Hydro-economic equilibrium and territorial scope of water policy in the local systems of Tuscany, Italy.

Topic: Sustainable Production and Consumption Policies
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The Tuscany region (Italy) does not present major issues in terms of water stress when analyzed at a regional scale (Venturi, 2014; Rocchi and Sturla, 2021). Sturla and Rocchi (2022a) demonstrated that when the regional economy is faced with 100 hydrological years, water exploitation indicators never exceed scarcity thresholds.

However, this regional perspective conceals significant spatial heterogeneities. Greater availability of surface and groundwater is found in the northern and northeastern areas. Water demand primarily concentrates in the central part of the region (74% of GDP).

To address this spatial variability, Sturla and Rocchi (2022b) studied the hydro-economic equilibrium (HEE) at the local systems (LLS) level using an interregional input-output hydroeconomic model. The study considers 49 LLS and estimates the extended water exploitation indicator (EWEI) for 100 years, comparing it with scarcity thresholds (STg).

SLLs are defined as aggregates of municipalities based on economic, not hydrological criteria. For LLS that could face water scarcity issues, sustainable resource management policies are required, which could be formulated at the local, watershed, river basin, or regional level.

In this context, an interesting research question arises: What are the characteristics of hydroeconomic equilibrium when considering hydrological spatial scales, and how does this determine the territorial scope of water policies in each LLS?

Therefore, this study aims to conduct an integrated economic-ecological analysis at the basin and sub-basin level to evaluate whether HEE is achieved in the analyzed spatial units. The objective is to determine the most suitable territorial scope for designing sustainable water management policies.

The analysis considers 4 basins and 10 sub-basins, assigning the 49 SLLs of the region to them, taking into account their area and existing hydraulic interconnections (AIT, 2023; ADAS, 2021).

To evaluate HEE, two interregional input-output matrices (56 economic sectors) are constructed based on the aggregation of the matrix at the SLL scale (IRPET, 2021). Sectoral coefficients for water use and restitution and those associated with water dilution requirements are calculated.

Hydrological component matrices are developed for basins and sub-basins, considering precipitation, evapotranspiration, surface runoff, and groundwater recharge. These matrices contain simulations for 100 hydrological years based on a spatial stochastic hydrological model (Dâ€™Oria et al., 2019; Pranzine et al., 2020).

Following the methodology proposed by Sturla and Rocchi (2023), an interregional hydroeconomic model is constructed to estimate EWEI and STg for each unit of analysis and hydrological year.

This study defines sustainability criteria as the situation where the exploitation indicator does not exceed the threshold by more than 15 years (out of 100 years). That is, a spatial unit is in HEE if this

condition is met.

The territorial scope of water policies is determined based on the spatial unit where water availability management required by an LLS for sustainable resource use must be addressed. Thus, four types of territorial scope are defined:

â€¢ Local Scope: if the SLL is in HEE
â€¢ Sub-basin Scope: If the SLL is not in HEE, but the sub-basin is
â€¢ Basin Scope: If neither the SLL nor the sub-basin is in HEE, but the basin is
â€¢ Regional Scope: If neither the SLL, sub-basin, nor basin is in HEE

Results indicate that 2 out of 10 sub-basins do not meet HEE, while all basins do. When considering the climate change availability scenario, sub-basins increase to 3, and basins without HEE are 2 out of a total of 4.

Results indicate that 33 LLS require Local Scope management, 10 require Sub-basin Scope, and 6 require Basin Scope. When considering climate change, 30 LLS require Local Scope, 8 require Sub-basin Scope, 4 require Basin Scope, and 7 LLS require Regional Scope.

The results show significant sub-regional heterogeneity not only concerning the balance between water demand and supply at different spatial scales but also regarding the required territorial scope for policies. This heterogeneity increases when considering climate change.

This study represents an advancement in the application of regional science methodologies for studying sustainability in local systems. Key highlights include:

â€¢ Pioneering use of sub-regional input-output matrices to study HEE at both hydrological and economic spatial scales, considering water requirements by economic sectors.
â€¢ Integration of the spatial dimension of water policies in a novel manner. The developed model allows flexible disaggregation and aggregation of the economic and hydrological systems.
â€¢ The proposed model enables simulation of water availability scenarios for climate change and evaluation of the effect of increased final demand on hydroeconomic equilibrium and policy scope.