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Managing the water-energy-food-ecosystems nexus under future climate water stress scenarios in the Ebro Basin (Spain)

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Increasing climate water stress and excessive and unbalanced water withdrawals by sectors are triggering substantial water depletion and environmental degradation in arid and semi-arid basins. Addressing the problem requires the integration of sectoral policies based on interdisciplinary knowledge and sustainable management strategies. The Water-Energy-Food-Ecosystems (WEFE) nexus is an innovative and comprehensive tool to guide river basin managers and stakeholders towards sustainable development goals. Several nexus approaches have been advanced for different sectors, basins, and time periods. However, none to date has presented a monthly dynamic optimization framework that includes ecosystems in order to assess the WEFE nexus for entire large basins. The contribution of this paper is to address water related challenges and highlight the gap in users engagement, by presenting the results of the cross-sectoral integration under future climate water stress (CC-2070; CC-2100), and by designing policy interventions to achieve sustainable outcomes. The WEFE nexus is analyzed for the Ebro River basin; first the analysis identifies the trade-offs and synergies among sectors and spatial locations, and then policy interventions under future climate water stress are evaluated for enhancing water, food and energy security, and for ecosystems protection. Findings provide efficient water allocation plans between competing sectors, emphasizing the importance of ecosystem services in maintaining biodiversity under future climate water stress scenarios. The policy analysis offers insights into the synergies between environmental and economic outcomes, although the costs of certain policies could be high for some groups of stakeholders. Results show that irrigation modernization, increasing reservoir storage capacity, and water trading policies provide efficient water use patterns, enlarging basin stream flows, protecting ecosystems and augmenting the private and social benefits. Sustainable agriculture and water storage management are crucial policies that promote food, water, and energy security and ecosystems protection. These critical results from interventions could help decision makers to bring about efficient water allocation

planning among sectors, and advance resilience and adaptation to climate water stress.