A methodological approach for supporting socio-hydrological modelling of a complex Nexus system

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ABSTRACT

The Water-Ecosystems-Food Nexus is increasingly studied and adopted both in the research and in the policy fields, since there is evidence of the side effects of sectoral policies implemented without considering any cross-sectoral analysis (Sušnik et al., 2021). In a scenario of accelerated changes, both from a climatic and socio-economic point of view (demographic and economic expansion), natural resources such as water are constantly threatened by competing multiple sectors such as agriculture, tourism, industry and environment (Karamouz et al., 2021). The complexity of natural resources management becomes more critical in areas where natural reserves are jeopardized by human action, such as the Doñana National Park, a coastal area in SW Spain where the environmental and economic interests have varied over time with increasing contrasts among stakeholders. The LENSES project is operating in the Doñana area (as one of the case studies in the Mediterranean area), with the objective to propose a new approach based on Participatory System Dynamic Modelling (PSDM) to recognize the major challenges and the drivers for the system, ultimately suggesting potential actions/strategies, using a Nexus approach. Our work focuses on the assessment of the system under current and future conditions, integrating PSDM with other sectoral models (in particular, hydrological modeling and water resources allocation). This integrated model supports decision making processes in view of the implementation of Nexus approaches, to make the system resilient and more sustainable over time.

1. The case study

The Doñana region, which covers one of the most important wetlands in Europe, is an area between the Tinto River and Guadiamar River estuary and overlooks the Atlantic. It is historically considered a place of high naturalistic value as well as a notable biodiversity hub straddling two continents (Serrano, 2016). Nowadays it is under protection by important institutions such as the WWF, as it has undergone different anthropogenic pressures over time such as channel diversion, and the overexploitation of surface and underground water bodies due of the increased water demand for irrigation and tourism. The effects of this exploitation regime are tangible, and, without a clear and coherent action plan, the situation can only become worse.

2. Methodological approach and preliminary results

The value added of the modeling approach presented in this work is the direct involvement of stakeholders in SDM development and analysis. In this regard, a series of individual interviews and workshops have been organized throughout project duration to elicit stakeholder knowledge on the main challenges over the area,

ultimately feeding the Causal Loop Diagram (CLD). The CLD was used to get a holistic perspective on the system under investigation, helping to analyze in a structured way the conflicts between intensive water users (such as green-house farmers) and environmental organizations interested in the protection of marshland ecosystems. In particular, during the first workshop a participatory mapping exercise was performed, to represent the complexity of the main processes (including bio-physical, socio-economic and behavioral variables) characterizing the study area. Stakeholders helped identifying the main processes, the central variables and critical interdependencies, supporting the definition of a comprehensive system picture. The key challenges identified for the area were the exploitation of the groundwater resources reducing the environmental flow to the wetland, the need to undertake strategies for the restoration of the different natural ecosystems (marshland and temporary ponds) and for the protection of biodiversity over the whole area. The analysis of the CLD supported highlighting the central role of water security for the state of the area, and a water resource allocation software (WEAP) was therefore used to investigate water management options. The WEAP model included demand nodes, supply nodes and connections between them, and was focused on the description (in a quantitative form) of the environmental water demand within the water balance of the area. One of the most useful and innovative outputs obtained through the water allocation modeling is the *unmet water demand* of the Doñana marshland during dry and ordinary years based on the historical climate records. The preliminary results of these modelling activities have been presented in the second workshop with local stakeholders, with the aim of discussing into details the competitive water and land uses in the study area, focusing the discussion on potential solutions to guarantee a sustainable transition of the area (e.g., Nature-based Solutions, different water allocation criteria, etc.). This participatory process, encompassing challenges and objectives of various stakeholders, resulted in a consensual need for developing a robust quantitative tool for the evaluation of the marshland water balance, enabling to investigate the environmental water requirements of Doñana coastal plain under different management scenarios. In this direction, we envisage the integration of the water allocation model with the PSDM (specifically, building a stock and flow model), in order to perform a 'what-if' scenario analysis able to consider the role of multiple drivers (e.g., climate change) and the impact of the suggested strategies.

3. Overview of future activities

The creation of future scenarios and the co-evaluation of their feasibility and potential effectiveness using a stock and flow model is a future result that aims to close the whole process started with the participatory identification of problems and the modeling of the baseline scenario. The scenario analysis will be also coupled with the definition and calculation of relevant indicators aimed at transferring the results of the modeling activities to stakeholders, in order to facilitate the understanding of system functioning and to better inform decisions considering the role and needs of actors (de Vito et al., 2019). The results obtained can be used in a simple and effective way also in other areas, to allow policy- and decision-makers makers to make informed decisions based on the development of a holistic view of complex systems based on a Nexus approach.

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