

Analysing a WEFE Nexus System in Portugal: Complementing systems thinking with institutional analysis

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The integrated governance of natural resources has gained increasing attention in the last decades among scientists and policy-makers, most notably under the approach of the Water-Energy-Food-Ecosystem (WEFE) nexus. It reflects the biophysical interdependencies between people and their use of water, and energy, the production of food, and the protection of ecosystems. Challenges of the WEFE nexus relate to often irreconcilable trade-offs between the use and protection of these natural resources. Furthermore, they are characterized by complex cause-effect relationships that are separated in space and time. To understand the root causes of these challenges and also develop strategies and policy instruments to address them, a systemic understanding is indispensable, but arguably often lacking in current debates on the WEFE nexus. To develop such a systemic understanding, systems thinking is considered crucial. Systems thinking is a holistic approach to understanding and addressing complex problems by considering the interactions and interdependencies among various elements within a system, identifying the drivers of system behaviour, and uncovering mental models. Rather than viewing phenomena in isolation, systems thinking emphasizes the interconnectedness of components and their dynamic relationships over time, and the idea that structure drives behavior (Meadows 2009). However, we argue that the role of governance and institutions in shaping systems behaviour and performance at multiple levels has not sufficiently been considered in related studies.

To address this gap, we complement systems thinking with institutional analysis in this paper. More specifically, we use Participatory Systems Dynamics Modelling (Sedlacko et al. 2014) to develop a systems map of the WEFE nexus in a case study on the Alentejo region, Portugal. Based on this systems map and through a polycentric governance perspective, we apply the Network of Adjacent Action Situations (McGinnis 2011) (NAAS) to zoom into decision-making processes within the WEFE nexus system, and understand how institutions at multiple levels drive actors' behaviour in this system. The NAAS allows us to understand how outcomes of one Action Situations impact actors' decision-making processes in other Action Situations. The concept is particularly useful for understanding the interconnected nature of WEFE nexus issues where actors intendedly and unintendedly influence each other in their usages of water, land, and energy resources, the production of food, and their impact on nature. Empirically, we aim to identify the institutional and governance-related drivers of the system under analysis, and the determinants of the system's performance from an institutional, and polycentric governance perspective. Furthermore, we are interested in leverage points and how to intervene in the system to solve the WEFE nexus problems.

The case study of the Alentejo region is located in southern Portugal, having a Mediterranean climate. Traditionally, the region has been characterized by extensive, multi-functional agricultural systems, such as the Montado. However, since two decades, the region is undergoing processes of agricultural intensification, and expansion of irrigated agriculture. The region is thus now shaped by intensive irrigated agriculture, which is mostly olive and almond cultivation, which has contributed to interrelated challenges such as biodiversity and ecosystem loss, soil erosion, and water salinization. Main drivers of this process include the construction of the Alqueva dam and the respective provision of water at an affordable price with relatively low water fees (Morgado et al. 2022; Silveira et al. 2018), and the payments of the Common Agricultural Policy (CAP) (Pinto-Correia and Azeda 2017). However,

we observe empirical research gaps on the underlying governance processes at different levels, the role of actors and their interests, and how different drivers, including institutions, interdependent and mutually influence each other. Furthermore, studies that adopt a WEFE nexus perspective seem to be missing in the Alentejo region. We aim to contribute to closing these empirical research gaps. From a conceptual and methodological point of view, we aim to advance the understanding of systems in polycentric governance literature, by addressing questions on the definition of system boundaries and understanding systems behavior; as well as the understanding of institutions in literature on systems thinking.