Adaptation to Climate Change Impacts on Groundwater-based Irrigation Cost under Uncertainty

Tohoku University Member ○ Golam Saleh Ahmed SALEM
Tohoku University Member So KAZAMA

1. INTRODUCTION

Climate change is the biggest environmental threat the World facing now. Rising temperature and changes in precipitation pattern will affect water resources, agriculture, energy and many other service sectors and make the vast population around the World vulnerable. The developing countries will be affected more due to poor infrastructure and insufficient adaptation capacity. It has been projected that economic costs of climate change will be a significant portion of national GDP for many developing countries, if no adaptation and mitigation measures are taken (Stern, 2006; Tol, 2002). This emphasizes the need for assessment of possible impacts of climate change on different sectors at national and regional scales. However, large uncertainties in climate projections have made impact assessment and adaptation planning a challenging task.

Hydrological changes are the most imminent impact of climate change. Changes in rainfall pattern and surface runoff are already evident in many parts of the world. This has changed groundwater recharge potential and therefore, groundwater level in many regions. Groundwater is the major source of irrigation in many countries across the World (Sibert et al.,2010). Changes in groundwater level have changed accessibility of water for irrigation and therefore, irrigation cost. As groundwater-based irrigated agriculture is the major source of income for a vast population, it is very important to assess the impact of climate change on groundwater level. The uncertainty in climate change projections is also required to take into consideration in adaptation planning. The objective of this study is to propose adaptation measures to mitigate climate change impacts on groundwater level with consideration the uncertainties in climate change impacts. It is expected that the finding of this study will facilitate decision makers in mitigation of climate change impacts in groundwater based irrigated agriculture.

2. STUDY AREA

The study area, located in northwest Bangladesh has a flat and low-lying topography with high population density. The study area (Fig. 1) extends from lat: 23.87˚ N to 24.78˚N; lon: 88.30˚ E to 88.89˚E), is part of the Ganges River basin. The mean annual rainfall in the region is 1500 mm of which about 75% occurs during the monsoon season (June to September) (Shahid, 2009). The maximum depth of groundwater level varies 2 to 18 m from the land surface in the study area. The major crops of High yield Boro rice cultivated during the dry season (January to May) contribute effectively to ensure food security of Bangladesh. Groundwater is the major source for irrigation in dry season rice. Most of Shallow tube well (STW) in the study area go blew the suction lift capacity in the irrigation period (Bangladesh Agricultural Development Corporation, 2006).

3. METHODOLOGY AND DATA

The bi-monthly data of the groundwater level recorded at 10 observation wells across the study area over the period 1991 to 2009 were collected from the Bangladesh Water Development Board (BWDB). Daily time series of rainfall, temperature and solar radiation were recorded at the Rajshahi (district) station located within the study area over the period 1991-2009 were collected from the Bangladesh Meteorological Department (BMD). The calendar for irrigated crops reported by (Mainuddin et al. 2015) was used to determine the irrigation periods. The climate downscaling, hydrological and irrigation cost models were integrated in this study to assess the impacts of climate change induced changes in groundwater level and consequent changes in irrigation cost. An empirical model was developed using SVM for simulation of groundwater depth from surface using climate and other influencing factors. A MLR model was developed to predict irrigation cost from groundwater level and other factors. Suitability of adaptation measures depends on different criteria including its acceptance to local community, cost-effectiveness and complexity (Kazama, 2011).

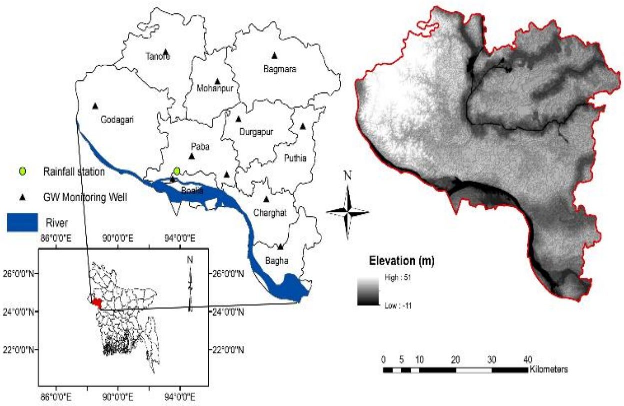

Fig.1 Location of study area and groundwater sampling points

Considering the social-economic condition of the study area and cost-effectiveness, two adaptation measures are found feasible for the study area — (i) the reduction of excess water use for irrigation; and (ii) shifting of harvesting date.

4. RESULTS AND DISCUSSION

4.1 Hydrological model calibration and validation

Separate SVM model was developed for each groundwater monitoring well. The SVM models were calibrated and validated with 70% and 30% of the

Keywords: groundwater level, adaptation, irrigation cost, Northwest Bangladesh.
Tohoku University, 6-6-20 Aoba Aramaki, Aoba-Ku, Sendai 980-8579, Japan. Tel & Fax: +81-22-795-7455

observed groundwater depth data, respectively. The RMSE values were found very low (0.84-2.12), and R^2 and NSE values were found greater than 0.59 in all of the cases.

4.2 Climate Change impact on Groundwater Depth

The calibrated and validated SVM models were used to project future changes in groundwater depth under the projected climate. It was found to decrease in the range of 0.04 m to 0.5 m for RCP 2.6, 0.02 m to 0.79 m for RCP 4.5 and 0.1 m to 1.23 m for RCP 8.5. The higher declination of groundwater table for RCP8.5 might be due to the higher increase of temperature for this scenario compared to other scenarios.

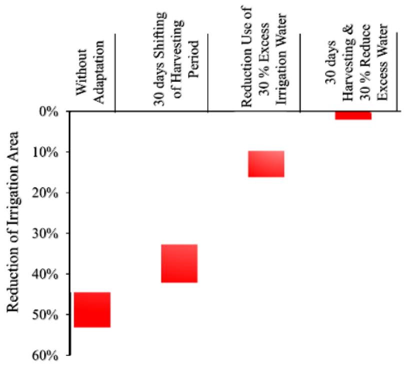

Fig.2 Reduction of irrigated lands required to revert declination of groundwater level for different adaptation measures.

4.3 Uncertainty in the Projected Groundwater Depth

The groundwater depths projected by different GCMs were used to estimate the uncertainty in the groundwater depth using Bayesian method. The upper and lower bounds of 95% confidence interval band along with the mean of the projected groundwater levels for the different future periods under three RCP scenarios.

4.4 Adaptation Measures for Sustaining Groundwater

Reduction of irrigated lands required to revert declination of groundwater level for different adaptation measures are shown in Figure 2.1. Groundwater irrigated area has to be reduced in the range of 44.1 to 53.2% to adapt with climate change impacts on groundwater level, with no adaptation measures are taken. By shifting of harvesting date by 30 days, the groundwater irrigated area has to be reduced in the range of 32.1 to 42.2% in order to adapt with climate change impacts under different scenarios with uncertainty. Reduction of the use of excess irrigation water up to 30% by growing awareness among the farmers and the reduction of groundwater irrigated area in the range of 7.1 to 16.2% can maintain the groundwater depth within sustainable limit.

The results indicate that both adaptation measures have significant impact on groundwater level. However, the reduction of excess water use by 30% as an adaptation measures have higher impact as the irrigated area reduction is far less for this adaptation measure compared to shifting of harvesting date by 30 days. However, both measures together can be every effective for the study area as almost no requirement of reduction of irrigated area when both are implemented. Therefore, those two adaptation measures can be implemented for sustainable management of groundwater resources in the area as well as to reduce the irrigation cost and increase farmer’s profit.

5. CONCLUSIONS

High dependency on groundwater for irrigation is the major cause of groundwater level declination in Northwest Bangladesh. Irrigation is 21.81% of the total cost of paddy production in Northwest Bangladesh. Therefore, the increased irrigation cost will certainly increase the price of rice in Bangladesh. Present study assessed the effectiveness of two adaptation measures namely, reduction of excess use of water for irrigation and shifting of harvesting date by 30 days. The study indicates that adoption of those two measure can effectively mitigate the negative impacts of climate change on groundwater level and irrigation cost in the study area. Sensitivity assessment of two measures shows that reduction of excess water use in irrigation is more effective compared to other adaptation measure in the study area. It is expected that the finding of the study will help decision-making in planning climate change adaptation.

ACKNOWLEDGEMENTS

This research was supported by Advancing Co-design of Integrated Strategies with Adaptation to Climate Change (ADAP-T) of JST/JICA, SATREPS.

REFERENCES

Bangladesh Agricultural Development Corporation (2006) Minor irrigation survey report, 2005-06 Irrigation Wing, Bangladesh Agricultural Development Corporation. Ministry of Agriculture, Government of the People's Republic of Bangladesh, Bangladesh.

Siebert S, Burke J, Faures J.-M, Frenken K, Hoogeveen J, Doll P, Portmann FT (2010) Groundwater use for irrigation- global inventory. Hydrology Earth System Science 14: 1863-1880.

Kazama S (2011) Climate change impacts and responses. In: Sumi A, Mimura N, Masui T (ed) Climate Change and Global Sustainability, United Nations University Press, Tokyo.

Mainuddin M, Kirby M, Chowdhury RAR, Shah-Newaz SM (2015) Spatial and temporal variations of, and the impact of climate change on, the dry season crop irrigation requirements in Bangladesh. Irrigation Science 33:107–120.

Stern, N. H. (2006). The economics of climate change. The Stern Review. HM treasury London, UK.

Shahid S (2009) Spatio-temporal variability of rainfall over Bangladesh during the time period 1969-2003. Asia-Pacific Journal of Atmospheric Science 45: 375-389.

Tol, R. S. J. (2002). Estimates of the damage costs of climate change, Part I. Benchmark estimates. Environmental and Resource Economics 21:47-73.