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Water-food-energy-ecosystems nexus in irrigation systems adaptation to climate change: a case study of the Adda basin (Italy)

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Water resources planning at the basin scale is the keystone to adaptation of water resources systems to socio-economic and climate changes. Simulation and optimization models can provide a useful support to the planning process. Besides including all significant processes, they need to incorporate the contribution of the relevant stakeholders from the early stages of their development, particularly in areas where multiple concurring uses of water resources occur and where surface water-groundwater interactions are important. This is the case of the plain of the Lombardy Region, Italy, where an ancient system of irrigation canals has been successfully used for centuries to supply huge amounts of water to a large irrigated area, which is also one of the most industrialized in Europe (Lombardy is one of the "Four Motors for Europe", a transnational network of highly industrialized regions including Rhône-Alpes, Baden-Württemberg and Catalonia). Indeed, the Lombardy water resources have suffered recurrent crisis in the last years and a huge pressure has been raising on irrigation water use, which is by far the main consumptive use. We illustrate here an integrated approach to the analysis of different strategies of adaptation of irrigation systems to changing conditions, which accounts for the links between water use, crop production, energy consumption and hydrological conditions (as a proxy of the ecosystems quality). We will consider the case study of the Adda river basin, an 8,000 km^2 basin including lake Como, where the requirements of hydropower production and irrigation supply need to strike a balance with lake tourism, flood protection and environment conservation.

The approach is based on a combination of simulation models (of upstream sub-basin, lake and downstream sub-basin) and optimization model (of lake regulation policy) that allow assessing the effects of different climate and technological scenarios. The former scenarios were obtained downscaling the regional climate projections provided by the CORDEX project till 2100, while for the latter we focused on measures to increase the efficiency of irrigation systems, that emerged as priority from the discussions with the stakeholders. Specifically, we considered different degrees of reconversion of irrigation methods from surface irrigation to more efficient methods (sprinkler or drip). The effects of the reconversion, under different climate projections, were assessed by running simulations with the IdrAgra spatially distributed agro-hydrological model, which provided the estimated values of crop water use, groundwater recharge, return flows, as well as of crop

production and energy consumption. The comparison of different reconversion intensities was carried out considering indicators for the satisfaction of crop water requirements, the energy consumption, the groundwater recharge, and the river hydrological regime. A number of remarks can be made from the analysis of the results, among which it clearly emerged that under the current trend of increasing temperature already at the mid of the century irrigation deficits and impacts on the river hydrological regime will be intolerable unless the irrigation system efficiency will increase significantly in vast portions of the study area. Finally, a preliminary estimate of the cost of interventions is provided.