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Impact and mitigation of global change on freshwater-related ecosystem services in Southern Europe

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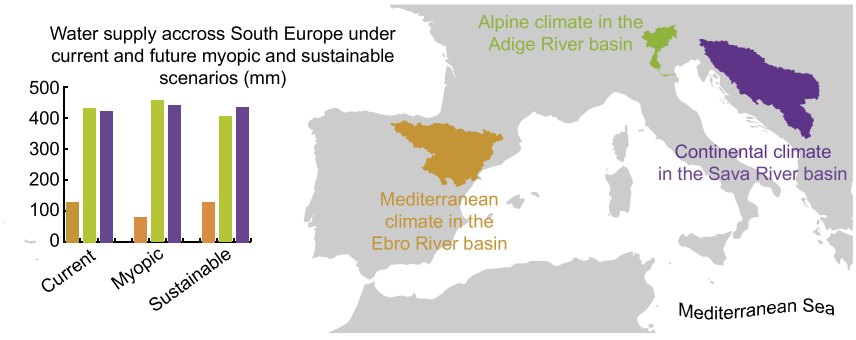
HIGHLIGHTS

- Mediterranean basins in Europe suffer great changes comparing to continental ones.
- Water supply varies from −37% to +6% depending on precipitation in studied basins.
- Sediment retention depends on precipitation, but export on agricultural practices.
- Total nitrogen production and retention, with homogeneous distribution, barely change.
- Total phosphorus production and retention increase up to +12% for the expansion of urban areas.

GRAPHICAL ABSTRACT



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ABSTRACT

Global change is severely impacting the biosphere that, through ecosystem services, sustains human well-being. Such impacts are expected to increase unless mitigation management actions are implemented. Despite the call from the scientific and political arenas for their implementation, few studies assess the effectiveness of actions on freshwater-related services. Here, by modeling water provisioning, water purification and erosion control under current and future conditions, we assess future trends of service provision with and without mitigation policies. In particular, two different storylines combine multiple climate, land use/land cover and agricultural management scenarios, and represent a pro-efficiency business as usual (myopic storyline) and a future that considers social and environmental sustainability (sustainable storyline). The mentioned services are modeled for the horizon 2050 and in three South European river basins: Ebro, Adige and Sava, which encompass the wide socio-environmental diversity of the region.

Our results indicate that Mediterranean basins (Ebro) are extremely vulnerable to global change respect Alpine (Adige) or Continental (Sava) basins, as the Ebro might experience a decrease in water availability up to 40%, whereas the decrease is of only 2–4% in the Adige or negligible in the Sava. However, Mediterranean basins are also more sensitive to the implementation of mitigation actions, which would compensate the drop in water provisioning. Results also indicate that the regulating services of water purification and erosion control will gain more relevance in the future, as both services increased between 4 and 20% in both global change scenarios as a result of the expansion of agricultural and urban areas. Overall, the impact of global change is diverse among services and across river basins in Southern Europe, with the Mediterranean basins as the most vulnerable and

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the Continental as the least. The implementation of mitigation actions can compensate the impact and therefore deserves full political attention.

1. Introduction

From the most pristine rainforests to the intensive agricultural landscapes, all ecosystems provide services that generate socioeconomic benefits to human societies (Daily et al., 2009; MA, 2005). Many of these ecosystem services (ES) are linked to the interaction between vegetation cover and freshwater, such as water provisioning and purification or erosion control, among others. Water provisioning benefits societies through domestic, industrial and irrigation water, hydropower and other in-stream uses like fishing or kayaking (Jorda-Capdevila and Rodríguez-Labajos, 2015). Erosion control is the retention of potential soil loss and sediment moving downhill for preserving soils and avoiding reservoir siltation (Pimentel et al., 1995). Finally, water purification is the retention of total nitrogen (TN) and total phosphorus (TP) contained in freshwater, which avoids eutrophication and improves drinking water and fisheries (Smith and Schindler, 2009). Regrettably, all these services are under threat by global change (Bangash et al., 2013).

Global change arises from the acceleration of resources extraction and waste disposal, linked to the rapid population and economic growth. It is a multi-facetted environmental problem that includes changes in climate, land use/land cover (LU/LC) and environmental management practices (García-Ruiz et al., 2011; Giorgi and Lionello, 2008). These changes impair ES provision hence putting human well-being at risk (Kubiszewski et al., 2017; Runting et al., 2017). At a South-European level, the decrease of the precipitation in summer and the increase of the frequency and duration of droughts are projected to increase water scarcity (Gampe et al., 2016; Jacob et al., 2014; Lehner et al., 2006; Schröter et al., 2005). Another example of impairment in the Southern Europe is that Greece, Italy, Portugal and Spain sum 51% of the total soil lost in the EU (Panagos et al., 2015), mainly caused in croplands in steep areas and sometimes in abandoned farmland in arid areas (García-Ruiz, 2010); while future trends of erosion are irregular (Guerra et al., 2016). Meanwhile, several studies reveal that the increase of levels of nitrogen and phosphorus loads to the environment have slowed down in the last decades (Grizzetti et al., 2012; La Notte et al., 2015; Lutz et al., 2016), mainly due to the implementation of wastewater treatment plants and improved fertilizer application strategies (Lutz et al., 2016). Moreover, there are assessments at a river basin level, which show negative or uncertain future prospects, that have been performed with the correspondent scale limitations, like the low representativeness of its biogeographical region (Bangash et al., 2013; Boithias et al., 2014; Lutz et al., 2016; Sánchez-Canales et al., 2015; Vrzel and Ogrinc, 2015).

Facing these challenges that emerge from global change, a recent publication estimated that governance focused on the environment and human well-being would increase the value of the biosphere by US$31 trillion/year in the 2011–2050 period, while an ongoing focus on economic growth together with nature protection would maintain the current ecosystems' value (Kubiszewski et al., 2017). In contrast, a free-market world would maximize GDP but lead to land degradation. In this sense, the European Union is currently moving beyond the approved environmental directives (*e.g.*, the Nitrates and Water Framework Directives) towards the EU Biodiversity Strategy that aims to have the Union's biodiversity and the ES it provides protected, valued and restored by 2050 (European Commission, 2011). In a mid-term prevision, The 7th Environmental Action Programme ensures that by 2020 "land is managed sustainably in the Union and soil is adequately protected", "water stress […] is prevented or significantly reduced" and the "nutrient cycle [nitrogen and phosphorus] is managed in a more sustainable and resource-efficient way" (European Commission, 2014).

In this study, we assess the impact of global change, together with the effectiveness of mitigation strategies, on the provision of freshwater-related services in Southern Europe, which has been identified among the most vulnerable regions of the world (Schröter et al., 2005). Specifically, the impact is assessed using two storylines developed in the GLOBAQUA Project. The first is a pro-efficiency business-as-usual scenario: *myopic* storyline; and the second a scenario of socio-environmental awareness with active mitigation policies: *sustainable* storyline. The influence of these storylines for water provisioning, erosion control and water purification is assessed in the Ebro, the Adige and the Sava River basins. These basins are representative of three distinct environmental contexts in Southern Europe, namely with Mediterranean, Alpine and Continental climatic characteristics. We used the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) model (Nelson et al., 2009) to assess impact and mitigation of global change by 2050 under the previously mentioned *myopic* and *sustainable* storylines. Our hypotheses indicate that in *myopic* conditions the ES provision will generally decrease in those areas with a marked Mediterranean nature and increase in those areas where a significant expansion of urban areas is foreseen, without mitigation of the impact to the environment. For the *sustainable* storyline, we expect that mitigation practices will be able to buffer the effects of global change.

2. Materials and methods

2.1. Study area

Three river basins are analyzed in Southern Europe. The Ebro basin (87,097 km^2) in the Iberian Peninsula has a typical Mediterranean climate, though it includes from the rainy Pyrenees to the semi-desert of the Ebro depression, where intensive irrigated agriculture abounds. Spain is the country that manages the bulk of the basin, while Andorra and France also have a small part. The Adige (12,370 km^2) is in the central Southern Alps and almost entirely in Italy. Embedded in a high Alpine environment, it concentrates intensive agriculture and dense urban areas in the valleys. The Sava (96,778 km^2) is the main tributary of the Danube and its basin embrace six countries: Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro and a bit of Albania. Agriculture in this basin is less intensive, but urban areas are larger. The climate there is Continental. Fig. 1 shows maps indicating the distribution of basic descriptors (altitude, annual precipitation, water bodies, land uses) under current conditions. Differences also take place in the threats of climate change, spanning severe impairment by droughts in the Ebro and increases of precipitation in the Sava (EEA, 2017; Gampe et al., 2016; Jacob et al., 2014; Vautard et al., 2014).

2.2. Development of scenarios

The development of scenarios take place in the context of the GLOBAQUA project (GLOBAQUA, 2017; Navarro-Ortega et al., 2015) and was based on two storylines developed from distinct combinations of Shared Socio-economic Pathways (SSP) and Representative Concentration Pathways (RCP) (O'Neill et al., 2014; van Vuuren et al., 2011). A storyline is a short story describing a potential future, a combination of socio-economic elements and trends. In this study, *myopic* and *sustainable* storylines are the basis for integrating climate, LU/LC, and environmental management scenarios. The data resulting from the scenario development is input for our ES models. Specifically the development of