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Using causal loop diagrams for the initialization of stakeholder engagement in soil salinity management in agricultural watersheds in developing countries: A case study in the Rechna Doab watershed, Pakistan

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ABSTRACT

Over the course of the last twenty years, participatory modeling has increasingly been advocated as an integral component of integrated, adaptive, and collaborative water resources management. However, issues of high cost, time, and expertise are significant hurdles to the widespread adoption of participatory modeling in many developing countries. In this study, a step-wise method to initialize the involvement of key stakeholders in the development of qualitative system dynamics models (*i.e.* causal loop diagrams) is presented. The proposed approach is designed to overcome the challenges of low expertise, time and financial resources that have hampered previous participatory modeling efforts in developing countries. The methodological framework was applied in a case study of soil salinity management in the Rechna Doab region of Pakistan, with a focus on the application of qualitative modeling through stakeholder-built causal loop diagrams to address soil salinity problems in the basin. Individual causal loop diagrams were developed by key stakeholder groups, following which an overall group causal loop diagram of the entire system was built based on the individual causal loop diagrams to form a holistic qualitative model of the whole system. The case study demonstrates the usefulness of the proposed approach, based on using causal loop diagrams in initiating stakeholder involvement in the participatory model building process. In addition, the results point to social-economic aspects of soil salinity that have not been considered by other modeling studies to date.

Key points

- A systems thinking and modeling methodology for the initialization of stakeholder engagement in soil salinity management is proposed.
- An integrated approach to soil salinity management (including environmental, social, economic and technical aspects) is proposed.
- The methodology supports the preparation of an integrated systems perspective through stakeholder-built causal loop diagrams.
- The methodology was tested through a case study of the Rechna Doab watershed in Pakistan.
- The case study results revealed important causes of soil salinity and solution strategies that have not been examined by other modeling studies to date.

1. Introduction

Soil salinity remains a very dynamic and challenging process to manage sustainably in the arid and semi-arid regions of the world. For example, on average, 14%, 20% and 26% of irrigated lands in Iran, India and Pakistan, respectively, are salt-affected (Shahid, 2013). An estimated 6 million hectares (Mha) of irrigated agricultural land in Pakistan, the focus area of this paper, is affected by soil salinity, causing a 62% loss in agricultural incomes (Tanwir et al., 2003). To solve the issue, the Pakistani government initiated a number of

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Salinity Control and Reclamation Projects (SCARPs) in the latter part of the 20th century; however, in 2000, further implementation was discontinued due to poor performance, high costs, and the short operational life of the associated infrastructure (Ghumman et al., 2012). The SCARP projects' demise resulted in weed growth in surface and subsurface drains, causing standing brackish water to accumulate on agricultural land. Such reclamation projects are usually designed based on the advice of local and foreign consultants, who in turn have based their advice on the results of physical modeling studies and site investigations. Some past physically-based soil salinity modeling studies in the area include LEACHM (Aslam and Van Dam, 1998), SALTMOD (Nasir et al., 2003), SWAP (Kuper, 1997; Qureshi et al., 2004; Sarwar et al., 2001) and UNSATCHEM (Condom et al., 1999). These studies, focusing only on the technical field-scale issues associated with soil salinity, recommended solutions without taking into account stakeholders in any meaningful way, or the social-economic aspects of the problem. This may result in the failure of policy decisions as observed in the SCARP case. Stakeholder participation is very important for successful policy decisions (*e.g.* Saadat et al., 2011; Adamowski et al., 2011; Adamowski et al., 2013; Halbe et al., 2014; Medema et al., 2014a, 2014b); in fact, Nutt (2002) showed that 50% of policy decisions usually 'failed' because decision-makers did not include the knowledge and interests of key stakeholders.

Stakeholder involvement in environmental management and modeling has received very little attention to date in Pakistan. Small landholdings, the poor economic status of farmers, limited modeling and mathematical skills, and a lack of technical, political, and financial support have hampered the adoption of participatory modeling of soil salinity issues in Pakistan. Researchers have highlighted the need for joint action by governments, NGOs and farmers for salinity control and have advocated for the inclusion of stakeholders in all stages of soil salinity modeling and management (Tanwir et al., 2003). The modeling approach proposed in this paper is directly focused on addressing these types of problems regarding the initialization of stakeholder involvement in developing countries such as Pakistan.

The benefits of applying local, along with expert, knowledge in modeling exercises have been widely demonstrated in various research studies (*e.g.* Campisi et al., 2012; Adamowski et al., 2009; Niazi et al., 2014; Halbe and Adamowski, 2011; Halbe et al., 2013; Langsdale et al., 2006). Meaningfully incorporating stakeholder contributions into the modeling process can help incorporate the ideas and knowledge of local key stakeholders, integrate physical and socio-economic components within a watershed or sub-watershed level, and improve model boundaries and completeness by ensuring that all relevant issues and views are addressed. Stakeholder engagement helps decision-makers take into account local realities, strengths, and constraints when developing appropriate policies and strategies, and can also reduce the level of conflict among stakeholders (Sterman, 2000). Stakeholder participation can also help garner support for the implementation of the most suitable strategies, as the involvement of local stakeholders in the development of these strategies creates a sense of 'ownership' and commitment to seeing the strategies successfully implemented (Pahl-Wostl et al., 2007; Straith et al., 2014).

The inclusion of stakeholders in water resources management has been advocated by many agencies in the water resources field (*e.g.* Global Water Partnership, European Union, International Water Management Institute) and frameworks (*e.g.* IWRM, adaptive management) as an integral component of sustainable water resources planning and management. However, to date, many organizations that are in charge of participatory watershed management have experienced significant challenges in finding effective and simple ways to, among other things, engage stakeholders in watershed modeling and management, especially in areas with low levels of expertise and funding, as is the case in many developing countries. Other significant challenges in participatory modeling are lack of stakeholder interest and unstable group composition. Burgin et al. (2013), having conducted a study of stakeholder engagement in water policy in Australia, reported that more than half of the participants attended only one of twelve meetings. In another study, Videira et al. (2009) highlighted the issue of unstable group composition in a participatory river basin management modeling study carried out in Portugal. In addition, it is often difficult to capture individual stakeholder points of views or 'mental models' in group meetings since, for instance, some stakeholders might be reluctant to voice their opinions in the presence of government officials or their superiors in the organization.

The innovative modeling approach proposed in this paper, based on causal loop diagrams, (Mendoza and Prabhu, 2006; Sendzimir et al., 2007; Stave, 2002; Videira et al., 2009) directly focused on addressing these types of problems. The proposed approach is based on 'co-construction' participatory modeling that allows for the direct involvement of stakeholders with limited technical expertise, even in situations with limited financial and time availability, as is frequently the case in developing countries such as Pakistan. The two main objectives of the research presented in this paper were to: (i) propose a step-wise and simple approach for engaging stakeholders in soil salinity management in developing countries under constraints of limited expertise, as well as financial and time resources, and (ii) explore the application of the proposed approach in Pakistan's Rechna Doab region.

The proposed participatory modeling process can be categorized into four successive stages: (i) problem framing, (ii) stakeholder analysis, (iii) construction of individual causal loop diagrams (CLD), and (iv) construction of an overall group CLD (*i.e.* a CLD that includes all the views of the different stakeholder groups). The first stage describes the process of problem definition, which is crucial in the selection of stakeholders. The second stage involves the categorization of selected key stakeholders according to their roles and attributes. This type of analysis is important in prioritizing stakeholders according to their roles and importance. The third stage discusses the process of representing stakeholder views and ideas in the form of causal loop diagrams (CLDs), while the fourth stage involves the process of merging individual CLDs (mental models) into a final group CLD.

This research is particularly innovative since, to date, no attempt has been made to develop a simple and easily adoptable methodology to initialize stakeholder involvement in the development and use of qualitative causal loop diagram models with the aim of resolving agricultural water management issues (in this case soil salinization), applicable even in situations where stakeholders have minimal expertise, financial resources and time, as is often the case in many developing countries. A description of the proposed stepwise qualitative modeling process is provided in the following section.

2. Methodology

Stakeholder initialization and involvement in model development is a central issue in participatory modeling, and a variety of approaches, methods and guidelines exist to involve stakeholders in participatory modeling. Reed et al. (2009) and Reed (2008) provide a comprehensive review of different stakeholder engagement techniques. Normally, stakeholders are engaged through group meetings or interviews in a pre-defined form. The main problem with group meetings is the poor attendance of stakeholders; for example, not all of the participants might be interested in attending meetings. Stakeholders, particularly in developing countries, tend to have a lower interest in participating in group meetings compared to individual interviews (Burgin et al., 2013; Videira et al., 2009), as in the former case they may not be able to