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Integrating SWAT and Participatory System Dynamics Modelling for analyzing the WEF Nexus: the Tarquinia plain case study

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A safe access to water, energy, and food that does not impact the state of ecosystems and natural resources are needed for human well-being as well as for economic and environmental sustainability. As natural resources availability is threatened by a multiplicity of stressors (including e.g. climate change), the interconnections and interdependencies among resources become stronger and more critical to investigate. Sustainable resources use thus requires a holistic 'Nexus' approach, which can contribute to reduce conflicts among sectors and create more synergies compared to a *silo* approach to water, energy, food, and ecosystems realms.

The importance of active stakeholder engagement in the management of natural resources is also increasingly acknowledged, although there is a lack of participation in policy planning phases and in the decision-making processes. When models are developed to support resources planning and management, the involvement of stakeholders from early stages is crucial to include their knowledge in model building, to tailor the model according to their needs, and to ensure that the potential implications of actions are correctly represented. This ultimately guarantees ownership of modelling results.

System Dynamics Modelling (SDM) includes a multiplicity of tools and methods to describe, model, simulate, and analyse dynamically complex systems taking jointly into account both scientific information (e.g. from sectoral models) and stakeholders' knowledge and perception. SDM has gained attention, in the recent scientific literature, in Nexus studies. Specifically, the use of qualitative SDM tools (such as Causal Loop Diagrams – CLDs) allows the analysis of the system behaviour based on a conceptual (mental) model focusing on linkages and feedback loops. Quantitative simulation models (stock-and-flow diagrams) use equations to quantify linkages between different types of variables over time. Stock and flow diagrams benefit from the information deriving from sectoral models, such as hydrological models, although the integration with such models has been limitedly explored to date.

The present work proposes an approach based on the use of SDM tools for the development of an integrated model supporting the analysis of a complex Nexus system. Particular attention is given to the analysis of the interdependencies between water quantity, quality, and management, and to the implications of irrigation and agricultural practices for the state of the environment. The main elements of innovation are: i) the coupling between SDM, built in a participatory form with the key stakeholders in the study area, and the Soil and Water Assessment Tool (SWAT); ii) the combination scientific and stakeholder knowledge to appraise the socio-economic and ecological effects of the various management situations co-designed with the stakeholders. Reference is made to one of the pilot areas of the LENSES project (PRIMA Foundation, GA n. 2041), namely the Tarquinia plain watershed, located in Central Italy, an area with a relevant environmental value, but characterized by intensive irrigated agriculture with severe impacts on water and ecosystems.