al., 2006; Moran, 2006; Cahill et al., 2007; Ladanyi and Erdelyi, 2007; Jones and Goodrich, 2008; Quiroga and Iglesias, 2009; Kenny, 2010), most studies lack explicit treatment of the role of human agency, and there are still gaps between research focussing on biophysical, agronomic, economic and human factors. Comparative studies are widely applied in viticultural research, either comparing different wine regions in the same country (Webb et al., 2007, 2008, 2011; Petrie and Sadras, 2008; Hall and Jones, 2010 in Australia; Alonso and O'Neill, 2011) or worldwide (Jones et al., 2005, 2009), with the main aim of critically analyzing the wine industry. Comparative regional analyses of the socio-ecological elements of wine production systems are particularly useful to determine how a change in one systemic component is affected by concomitant changes in other elements. In fact, it could be argued that the comparison of the adaptive capacities of different systems is now crucial to facilitate learning that can be generalized and operationalized to guide effective responses to change (Ostrom et al., 2007).

By applying a socio-ecological research approach to a commercial agriculture in two industrialized countries, we aim to: (i) frame the complexity of biophysical and socio-economic factors that interact in building adaptive capacity, (ii) bridge different perspectives on adaptation to climate change in order to facilitate a comprehensive understanding and operationalization of adaptation opportunities, and (iii) test whether such a holistic research approach is well-suited to frame studies on the adaptive capacity of the wine industry. This kind of holistic, international approach has to date received little attention from researchers (Battaglini et al., 2009), but could be a powerful research approach to identify opportunities and limits to adaptive capacity of viticultural systems. A mixed-methods approach is applied that combines primary and secondary data to critically analyse the socio-ecological components of the two systems. Secondary data from climate stations and published material is used to assess exposure to global changes in climate and economy. Results are compared with primary data from in-depth interviews in both regions, in order to analyse the sensitivity of local systems, and to begin to identify and classify adaptation strategies to current and future change.

2. Methods and data

2.1. Field sites choice and description

French and Australian regions were selected, based on the presence of Mediterranean climatic viticulture in both places and their contrasting traditions and regulations. In each country, one Mediterranean wine production area was chosen: Côte-du-Roussillon-Villages in southern France and McLaren Vale in South Australia (Fig. 1). Besides similar climatic characteristics, they were chosen for: their plantings of similar *V. vinifera* varieties; the paucity of previous studies compared to other viticultural areas; and, their delimitation by administrative and Geographical Indication (GI) boundaries that facilitated statistical analysis (Fig. 1).

In France, viticultural activities in the area of Côtes-du-Roussillon-Villages (lat: 42°N, long: 1°E) were analysed. Grape production is situated in two hilly corridors a few kilometres (km) north-east of the city of Perpignan, bordered to the south by the Têt