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Data-driven modelling of potential trajectories of the global water-energy-food nexus system

Sara Masia and **Janez Susnik**
IHE Delft (s.masia@un-ihe.org)

There is increasing interest in the global water-energy-food (WEF) system and potential future system trajectories under global change, especially considering growing concerns over resource exploitation and sustainability. Previous studies investigating different aspects of this system have a number of shortcomings including not analysing all nexus sectors and/or not accounting for possible feedback between sectors, meaning it is difficult to identify system-wide tradeoffs, and makes comparison difficult. A global analysis of the WEF system linked to changes in potential gross domestic product (GDP) growth is presented, integrating the four sectors (water-energy-food-GDP) into a coherent analysis and modelling framework. GDP was included as previous related work demonstrates a link between GDP and each WEF sector. A system dynamics modelling approach quantifies previously qualitative descriptions of the global WEF-GDP system, while a Monte-Carlo sampling approach is adopted to characterise variability in resource use and growth at the global level. Correlative and causal analysis show links of varying strength between sectors. For example, the GDP-electricity consumption sectors are strongly correlated while food production and electricity consumption are weakly correlated. Causal analysis reveals that 'correlation does not imply causation'. There are noticeable asymmetries in causality between certain sectors. Historical WEF-GDP values are well recreated with the exception of electricity production/consumption. Future scenarios were assessed using seven GDP growth estimates to 2100. Water withdrawals in 2100 and food production in 2050 are close to other literature estimations arrived at using very different means. Results suggest that humanity risks exceeding the 'safe operating space' for water withdrawal. Reducing water withdrawal while maintaining or increasing food production is critical, and should be decoupled from economic growth. Electricity production/consumption is also expected to grow, with the strength of growth linked to GDP pathways. Climate impacts of the production and consumption will depend greatly on the fuel source for the generation of power. This work provides a quantitative modelling framework to previously qualitative descriptions of the WEF-GDP system, offering a platform on which to build.