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Economic indicators of hydrologic drought insurance under water demand and climate change scenarios in a Brazilian context

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ABSTRACT

Developing countries face large losses to extreme natural hazards. Regarding droughts, planning instruments are important for managing water resources and diminishing the losses. Under increasing demand scenario, varied criteria should be incorporated indicating society's capacity to bear the consequences. Here we present a Brazilian-contextualized insurance model and suggest its outputs as complementary criteria to assist water resources management and to inform the stakeholders. From the streamflow simulated using hydrologic models driven by a climate scenario, we applied the Hydrologic Risk Transfer Model (MTRH-SHS), an insurance fund simulator under a multi-year policy, to assess sustainability indicators and the premiums a community would pay to cover the expenses of water deficits. Multiple scenarios generated with MTRH-SHS link water yield and seasonality related to both premium and loss ratios. A 20% increase in water demand elevates the premium up to 0.1% of a local GDP. Even under current demand, premiums may surpass 0.5% of GDP because of changes in the hydrologic regime. Proportionally, more seasonal or varied regimes result in more heterogeneous loss events, which in turn is linked to higher insurance premiums. MTRH-SHS might raise awareness for decision-makers to cope with drought under changing water demand and climate in the Brazilian context.

1. Introduction

Climatic changes, as indicated by several studies (Arnell and Gosling, 2016; Huang et al., 2014; Šraj et al., 2016) and the IPCC (Intergovernmental Panel on Climate Change, 2014, 2012), is affecting the hydrologic regime of several rivers and is leading many of them to more frequent extreme hydrometeorological events. Recorded economic and life losses become larger as extreme events become more frequent and intense, but also as populations exposure and wealth increase (Aerts and Botzen, 2011; Güneralp et al., 2015; UNISDR, 2011).

Developing countries are usually the most affected by natural catastrophes (Munich Re, 2014), including droughts, entering a "poverty trap", as they are hit again before recovering from the last event. Because droughts develop slowly and a great share of the population are not aware of such risks, especially in urban areas where they are disconnected to the evolution of nature, a share of the population do not feel at risk and so do not act to lower it (Oliveira and Nunes, 2007).

There are now several approaches found worldwide to "move from crisis management to risk management", as explained by Wilhite et al. (2000), especially in the drought context. There are different drought types defined in the literature. Here, we refer to drought as (i) hydrologic and (ii) socio-economic drought, i.e. (i) the low storage of water in superficial reservoirs (e.g. lakes, rivers, shallow soil) in a level that (ii) disrupts water supply and other user sectors (Mishra and Singh, 2011; Wilhite, 2000).

Water security can be understood as a state (opposed to water insecurity) in which water-related risks are in an acceptable level (Grey et al., 2013; Lemos et al., 2016), and is a consequence of adaptive capacity (Lemos et al., 2016). Society seeks features that might be controlled to move into a state of water security, such as infrastructure and governance, while other features, such as climate variability and catastrophic events that are beyond society's control, might lead to a state of water insecurity.

Within this context, insurance, a risk transfer mechanism, is pointed as an important adaptation measure against climate change (Hudson et al., 2016; Schwank et al., 2010), and also as a resilience building mechanism (International Strategy for Disaster Reduction, 2005), for it might break the above mentioned "poverty trap" (J. David Cummins and Mahul, 2008; Schwank et al., 2010) and its consequences on better use of the water resource. The existence of a strong market of insurance against water risks leads to the growth of studies and data, useful not only for the insurer agencies themselves, but all the community, and allow public administration to assume other risks (Sanders et al., 2005; UNEP FI, 2007) improving resilience and the civil society to

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improve its livelihood (Hazell and Hess, 2010; Kost et al., 2012). On the contrary, being hit by frequent extreme events without a support for resilience building weakens the local economy, reinforcing the "poverty trap" they are in. In the water scarcity context, insurance schemes have the potential to promote good water management, either by discouraging illegal uses or by raising awareness (Perez Blanco and Gomez, 2014).

A functional insurance scheme provides a financial relief that, together with proper education and risk information, move the population into a higher income situation, which in turn gives basis to investments in risk reduction. Therefore, these potential effects put insurance as an economic resilience building (Hallegatte, 2014) by providing means of resisting or recovering from an event.

Benson et al. (2012), Surminski (2016), and Warner et al. (2009) agree that insurance alone will not build climate resilience. The tool is otherwise able to promote risk reduction and build climate resilience if well designed, for example by giving discounts to policyholders that install risk reduction measures; and/or in the case supported by a legal framework that allows the insurer agency to require, for example, proper land use planning, as in the United Kingdom where the agency requires from the policyholder housing standards and even share the post-event recovery management (Crichton, 2008).

The scientific publications on insurance for droughts are yet scarce (Sampson et al., 2014) and few have shown numerical models to enhance this kind of studies (Tariq et al., 2013). Catastrophes can be projected by numerical models that generate a range of possible outcomes, each of which is assigned a risk. In the context of water risks, given that the hydrologic regime itself is a changing system, its characterization should not rely on stationary conditions (Ehret et al., 2014), leading to the adoption of probabilities or the risk concept (Sampson et al., 2014). Indeed, climate change may affect insurance on many fronts. In particular, given that the frequency and magnitude of extreme events are likely to increase, current premiums, funds, and risk valuations may begin not to suit these changing conditions (Dlugolecki, 2008).

In an index-based insurance scheme, indemnification is activated by the magnitude of a characteristic variable such as precipitation, discharge, or reservoir levels. Such an approach overlooks a punctual local evaluation of losses, which while easing the insurance operation and diminishing administrative costs, requires a more accurate risk calculation because of spatial variability as well as a way of monitoring the index (Dixit and Mcgray, 2009; Hazell and Hess, 2010). As the insured community is subjected to the index, it is in their own interest to reduce their risk and thus their losses. For the drought case, the existence of insurance also discourages illegal water withdrawals, for example. Moreover, for low-income households, the index-based insurance scheme should be implemented as a way of supporting more productive actions than being solely a risk protection measure (Osgood and Shirley, 2010). Not only would insurance reduce the insured person's income variability, but also other actions must be sought to elevate his or her average income and lead him or her out of the 'poverty trap'.

In developing countries, where insurance market has low penetration (The World Bank, 2014), data availability on insurance is even more rare. In 2013, non-life insurance penetration in Brazil was just 1.2% compared with 6.1% in the United States and 3.7% in Germany (Organisation for Economic Co-operation and Development [OECD], 2016). In some developed countries, as in England, the insurer agency is responsible of accompanying the recovery stage and give benefits for those policyholders that take risk reduction measures (Clemo, 2008; Crichton, 2008; Ward et al., 2008).

In this article, we present an insurance fund simulator coupled with a model for drought indirect losses estimation as a tool for water use management, contrasting the expected losses to the local capacities under climate change and varied water demand scenarios. More details on the coupled model and previous applications are shown in a companion paper by Guzman et al. (submitted) and a Supplementary material. In this study, we propose the use of economic indicators from an insurance model to complement water resources management, specifically the demand management. The adoption of such insurance-based indicators should improve risk perception, incentivize risk reduction, and translate the potential water deficit into a more tangible value for managers and policymakers. A reasonable estimation of expected losses (or equivalent premiums for the functioning of an insurance scheme) would allow the government or river basin committees to explore different mechanisms for compensating for such losses, for example charging for water use or paying for those that foster environmental services.

2. Material and Methods

2.1. Study Case

The headwaters of the Piracicaba River Basin, Southeast Brazil, are dammed to transfer waters for the Brazilian largest city, São Paulo. The set of 4 reservoirs (National Water Agency/São Paulo state Water and Electricity Department [ANA/DAEE], 2015) forms the "Equivalent System" of the Cantareira Water Supply System (CWSS) (Fig. 1) that once supplied water for more than 8 Million people. However, the precipitation in the Cantareira System's drainage area in 2012 was only 92% of the historical average, value that dropped to 69% in 2013 and 61% in 2014, before rising to 104% in 2015 (SABESP, n.d.), situation that lead to a reduction of its coverage to less than 6 million people (Costas, 2015). One study using 2015 data suggested that the drainage area of Cantareira approximates a regime shift, with a lower ratio between rainfall and the flow into the reservoirs (Coutinho et al., 2015), which might be a result of the decrease in soil water levels.

The region is under the Atlantic Forest Biome, with an average annual rainfall of 1577 mm and an average discharge of 39 $m^3 \cdot s^{-1}$ (National Water Agency/São Paulo state Water and Electricity Department, 2015). The Southeast Brazil is a region of low certainty regarding the effect of climate changes in precipitation, with studies indicating decrease (Chou et al., 2014a) or increase (Magrin et al., 2014) of annual rainfall. The Cantareira System started operation in 1974 with a 30-year permit for transfer up to 35 $m^3 \cdot s^{-1}$, which was renewed for 10 years, and is currently under new studies for a new permit.

The study case area comprises the towns of Camanducaia, Extrema, and Itapeva in the state of Minas Gerais, plus Joanópolis, Nazaré Paulista, Piracaia, and Vargem in the state of Sao Paulo, summing up about 92 thousand people living in urban areas and about 16 thousand in rural areas (COBRAPE, 2008). These municipalities sum up a base 1.24 $m^3 \cdot s^{-1}$ water demand, split in domestic (26%), industrial (29%), livestock (3%), and irrigation (42%).

Table 1 shows the current demand per sector for each station and the cost per volume of the water deficit. Notably, the environmental sector (dilution of organic loads) has the most water demand (more than 75%). All values were calculated in Brazilian Reais and converted into US Dollars at the ratio of 2.85, the average of the past two years (2014–2015).[1]

Because the socioeconomic data are related to municipalities rather than watersheds, the outlets that delineate the drainage areas of the reservoirs (see 'B' for barrage in Fig. 1) are more difficult to simulate the water withdrawal and the final use within a municipality may be in different watersheds. Therefore, only watersheds upstream the reservoirs were considered. Three of them are within the Jaguari River Basin, two basins (the F28 and F23 stations, hereafter named by the initials, order, and drainage area, as JAG1-277 and JAG2-508) contributors upstream to a third one (F25B station, named JAG3-972), and a fourth basin (F24 station, named CAC1-294) in Cachoeira River Basin. Note in Fig. 1 that JAG2-508 is placed in the northern river before the junction with the

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[1] http://economia.uol.com.br/cotacoes/cambio/dolar-comercial-estados-unidos/?historico.