Unravelling the Unintended Consequences of Water Interventions
Challenges of Understanding Adoption within Human-Water Systems and a Way Forward

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68. Unravelling the Unintended Consequences of Water Interventions: Challenges of Understanding Adoption within Human–Water Systems and a Way Forward

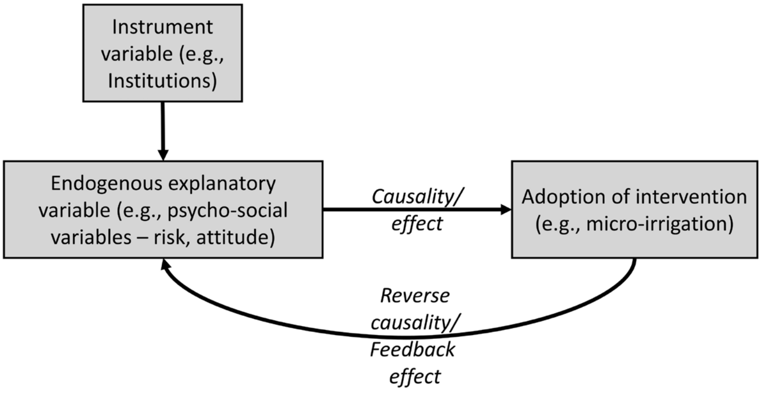
Introduction

Changes in the water cycle (availability/variability of water) influence and shape human society (e.g. floods and droughts have shaped human civilization), whereas decisions humans take (e.g. building dams, irrigation) influence the water cycle. The study of these coupled and co-evolving human–water systems is central to sociohydrology (Sivapalan et al., 2012). For example, irrigation efficiency measures can lead to increased water use, rather than the expected reduction (Perry and Steduto, 2017), or the unplanned proliferation of rainwater harvesting structures such as check dams in river streams can reduce downstream flows leading to upstream–downstream conflicts or even increased demand (Alam et al., 2022; Calder et al., 2008). While the motivation of such interventions has been to make regional agriculture climate resilient, they can have unintended negative impacts such as shifts toward more water-intensive crops, increased vulnerability to droughts and groundwater exploitation (Alam et al., 2022). While farmers of all income groups behave similarly, poorer farmers who cannot adapt to these negative consequences (e.g. by drilling deeper groundwater wells) bear most of the negative impacts (Bouma et al., 2011; Narayanamoorthy, 2015). Without accounting for the bidirectional feedback of human–water systems, investments in interventions to increase irrigation efficiency or harvest rainwater can lead to long-term unintended consequences, exacerbating existing vulnerabilities and social inequities, or impacting the sustainability of resources. We propose a way forward to disentangle such bidirectional feedback so that coupled human–water systems (e.g. human agricultural systems) can be realistically modeled and the effects of the intervention on human well-being are more accurately estimated.

Adoption of interventions: Influence of behavioral factors and reverse causality

One key indicator of the success of investments made in water-related interventions is their adoption by the targeted population. It is influenced by a range of behavioral factors such as norms, risk perception, attitudes and cultural and socioeconomic factors (Daniel et al., 2019; Kaufmann et al., 2009). Thus, understanding the drivers of the adoption of interventions is the first step in developing effective behavior change interventions. Generally, many behavioral theories grounded in social science consider the influence of psychological factors such as norms, attitude, ability and risk perception on behavior (Mosler, 2012). They generally do this by regressing dependent behavior (e.g. adoption of water treatment technology, irrigation efficiency measures) on such psychological factors (Daniel et al., 2021).

Research has shown that explaining adoption behavior is often more complex (Daniel et al., 2022). This is because behavior that influences adoption may itself be influenced by the prevalence of the practice. For example, attitudes toward the adoption of irrigation may themselves be influenced by the prevalence of irrigation practices, yielding bidirectional feedback. This is referred to as endogeneity in economics, exemplified by situations where an explanatory variable is correlated with the error term, resulting from reverse causality or the feedback effect from the dependent variable to the independent variable (Heckmann, 1978) (Figure 68.1). One example is the use of social norms as independent variables to predict the adoption of water filtration by a community under the assumption of a one-way influence of social norms on adoption behavior. However, one can expect that households that already use water filtration in a community influence the social norms of that community. This exemplifies a two-way (or bidirectional) feedback between the psychology and the behavior of households (Daniel et al., 2022).



Source: Image modified from Daniel et al. (2022).

Figure 68.1 Description of the feedback effect or reverse causality applied to irrigation adoption behavior

Currently, most applications of behavioral theories do not consider these bidirectional feedbacks. As a result, analyses and recommendations considering these bidirectional feedbacks may lead to biased outcomes. This, in turn, may under or overestimate the adoption of water interventions such as groundwater recharge systems or household water treatments (HWTs), and unintended outcomes may emerge as a result. Also, as human–water systems co-evolve, these bidirectional dynamics may also evolve. Daniel et al. (2022) demonstrated this in the context of the adoption of HWT technologies across eight countries. The authors found that the effect of attitude and norms is underestimated by 59 percent and 40 percent, respectively, when reverse causality is ignored, thereby underestimating the impacts of interventions that influence such factors to increase adoption rates.

IV regression and survey design: Treating for reverse causality

To account for such reverse causality and endogeneity in regression analysis, an instrument variable (IV) is often used. In the case of the adoption of interventions, IVs remedy the potential reverse feedback of adoption behavior on psychological factors. In doing so, IVs are used first to predict the psychological factors which are then used to predict behavior (Daniel et al., 2022). The psychological factors do not act as predictor variables alone, but as endogenous explanatory variables, that is, predictor variables whose values are determined by other variables or IVs. The IVs are then used to first predict the psychological factors, which are then used in the second stage regression to obtain unbiased estimates of the effects of human psychology on adoption behavior (Bascle, 2008). However, identifying appropriate IVs and collecting corresponding data are a challenge. This is because IVs are required to meet the criteria that they should only be directly related to psychological factors and only indirectly to behavior (Mehta, 2001). In the case of human–water systems, similar to Tabellini (2010) and Akerlof and Kranton (2000), Daniel et al. (2022) argue that historical institutions, a system of social factors that conjointly generates a regularity of behavior (Greif, 2006), can act as suitable IVs as their impact on the adoption of interventions is mediated by the culture which influences the risk perception, attitude toward new technologies and prevalent social norms of the population. Institutions evolve slowly and are influenced by history, political systems or the geographical location of a place and influence the psychology of the population (e.g. attitude, perception of risk). For example, trust in governmental agencies that manage the water supply could influence the perception of the quality of the distributed water (Doria, 2010). There could also be an interplay between institutions, the perception of risk and the attitude that influences a household's decision to treat water, for example, regarding the smell, taste, color and turbidity aspects of distributed water (Crampton & Ragusa, 2016; Jain et al., 2014). Thus, while there is strong evidence in the literature to support the correlation between the quality of institutions and the psychology of the population, especially with social norms, it remains to be tested whether the quality of institutions is a 'valid' IV.

Data on such slow-moving indicators are not readily available. One way is to use proxy indicators for the same. Daniel et al. (2022) used governance indicators as a measure of institutions for analyzing HWT adoption behavior in eight locations across Asia, Africa and South America. As data on local institutions are difficult to come by, they used country governance indicators taken from the Worldwide Governance Indicators (WGI) capturing six dimensions of governance: (1) voice and accountability, (2) political stability and absence of violence/terrorism, (3) government effectiveness, (4) regulatory quality, (5) rule of law and (6) control of corruption.

However, it is known that institutions and governance indicators can vary greatly within a country. At the same time, local-level data on institutions and governance are difficult to collect and are often not collected. Here, we call for the need to integrate the collection of institutional indicators as part of behavioral studies. Questions on institutional quality as perceived by individual households within a study area (village, towns, districts, etc.) can be added to surveys. These may include the respondents' perception of institutional performance, their trust in institutions, their knowledge of what the institutions have done in that area and whether the institutions involve relevant stakeholders in planning, executing, monitoring and evaluating the project and so on. Such questions, in cross-sectional surveys, can help better understand the barriers to adoption, the role of institutions and the design of appropriate interventions. The collection of data on IVs at a local scale across surveys also provides a way to cross-compare results. However, to know the impact of any interventions on institutions, slow-changing, long-term longitudinal surveys will be required.

A way forward: Embedding disentangled feedback in agent-based models

Developed relationships, using surveys on adoption, psychology and institutions, provide a way forward to develop dynamic models. In general, scenario-based modeling considers the adoption of interventions as exogenous scenarios, considering water and human systems as independent, ignoring the reality that human decisions are influenced by changes in environmental and socioeconomic conditions. The inclusion of results from behavioral theories in system dynamics models has been gaining ground (Pouladi et al., 2019; Ghoreishi et al., 2021; Alam et al., 2022) and provides a means to model coupled human–water systems. By disentangling reverse causality, realistic and dynamic feedback can be embedded in system dynamics and agent-based models (ABMs). ABMs are promising tools in incorporating these relationships to understand and explore the evolution of coupled human–water systems and unraveling and understanding the adoption of interventions and their subsequent impacts. This is because ABMs can explicitly account for farmers' individual behavior, micro-constraints and interactions with society and the environment. This would consequently facilitate more representative modeling of human–water systems and highlight unintended consequences and inequitable impacts. ABMs have been widely used to study the evolution of different systems including land use, urban, forests, ecosystems, epidemiology, social-ecological and agricultural systems (Page et al., 2013). ABMs have investigated the adoption of water conservation behavior and technologies (Pouladi et al., 2019; Rasoulkhani et al., 2018), irrigation efficiency measures (Ghoreishi et al., 2021), clean technology (Pakravan and MacCarty, 2020) and investment decisions (Schreinemachers et al., 2009; Marvuglia et al., 2022) by farmers.

Alam et al. (2022) reviewed the application of ABMs to water interventions, which showed that while ABMs have been extensively used, gaps remain. One key limitation has been the simplistic simulation of farmers' behavior with over-reliance on rational choice theory or simple heuristics. They suggest that behavioral theories should be grounded in social science and use rich empirical data collected from the field to formalize them.

We believe that adding reverse causality in these socially grounded behavioral theories can further strengthen the ABMs and make them more useful to unravel future unintended consequences of water interventions. For example, the adoption of drip irrigation technology (or any other practice/technology) by farmers is usually modeled as a function of one or a combination of factors such as farmers' socioeconomic factors, social interaction and perception of technology. This can be strengthened by including IVs on local institutions. This will account for how farmers' social interactions and perceptions are themselves modulated by the existing institutions and the farmers' perception of them (e.g. concern about water use, trust in institutions and their advice, corruption) in the area.

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