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A New Way of Understanding Rebound Phenomenon in Agriculture Water Demand Using A Global Sensitivity Analysis Approach

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Effective use of water resources has been identified as a means to improve resilience to drought, particularly in the agricultural sector. In recent decades, the idea of shifting to more efficient irrigation systems (e.g., sprinkler irrigation systems) has received increasing attention to reduce the amount of water loss by traditional irrigation systems (e.g., flood irrigation systems), requiring considerable capital investments. However, there are indications that such investments do not lead to a reduction in water use in the long-run, which may even increase paradoxically; a phenomenon known as the rebound phenomenon or Jevon's paradox. One of the fundamental information gaps concerns an explicit evaluation of coevolutionary dynamics and the interactions among socio-economic factors in the rebound phenomenon in agriculture, which calls for the application of systems-based methodologies such as global sensitivity (GSA) analysis methods to look at time-dynamical aspects of the coevolutionary dynamics between various factors influencing rebound phenomenon. In this study, we use a previously calibrated and validated Agent-Based Agricultural Water Demand (ABAD) model applied to the Bow River Basin in Alberta, Canada - home to extensive irrigated farmlands with a history of drought experience. We perform a time dependent variance-based GSA on the ABAD model to examine the direct impact of factors as well as their joint influence due to interactions on rebound phenomenon. The overall findings show that the economic factors are the most important elements, which has an upward trend in the simulation time, in the rebound phenomenon. This finding is supported by the local observation as the net income of irrigated land has an upward trend in this time period. In addition, although the individual effect of the factor representing the social interaction among farmers is less important compared to the irrigation expansion factor, its total-order effect (i.e., the total contribution of a single factor including interactions with all other factors) becomes more important indicating the significant interactions among model factors. This analysis provides a deeper understanding of the coevolutionary dynamics of the rebound phenomenon and paves the way for better management of water resources.