Integrated assessment of climate change adaptation options for water resources management using participatory and hydrological modelling approaches

Ajay Gajanan Bhave [a], Ashok Mishra [b], Narendra Singh Raghuwanshi [c]

[a,b,c] *Department of Agricultural and Food Engineering, Indian Institute of Technology Kharagpur, Kharagpur-721302, India*

[a] +919564008738

[b] +919932855388

[a] ajay.bhave@agfe.iitkgp.ernet.in
[b] amishra@agfe.iitkgp.ernet.in
[c] nsr@agfe.iitkgp.ernet.in

Abstract

Climate change adaptation (CCA) is a vital strategy for river basin water management which binds together environmental, agricultural and human water requirements in an uncertain future climate. Policy makers face a difficult task balancing demand and supply for conflicting water requirements, especially to justify present day economic costs for future benefits, like in CCA. No-regret adaptation options, applicable in both, current and future uncertain conditions, provide a way of dealing with these issues. However, determination of such options needs to be based on an integrated assessment of hydrologic, environmental, social, economic and institutional characteristics to be suitable in the future. Here, a three step process for determining no-regret options is presented, having been applied to the Kangsabati River basin in India. Firstly a participatory approach is used to identify potential CCA options, followed by a Multi Criteria Analysis (MCA) to determine the no-regret and suitability characteristics for the region. This approach was replicated at three levels; community, district and state (sub-national), targeting different stakeholders. Finally, hydrological modeling using Water Evaluation And Planning (WEAP) model, of the high ranking adaptation options show the expected efficacy in hydrologic terms. MCA generated no-regret options show importance of currently promoted soil and water conservation measures, like afforestation and check dams and the need for future focus on cropping pattern change. Evaluation criteria important to different stakeholders were also determined in the process, a valuable by-product useful for future water management. Present and future scenario based modelling of CCA options provides comparability in terms of suitability, scale of impacts and costs. Such assessments can be valuable tool-set for policymakers to make evidence based decisions on choice of adaptation measures and their spatio-temporal applications to improve water availability in an uncertain climate.

Keywords – Climate change adaptation, evaluation, water, stakeholder, modelling

Introduction

Climate Change Adaptation (CCA) is an important response to climate change. Although sectoral adaptation options are often proposed (Bates et al. 2008), generic options are not suitable due to physical and socio-economic differences between regions. Suitability for local conditions, ability to address adaptation requirements and feasibility are, therefore, key characteristics of an adaptation option. Another desirable characteristic of an adaptation option is its "no-regret" characteristic. No-regret options, defined by de Bruin et al. (2009) as 'options which should be implemented irrespective of climate change', need to be examined to facilitate mainstreaming of CCA. CCA evaluation is the assessment of value of an option based on desirable characteristics (Smit and Pilifosova 2001). Due to multiple stakeholders, conflicts and natural constraints, scientific assessment and stakeholder involvement is crucial for a holistic assessment of no-regret options in the water sector. We test such an approach for the Kangsabati river basin, through the following objectives.

- Identification of adaptation options for the basin using a participatory approach
- Performance evaluation using Multi Criteria Analysis and scenario analysis.
- Hydrological evaluation of no-regret options using Water Evaluation And Planning model

Study area

The Kangsabati river basin (Figure 1) with an area of 5796 sq.km covers three districts, Purulia, Bankura and Midnapore of the eastern state of West Bengal. This agricultural basin has low socio-economic development. While high monsoon rainfall causes floods, extended dry periods cause frequent drought conditions.

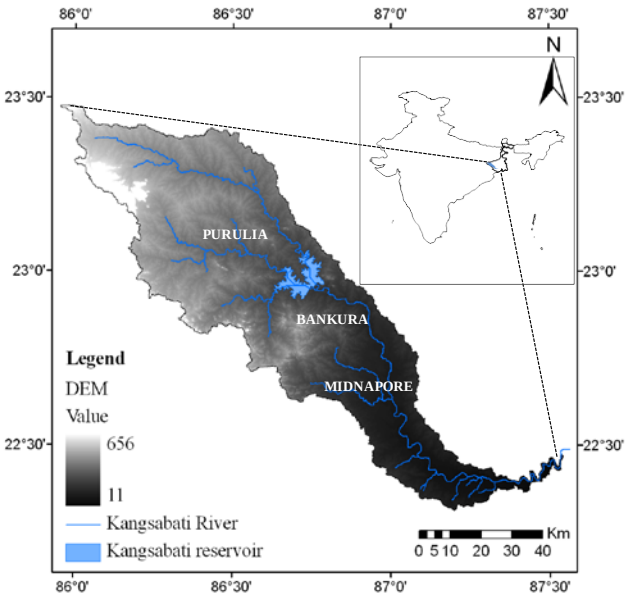

Figure 1. Study area: Kangsabati river basin and districts, Purulia, Bankura and Midnapore of West Bengal

Method

The methodology of application follows the schema shown in Figure 2. Identification and participatory evaluation of adaptation options was carried out through 11 multi-level stakeholders' consultative workshops (seven for identification and four for evaluation).

Identification Phase

For identifying adaptation options a participatory brainstorming tool, referred to as the 'problem web-solution web' was used. Stakeholders pool in their perceptions regarding water resources issues, interrelationships and target problems based on expected climate change impacts in the region. A variety of adaptation options based on target problems are then elicited to form a solution web. Through this process, basin and district level adaptation strategies were obtained.

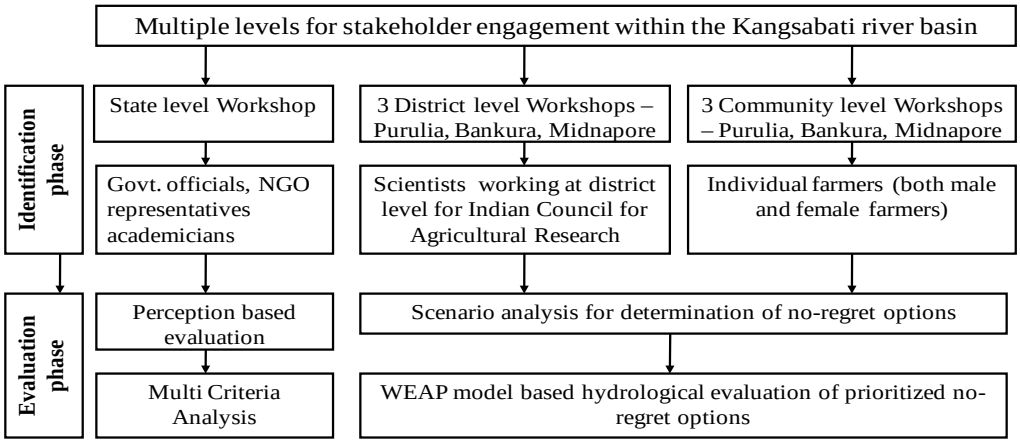

Figure 2. Schematic for identification and evaluation phases of the study

Evaluation Phase

The evaluation phase constitutes three types of analysis; MCA, scenario analysis and hydrological modelling. For MCA, stakeholders evaluated importance of each option for each criterion, on a scale of 1-10, based on their perception. Simple additive weighting, a regularly used method of MCA was used to analyse the data with the help of commercial MCA software, D-sight (http://www.d-sight.com/). Scenario analysis is used to visualize a set of conditions in the future. Here, four scenarios were created by having socio-economic development (low to high) on the Y-axis and climate change impact (low to high) on the X-axis. Stakeholders assessed applicability of each option in each scenario. This mapping revealed options applicable in all scenarios, which were interpreted as 'no-regret' options.

Modelling studies for evaluating adaptation options, such as land use change and increasing irrigation efficiency have been carried out before to determine magnitude of impact. WEAP, an integrated water resources systems model, has been used to analyse and compare future scenarios with and without adaptation and has proven advantageous (Purkey et al. 2008). After due calibration and validation of the model for the 2 sub-catchments (Kumari and Kangsabati) of the river basin, the WEAP model has been run for a future period of 2021-2050. An ensemble of four high resolution (25km) Regional Climate Model simulations (HadCM3-HadRM3, HadCM3-REMO, ECHAM5-HadRM3, ECHAM5-REMO) for A1B

future scenario has been used for incorporating future climate information. Increasing forest cover, a no-regret option determined through stakeholder process was analysed for its performance in future circumstances.

Results

A wide variety of adaptation options were revealed through stakeholder participation at different levels (Table 1). Both, district specific and basin-wide adaptation options were obtained. Being an agricultural basin, several options included improving agriculture practices.

Table 1 Adaptation options identified by state level and district level stakeholder

State level	Purulia	Bankura	Midnapore
• Changing cropping pattern • Waste water reuse • Increase forest cover and intensity • Check dams • Traditional rainwater harvesting structures	• Increasing forest cover • Happa (village pond) • Orchard development • Decentralization of water management • River lift irrigation • Check dams • Agricultural education	• Migration • Training • Increase irrigation efficiency • Livelihood diversification • Rainwater harvesting structures • Weather forecasting • Artificial ground water recharge • Improving last mile connectivity	• Awareness camp • Organic farming • Short duration varieties • Increasing forest cover • Check dam • Field bunding • Integrated farming • Crop diversification

MCA (Figure 3) revealed that waste water reuse, an important option from drinking water perspective, did not perform well against most criteria. This may be due to the low level of socio-economic development and urbanization in the region.

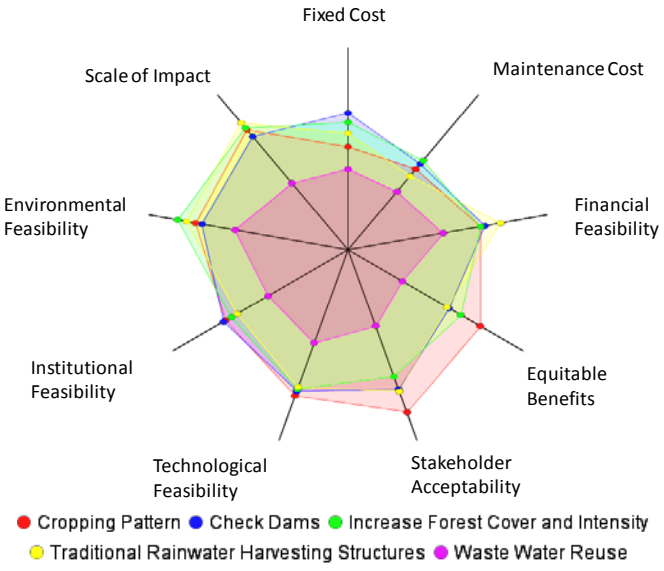

Figure 3. D-sight based MCA results of statelevel stakeholders' evaluation of options

Scenario analysis revealed several no-regret options including increasing forest cover, field bunding, organic farming, decentralization of water management, agriculture education,

rainwater harvesting systems and improving last mile connectivity. From these, increasing forest cover was chosen for hydrological evaluation. Dense forest cover was increased in the 'with adaptation' scenario by conversion of all open forest area into dense forest, and conversion of barren land into open forest. WEAP results (Figure 4 and 5) show that annual runoff decreases due to increased forest cover. This increases water availability in the basin through greater retention of rainfall in the form of soil moisture and groundwater recharge.

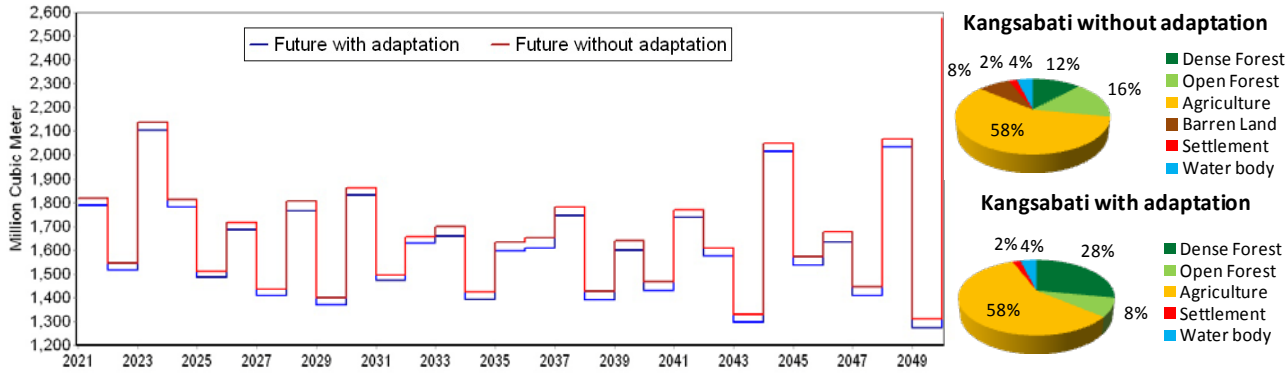

Figure 4. Comparison of annual runoff at Kangsabati sub-catchment outlet for WEAP scenarios without adaptation and with adaptation during 2021-2050 based on 4 RCM ensemble

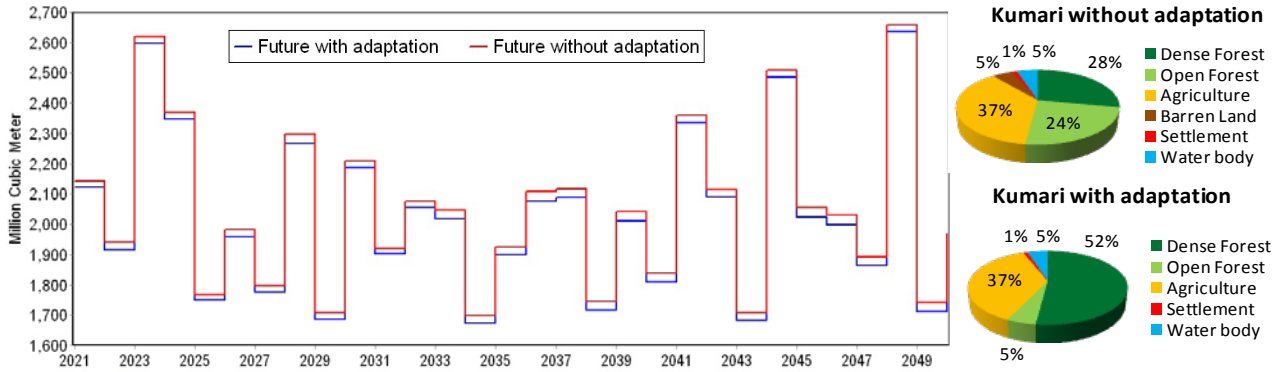

Figure 5. Comparison of annual runoff at Kumari sub-catchment outlet for WEAP scenarios without adaptation and with adaptation during 2021-2050 based on 4 RCM ensemble

Conclusion

A combined stakeholder based and hydrological evaluation of adaptation options has been carried out with specific focus on no-regret options. The study provides three main conclusions.

(i) Identification of adaptation options through stakeholder participation provides an array of options for evaluation.

(ii) Stakeholder based MCA and scenario analysis helps in prioritizing options based on local relevance and feasibility.

(iii) Integrated water resource systems models such as WEAP provide useful scenario analysis capabilities in incorporating location specific current and future climatic conditions for hydrologically relevant assessment of potential adaptation options.

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