

**Socio-economic Assessment of the rural Vulnerability of water users under stressors of global changes in the Hard rock area of South India.
The SHIVA ANR project.**

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SUMMARY

Vulnerability assessment is in growing demand in policy circles in order to choose adapted measures and policies to reduce vulnerability of water users and resources. Within the SHIVA ANR project, we present a method to first assess and map the vulnerability of South-Indian farmers to both climate and socioeconomic changes, and second assess the costs and benefits associated with farmers' vulnerability evolution at two time scales (medium and long term). The project is focusing on hard rocks area of South-India as in this geological context, both surface and ground water resources are naturally limited. We also target farmers' population as they are the main water users of the area and they rely exclusively on groundwater. By the end, the area covers the semi-arid zone of South-India, with a rainfall gradient from 1100 mm to 600 mm. Vulnerability is then expected to vary according to this local climatic conditions but also to socioeconomic characteristics of farmers' households. After a 10 months research, we present the first results of the project.

INTRODUCTION

Global changes are already impacting water resources and uses in water-stressed regions around the world and this impact will increase significantly in the near future especially in developing countries, such as the rural southern India, where changes are rapid and occur at a large scale (IPCC 2007). Vulnerability assessment is then in growing demand in policy circles in order to choose adapted measures and policies to reduce vulnerability of water users and resources. Within the SHIVA ANR project, we develop a method to first assess and map the vulnerability of South-Indian farmers to both climate and socioeconomic changes, and second assess the costs and benefits associated with farmers' vulnerability evolution at two time scales (medium and long term). The project is focusing on hard rocks area of South-India as in this geological context, both surface and ground water resources are naturally limited. We also target farmers' population as they are the main water users of the area and they rely exclusively on groundwater for irrigation. By the end, the area covers the semi-arid zone of South-India, with a rainfall gradient from 1100 mm to 600 mm. Vulnerability is then expected to vary according to this local climatic conditions but also to socioeconomic characteristics of farmers' households.

Our research team is split in six thematic groups in order to face the different scientific issues which are: climate regional scenario downscaling, spatial agricultural prospective, vulnerability assessment and quantification, vulnerability mapping, hydrological modeling and upscaling, and vulnerability impacts assessment. Our approach is multidisciplinary to deal with the numerous inherent themes and integrated as vulnerability is a dynamic and multidimensional concept. The project began in January 2009 for a period of three years. In this paper, we illustrate the first methodological results of this

ongoing project. Section 1 presents the study area and the method used to choose three representative pilot sites. Section 2 develops the general methodologies of the project in relation with the above research issues. Section 3 shows the first results achieved after a 10 months research. Finally, we conclude on a discussion of the first results and how they drive the coming work.

1. THE STUDY AREA

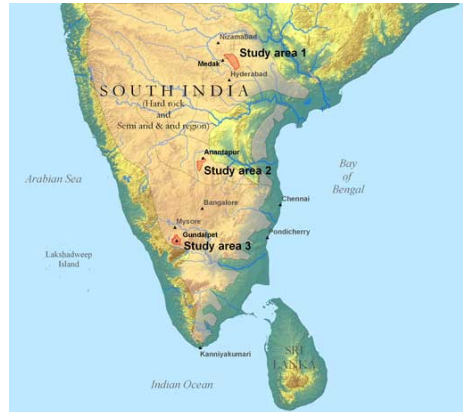


Figure 1: SHIVA study area and the 3 pilot sites (<http://www.shiva-anr.org>).

The project area has been delimited according to three factors characterizing water stressed areas in India. They are: (i) the hard rock geological context. Groundwater modeling on hard rocks is very specific with groundwater recharge depending on a fissured layer that must be characterized; (ii) the semi-arid climatic context. It has been defined according to Indian ecoregion map. Annual rainfall varies from 600 mm in the middle of the area to 1100 mm in North-East and South-West; (iii) the reliance on groundwater resources. Regions mostly irrigated by surface water (e.g., in the vicinity of Krishna river) are excluded of the research area as it is considered that farmers' vulnerability need a specific approach in this case. Mandals (Indian municipalities) relying by more than 80% on groundwater are part of the project area.

Within this area, three pilot sites have been delimited (Figure 1). They correspond to three watersheds of around 650 to 800 km². They are representative of the climatic gradient of the project area (Figure 1). Two are located in Andhra Pradesh (Kudaliar and Padam Eru watersheds) and the third one near Mysore in Karnataka (South Gundal watershed). They are all located in rural zones relying on agriculture, mainly cropping and small breeding.

2. METHOD

The general method of the project combines socio-economic and physical approaches to analyze the interactions and feedback mechanisms between the water systems and the rural society (Figure 2).

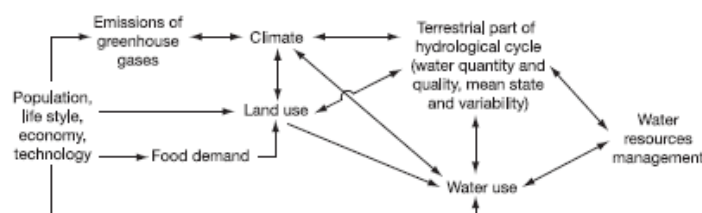


Figure 2: Impact of human activities on freshwater resources and management (issued from IPCC (2007)).

As highlighted in Figure 2, global changes integrate both climate and socioeconomic changes. Both influence the water resources supply and demand, which in return influence global changes. The scenarios approach is widely used to foresee either climate or socio-economic trends (Abildtrup, Audsley et al. 2006; Randall, Wood et al. 2007). They give a picture of possible futures in a given area. In a concern of global consistency, the SHIVA project uses IPCC climate scenarios in one side (Randall, Wood et al. 2007), and the so-called SRES scenarios from the Special Report on Emission Scenarios (SRES) on another side (2007). The two kinds of scenarios are global or regional and will

be downscaled at the appropriate level (pilot sites and project area). Both kinds of changes are likely to affect water resources, and particularly groundwater. Existing models are developed to characterize the water table fluctuation in hard rock aquifers depending on the monsoon variability and groundwater abstraction for irrigation (Dewandel et al. 2006, 2007). Though, these models do not reflect spatial fluctuations of the water table. Thus, the project hydrologists are currently developing a lumped model constituted by two reservoirs (upper and lower ones). This model will be able to take into account daily climate variations and landuse changes at the village level. Spatial mapping and simulations will be used to assess how both kinds of changes are likely to affect water users' decisions at the very local scale, some of them being more affected by climate change, some others by anthropogenic change and at least a part of the water users being exposed to both changes (O'Brien and Leichenko 2000).

Vulnerability has been defined by IPCC as *“the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes”* (IPCC 2007). The SHIVA project is in line with Eakin and Bojorquez-Tapia (2008) approach of the vulnerability multidimensional concept. Vulnerability is described through a hierarchic matrix composed of numerous indicators. Weights are attributed to indicators using multicriteria decision analysis (MCDA). The method allows explaining how different profiles of farmers have finally the same vulnerability score. The project also follows O'Brien (2004) and Sullivan (2006, p.1) recognizing that *“a key aspect of vulnerability is that it is spatially variable, reflecting local economic, social and cultural characteristics, as well as the local physical conditions and impacts brought about by climate change (floods, droughts, tidal waves, incidence of disease vectors etc)”*. Remote sensing and GIS tools can then contribute to the assessment of the changes processes. Through a mapping of rural vulnerability to both climate and anthropogenic changes, it is expected to obtain a more precise idea of the foreseen pictures of the rural area of South India over a medium and long term period of time. GIS offers the possibility to superpose various information (differentiated vulnerabilities, water resources, land cover, economic activities, population, etc.) at a predefined geographical scale (O'Brien, Leichenko et al. 2004; Metzger, Leemans et al. 2005; Meadows 2006; Procter, Comber et al. 2006).

Evaluation of the rural vulnerability impacts will then be realised through an economic (costs and benefits) and social assessment. A brief review of the literature shows that authors focus mainly either on the costs of climate change damage within a do-nothing scenario (Ruth, Coelho et al. 2007), or on the benefits and cost of climate change policies and measures (Watkiss, Downing et al. 2005), or the costs of one damage (e.g. flooding, seawater rise) estimated locally for various scenarios (Elzen and Rotmans 1992). The SHIVA project aims at assessing the rural vulnerability impacts of global changes on water users from a more holistic point of view, taking into account impacts on the rural economies but also on the social organization in the study area. Only then, collective adaptive capacities will be considered (policy measures or initiatives) in response to economic and social assessment.

3. RESULTS

After delineating the project area and the three pilot sites (Figure 1), methodologies for each issue have been collectively discussed and partly set in order to avoid any scale or input/output data problem. This is particularly important for an integrated work between climate, economic, remote sensing and hydrology groups.

3.1. Climate regional scenario downscaling

In order to investigate the potential stress linked to global climate change on the local hydrological cycle of the three pilot watersheds, statistical downscaling methods are used on a set of IPCC SRES-A2 scenario projections issued from a pool of Global Climate Models (GCMs). A preliminary insight is provided using the delta method from Déqué (2007). Then a probabilistic downscaling method (PDM) developed by Michaelangeli et al. (2009), the Cumulative Distribution Function transform (CDF-t), is applied to GCM precipitation and temperature output. First, the PDM is validated on a historical period by downscaling precipitation/temperature CDFs over the three Indian basins considered. Then, the CDF-t is used on GCM output fields to project changes in precipitation/temperature anomalies for the 21st century under A2 scenario.

3.2. Vulnerability assessment and quantification

Farmers' vulnerability to global change in South-India is described through 81 indicators characterizing either farmers' sensitivity to global change, either farmers' adaptation capacity. They are organized into a hierarchical matrix. More than 15 local experts (government, NGOs, research areas) have participated to the matrix stabilization and to the weighting process (pairwise comparison according to Analytic Hierarchy Process, AHP method). At least 3 similar weights profiles are identified and will be used as vulnerability sensitivity analysis. The results of a survey of 153 farmers of the small watershed of Gajwel (within Kudaliar pilot site) are currently analyzed in order to quantify each indicator of the matrix. After a normalization procedure of the indicators, a vulnerability score is calculated for each farmer, corresponding to present vulnerability state. This should allow characterizing vulnerability among official farmers' category and discussing the reasons. In parallel to this work, an econometric analysis is carried on the survey data to better characterize farmers' production and consumption systems. This survey serves as a test before the launch of 9,000 surveys in the three pilot sites.

3.3. Hydrological modeling and upscaling

At the present stage of the project, the proposed approach for water cycle modeling is a lumped model constituted by two reservoirs: (i) The upper reservoir simulates the water content in the soil according to rainfall and reference (or potential) evapotranspiration rates. Output from this reservoir is the partition of rainfall between real evapotranspiration and recharge assuming most of the time that runoff is negligible; (ii) The lower reservoir simulates the water table in the aquifer according to recharge and pumping rates, and possible baseflow (maybe negligible).

The model could be run at a daily time step. This modeling approach allows taking into account the impact of climate change (evapotranspiration change, rainfall amount change and rainfall dynamics change) on recharge process and therefore, on water table elevation. The different types of land-uses characterized by different water uses are defined through satellite images and field surveys: forest, grassland, drip-irrigated crops, paddy fields, vegetables, flowers, etc. Economical survey are providing cropping pattern (repartition in % of crops) and pumping rates at the village scale. Each land-use type is simulated by a specific upper-reservoir. All the upper reservoirs then percolate into a common groundwater reservoir at the village scale, according to surface-weighted recharge rates. It means that the water table is computed at the village-scale: this provides an estimate of the global behavior of the water table at the village-scale. The model is calibrated on historical piezometric time series that are delivered by State Groundwater Departments.

CONCLUSION

This first year of the SHIVA-ANR project focuses on methodological issues sharing and setting which is crucial for this type of multidisciplinary work. Climate, socioeconomic and hydrological methodologies have been set and outputs are expected from the end of 2010. Next challenge for the SHIVA team concerns mapping issues. Mapping is all together a method (spatial prospective) and the "mirror" of the project results (web mapping, vulnerability mapping). Vulnerability impacts assessment issues and guidelines for policy markers and groundwater managers are expected to rely on mapping analyses and will start during the year.

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