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Global change effects on land management in the Mediterranean region

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ABSTRACT

The Mediterranean region faces significant challenges to supply its growing population with food and living space. The region's potential to do so in the future is even more uncertain in the light of global change effects. Climate change will impact water availability in the region, which is already limited and often used at unsustainable rates. To investigate the effects of global change and explore alternative development pathways of Mediterranean land use, we simulated two future scenarios with different land, water and biodiversity management transitions. We adopted a land systems approach, where land use and land cover are combined with data on land management, irrigation and livestock density, taking into account the characteristics of Mediterranean multifunctional landscapes, specific agricultural products, such as permanent crops, and irrigation water demands. Future land system changes were explored using the CLUMondo model for different development pathways of the region. We constrained the withdrawal of irrigation water based on existing freshwater resources. In a 'growth' scenario, we simulated a hypothetical future without consideration of environmental constraints and where food production and urban expansion are main priorities. The 'sustainability' scenario represents a future where limited water resources are extracted in a sustainable way and where areas of high biodiversity value are protected. The growth scenario projected significant intensification of land management, and loss of agro-silvo-pastoral mosaic systems. To achieve this, we calculate that the region would need to increase water withdrawal for irrigation significantly, resulting in increased pressure on freshwater resources. The sustainability scenario presents a way of increasing food production and at the same time improving the state of water resources, wetlands and traditional landscapes. Achieving this future would require improvements of yields of rain-fed systems and efficiencies of irrigated systems. The results indicate that coordinated environmental policy together with appropriate market access are needed to steer the regions land management towards a more sustainable future while ensuring food production.

1. Introduction

Most of the Earth's land surface has been changed as a result of human use, with large environmental consequences and both positive and negative impacts on human well-being (Ellis et al., 2010; Schmitz et al., 2012). With limited resources of land and water, a large societal challenge consist of meeting the increasing demand for food and living space for growing populations in the context of climate change. These challenges are especially significant for the Mediterranean, a dynamic and densely populated region with severe constraints on land and water resources (Giorgi and Lionello, 2008; Giannakopoulos et al., 2009; García-Ruiz et al., 2011; Fader et al., 2016). The Mediterranean has a long history of land use, resulting in valuable cultural landscapes created throughout centuries (Blondel et al., 2010; Tieskens et al., 2017), and is one of the most rich areas in terms of biodiversity (Cuttelod et al., 2009). On the other side, human activities in the region have resulted in significant degradation of soil and water resources (García-Ruiz et al., 2011; Karamesouti et al., 2015).

Resulting from its cultural and environmental characteristics and its long land use history, the Mediterranean Basin hosts a diversity of land systems of varying intensities and levels of (multi)functionality. Intensive systems have higher yields and produce most of the crops in the region, a large part of them being exported. These systems however also have high water demands (Daccache et al., 2014) and can negatively affect the quality of soil contributing to land degradation (Karamesouti et al., 2015). Traditional mosaic systems represent

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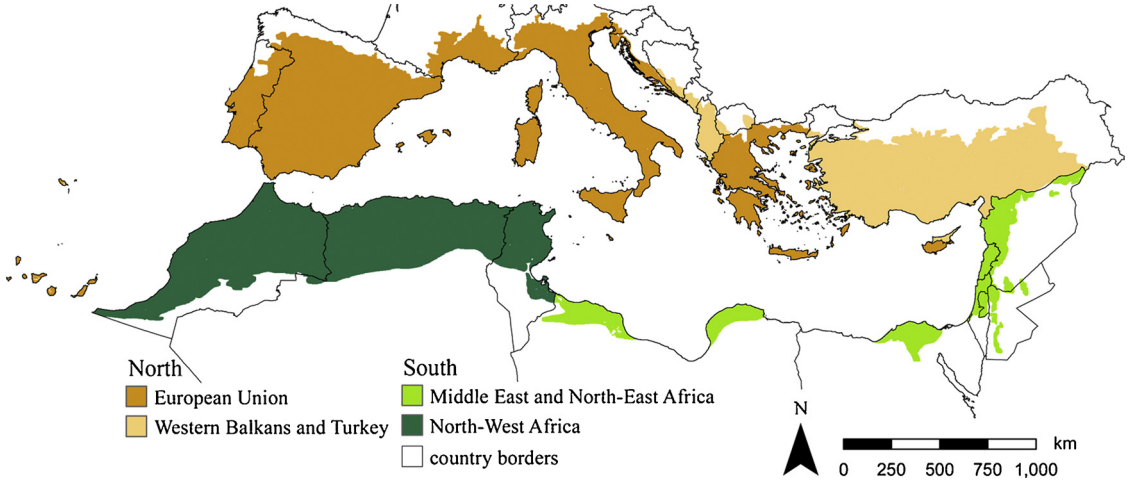

Fig. 1. The studied Mediterranean ecoregion with its 4 sub-regions.

landscapes, where human activities and environmental conditions are intricately linked. An example is the *dehesa / montado* system of Spain and Portugal, where different activities such as livestock grazing, cereal production, and forestry occur simultaneously (Joffre et al., 1999). Although these areas have lower yields, they contribute significantly to total regional food production (Blondel, 2006; McAdam et al., 2008). Many of the traditional mosaic systems are associated with high biodiversity values (Médail and Quézel, 1999). These landscapes are particularly vulnerable to global change, threatening their supply of not only food, but a number of ecosystem services (Zamora et al., 2007; Guiot and Cramer, 2016).

The Middle Eastern and North African part of the Mediterranean region is characterized with high population pressures and increasing dependence on food imports (Wright and Cafiero, 2011). Depending heavily on food imports makes the region more vulnerable to fluctuations in food supply and prices (Sowers et al., 2010). The region hosts a considerable portion of cropland with relatively low yields, meaning that future cropland expansion and intensification will play a crucial role in satisfying the demand for food (Mueller et al., 2012). This can however exacerbate soil and water degradation, and appropriate land management will be needed to reduce these consequences, or restore soil and water resources (Cerdan et al., 2010; García-Ruiz et al., 2011). Moreover, water and land grabbing are also significant issues in the region, leading to conflicts (GRAIN, 2012; Houdret, 2012). The European Mediterranean area hosts high-input intensive agricultural systems significant for regional food production and global commodity markets. However, recent socio-economic development, such as the Greek financial crisis, have influenced the steadiness of supply of agricultural products (Pfeiffer and Koutantou, 2015). Other global change effects are the abandonment of traditional livestock grazing systems due to low economic competitiveness and reduction of livestock productivity (de Rancourt et al., 2006; Bernués et al., 2011). In summary, future global change, particularly changes to climate and population, could significantly impact the potential food supply of the Mediterranean region (Evans, 2008; Sowers et al., 2010).

Published global land change scenarios suggest significant intensification of crop production and grazing, together with urban expansion in the Mediterranean region (Hurtt et al., 2011; Letourneau et al., 2012; Souty et al., 2012; van Asselen and Verburg, 2013). These global studies often do not consider specific regional characteristics that could affect these processes, such as the existence of a large share of permanent crops and traditional mosaic systems, and severe water limitations. Water limitation also affects intensification and cropland expansion, feedback loops which are currently not possible to study with land use models in which water availability is represented by a proxy, such as precipitation (NRC, 2014). Simplified proxies can only influence the spatial distribution of intensive systems and do not limit cropland expansion or intensification based on available water resources. Land use modeling studies that do take into account water scarcity are often unable to generate land use patterns with the spatial detail of most biophysical models (see for example Lotze-Campen et al., 2010).

In this study, we determine the impact of two potential future scenarios on land management in the Mediterranean region to study environmental consequences of increasing food production in the Mediterranean for the year 2050. We advance from the existing knowledge by combining global outlooks of socio-economic and climate change in a land system change model with regional spatial characteristics and configuration of land use. We are particularly interested in how global change might affect traditional Mediterranean landscapes and water resources. We also demonstrate how water resources limitations can be represented in land system models.

2. Future challenges for land management in the Mediterranean region

2.1. The Mediterranean region

We focused on the Mediterranean ecoregion defined by the approximate extent of representative Mediterranean natural communities from a biogeographical study (Olson et al., 2001). We expanded the ecoregion by also including the Nile Delta, the Po floodplain and numerous “islands” of similar ecoregions within the Mediterranean ecoregion (Fig. 1). Thematically, we divided the region into two parts, North and South, which, based on land use characteristics and biodiversity trends (Galewski et al., 2011), were subdivided into two subregions each (Fig. 1). In addition, this subdivision accounted for more uniform markets that need to fulfill their own demands for food and living space and took into account socio-economic disparities between the Northwest and South. In total, the study area covers 2.3 million km^2 in 27 countries with around 420 million inhabitants in 2015 (CAPMAS, 2015; EUROSTAT, 2016c; IIASA, 2016).

We identified four major challenging trends for the region based on various documents on the future of the Mediterranean (Appendix A): 1) increasing population and continuous urban sprawl; 2) agriculture and food production; 3) threatened biodiversity, and 4) significant climate change impacts and increasing water scarcity.

2.2. Population and urban expansion

The total population in the southern (Fig. 1) Mediterranean countries is expected to increase by 43% until 2050, and by 16% in the