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Simulating the viability of water institutions under volatile rainfall conditions – The case of the Lake Naivasha Basin[☆]

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ABSTRACT

This study views the Lake Naivasha Basin in Kenya's Rift Valley as a hydro-economic system with slowly emerging basin-wide water management institutions. Possible institutions face two interlinked challenges. Firstly, large scale horticultural activities as a core economic activity in the basin require substantial and regular amounts of irrigation water, abstracted from the lake and its aquifer. The lake level and thus irrigation water availability reveal a falling trend over the last two decades, which calls for institutions aimed at restricting further expansion in water use. Secondly, the region is characterized by volatile weather conditions where periods of average and above average rainfall have alternated with prolonged droughts for centuries. That leads to highly volatile water inflows into the lake. The two challenges combined thus call for water management institutions that support sustainable water use in both the short and the long run. This study therefore investigates the effect of water institutions already existing or proposed by local stakeholder organizations on preserving target lake levels against a background of highly volatile water availability which negatively affects the economic viability of institutions. To take the absence of functioning basin-wide coordination mechanisms for water allocation into account, we employ the solution format of Multiple Optimization Problems with Equilibrium Constraints (MOPEC) in our integrated hydro-economic model. Stochastic scenario simulations with the model reveal that compliance to water regulations and thus the viability of water institutions in the Naivasha Basin would require very high penalties which are not likely to be accepted by users.

1. Introduction

This study views the Lake Naivasha Basin in Kenya's Rift Valley as a hydro-economic system with slowly emerging basin-wide water management institutions. Since the beginning of the 1980s, a large horticultural industry has developed in the basin, providing 70% of Kenya's flower exports and employing more than 70,000 people. While most horticultural farms are located close to Lake Naivasha, water demand in the upper part of the basin has also increased in recent years (De Jong, 2011). The large scale horticultural activities in the basin require substantial and regular amounts of irrigation water. However, the region is characterized by volatile weather conditions where periods of average and above average rainfall have alternated with prolonged droughts for centuries (Verschuren et al., 2000). That leads to highly volatile water inflows into the lake. As the lake has a low volume and lacks a natural outlet, these changes in inflows can cause the lake level to vary for several meters within a couple of years. Influenced by increased water abstraction for irrigation, lake levels (and volumes) have been relatively low in recent decades (Van Oel et al., 2013), increasing the risk of severe water scarcity. Still, periods of abundant rainfall lead to above-average lake levels, as can be observed since 2011.

But even though natural variability is the overwhelming factor determining short-term changes in the lake level, long-term average lake levels are prone to decrease with further increasing human water use (Becht and Harper, 2002; Van Oel et al., 2013). This calls for water management institutions that support sustainable water use in both the short and the long run. Moreover, appropriate institutional design has the potential to increase the economic efficiency of water use on the basin scale (Livingston, 1995). The volatile climate of the Lake Naivasha Basin with its irregular change between water abundance and droughts creates difficulties for the establishment of viable water institutions. As Bardhan (1993) points out, an important condition for the

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emergence of stable and effective resource management institutions is that the resource is felt to be moderately scarce for its users. But in some years the lake still provides water in abundance, such that there is no perceived need to run water institutions with their high transaction costs due to the large number of agents and pervasive monitoring needs. In periods of extreme scarcity, on the contrary, existing institutional arrangements may break down (Bardhan, 1993). In that case, in addition to the transaction cost problem, water becomes so scarce and thus its marginal economic value so high that it is more profitable to violate than to follow rules. Fig. 1 illustrates the resulting relation between water scarcity and viability of water institutions, interpreted as the level of compliance to rules of water use.

The collapse of institutions which govern access to water need not necessarily lead to violent conflicts over water resources as investigated by Gizelis and Wooden (2010) in a cross-country analysis. But at least it means that water use may become economically less efficient, while resource and environmental preservation goals may no longer be met. Poverty among water users and traditional contexts with weak government institutions can further negatively affect the performance and viability of water management institutions, particularly with regard to monitoring and enforcement, as empirically demonstrated by Cleaver and Franks (2005) for Tanzanian river basins. Acemoglu (2006) theoretically shows that inefficient institutions might persist if they serve the private interests of national or regional elites. We assume that similar conditions (poverty, weak and/or self-interested government actors) play a role in the Naivasha case, leading to difficulties in creating effective water institutions.

Our modeling study aims at answering a set of questions related to the viability of existing and envisaged water institutions in the Lake Naivasha Basin. First, how likely are severe water scarcity situations, and how much does human water use contribute to increasing water scarcity? Secondly, do existing institutions (water permits and charges) contribute to the mitigation of severe water scarcity situations? Thirdly, will institutional arrangements proposed by local stakeholders be viable and effective under recurrent water scarcity situations that inevitably result from volatile local rainfall patterns? As the Lake Naivasha hydro-economic system is characterized by numerous non-linear and interrelated hydrological, ecological, agronomic and economic processes, systematic analysis based on numerical simulations offers the possibility to explore the suggested research questions in an integrated fashion. While there is a large body of simulation studies on the effect of

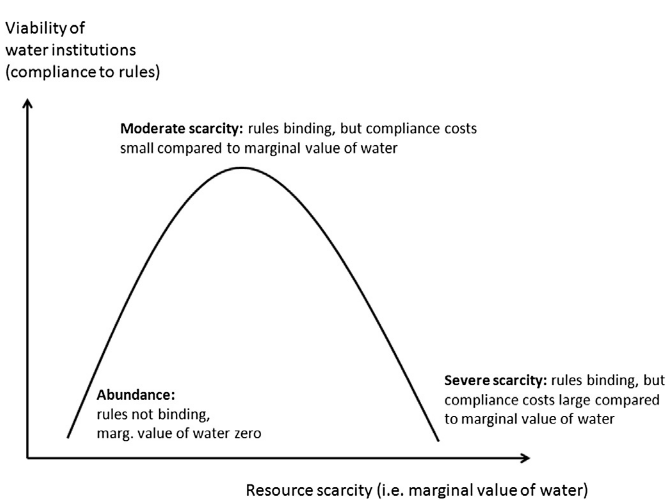

Fig. 1. Proposed relation between resource scarcity and the viability of institutions.

human water abstraction and water institutions on long-term water availability and use in river basins, attempts to simulate institutional change and viability have been limited so far. Barreteau and Bousquet (2000) and Barreteau et al. (2004) use the SHADOC multi-agent system to explore the viability of irrigation systems in Senegal depending on individual behavior and social networks. Feuillette et al. (2003) follow a similar approach using the SINUSE model for an irrigation district in Tunisia. Valkering et al. (2009) report on an agent-based model for the Ebro river basin that aims at stakeholder participation in a kind of resource use game. Users of this model can simulate the outcomes of different institutional regulations on the hydrological conditions in the basin. Schlüter and Pahl-Wostl (2007) propose an agent-based model to investigate the resilience of the hydro-economic system in the Amudarya River basin under different water institutions and a high variability of water availability. But while these exemplary studies try to enumerate the impact of institutions on water use, they consider institutions (in the sense of rules for water use) and their performance or effectiveness as largely fixed within a certain scenario. In this study we try to expand this kind of institutional analysis by simulating the economic incentives that institutions provide regarding water use and the compliance to the rules that these institutions incorporate. Specifically, we investigate how these incentives – and the behavioral constraints they provide to water users – change with water scarcity.

We interpret increasing non-compliance to rules and the resulting collapse of the underlying institution as a systemic change in the hydro-economic system for two reasons. First, as non-compliance tends to aggravate water scarcity, it skips the system into a positive feedback loop, as scarcity in turn lowers the relative costs of non-compliance as argued above. Our simulation model will demonstrate this process that has the potential to tip the system out of balance. Second, if rules are no longer followed by a considerable number of water users, it is unlikely that the consensus among all users to uphold the institution will prevail. The damage done to the reputation of the institution by pervasive non-compliance will likely mean that the institution will become more and more ineffective and may even be abandoned eventually. Without an effective institution, water use in the basin will be no longer regulated, which, to our opinion, qualifies as a systemic change in the hydro-economic system.

In recent decades, resource allocation problems have increasingly been analyzed quantitatively using numerical biophysical-economic simulation models, with hydro-economic models being applied in the water sector (Harou et al., 2009). 'Biophysical-economic' means that biophysical and economic processes are simulated simultaneously (e.g. Qureshi et al., 2013) and not by consecutively solving separate, specialized models such as in Carmona et al. (2013). While typically sacrificing biophysical detail compared to specialized models, this approach offers theoretical coherence as well as organizational and computational efficiency. Following that approach, we use the integrated river basin model LANA-HEBAMO (Lake Naivasha Hydro-Economic Basin Model), encoded in GAMS, to simulate institutional viability. Institutional scenarios are combined with weather scenarios that reflect rainfall events in the Naivasha basin of the past fifty years. The simulation model is an empirical application of the 'Multiple Optimization Problems with Equilibrium Constraints' – (MOPEC) format (Ferris and Wets, 2013). The use of MOPEC in river basin models enables policy analysis under the assumption of imperfect institutions. At the same time, MOPEC facilitates the representation of independent agents within a simultaneous model, making the model capable to resemble a multi-agent system. The solution format simulates optimal behavioral responses of each agent given the strategy of others agents and determines *individual* opportunity

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