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Abstract

Land use changes, and especially urbanization, significantly impact water and energy systems, and the associated greenhouse gases (GHG) emissions. However, studying the urbanization and population dynamics and quantifying their effects on coupled water-energy-emissions systems remains underexplored in certain countries. Greece, for instance, has been slow to integrate those systems into data-driven models assessing their feedbacks. To fill this gap, this research investigates these dynamics in Greece, for the period 2022-2050, by combining different modelling approaches, for the first time to our knowledge. A Remote Sensing analysis, utilizing freely available satellite data and open-source tools such as QGIS, was applied to map and monitor land use changes, including urbanization. Greece has been proved to be a particularly interesting case study as simultaneous population decline and increasing urbanization are reshaping key sectors of the developing urban centers, such as the residential and services sectors. To capture the complex feedbacks between the developing urban centers with the changing population, to their water-energy-emissions responses, we coupled the LEAP (Low Energy Analysis Platform) model with the WaterReqGCH model. Thus, the energy consumption and the associated GHG emissions were simulated along with the water consumption of the residential and the services sectors. The results reveal critical trends: population decline drives a reduction of the overall water and energy consumption, yet, despite the reducing trends, urban areas claim increasing shares of these resources over time. Similarly, GHG emissions decrease but exhibit shifts in pollutant distribution, with certain emissions holding larger shares in urban contexts. This integrated land-water-energy-emissions analysis underscores the value of holistic assessments to manage these systems sustainably, and highlights the need to develop plans considering them as a whole. The provision of detailed information on the evolution patterns and feedbacks of those systems is critical to shape integrated policies aiming at multiple benefits. By linking urbanization patterns with resource dynamics and environmental impacts, we discuss how our findings can be translated into actionable insights for sustainable urban planning and resource management strategies.

Keywords: Land cover change; Urbanization; Remote Sensing; Satellite Imagery; Water-Energy Nexus; Water consumption; Energy-Emissions modelling.

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