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Impacts of Climate Change on Rice Production and Farmers' Adaptation in Bangladesh

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Abstract

Bangladesh is frequently cited as one of the countries most vulnerable to climate change, despite the country's insignificant contribution to climate change. Crop production, especially rice, the main food staple, is the most susceptible to climate change and variability. Any changes in climate will, thus, increase uncertainty regarding rice production as climate is major cause of year-to-year variability in rice productivity. This thesis is motivated partly by the susceptibility of rice farming to climate change and partly by the limited studies of Bangladesh on this topic. The overall aim of this thesis is, thus, to analyse the impact of climate change on rice production at three levels (aggregate-national, disaggregated-climate zone and micro-farm level), and to evaluate the adaptation strategies practised by farmers in a severely drought-prone area.

At the aggregate level, this thesis first investigated national data from secondary sources to examine changes in maximum temperature, minimum temperature and rainfall over the past 60 years. Results from a linear trend model reveal that the time trend is statistically significant for all three major climate variables. This implies climate has changed over the whole period. However, the findings from quantile regression indicate that the explanatory power of the time trend is higher in the higher quantiles than the lower quantiles for all three climate variables. This latter method thus offers a more complete picture of the changing climate at different points of time. Given these changes in climate and using production function theory, an evaluation of the impacts of changing climate on the yields for three rice crops in Bangladesh: Aus, Aman and Boro, was made. The findings confirm that the changes to both maximum and minimum temperatures are statistically significant for Aus and Boro rice. However, changes to the average minimum temperature are found to affect Aus rice production adversely and the average maximum temperature is also negatively related to Boro rice yield. On the contrary, the impacts of maximum temperature and rainfall are more pronounced for Aman rice compared to minimum temperature whose effects are adverse. Given these adverse effects of temperature on rice crops, policy makers should design strategies for the development and use of temperature tolerant rice varieties. However, this analysis of national level data

is unable to reveal regional level differences in climate and their differential impacts on rice yield which warrants disaggregated level analysis.

Under the theoretical framework of Just-Pope stochastic production function, the objective of the disaggregated level analysis was to assess the effects of climate change on the yield and variability of Aus, Aman and Boro rice using cross-sectional time series (panel) data. The results reveal that maximum temperature is risk increasing for Aus and Aman rice while it is risk decreasing for Boro rice yield. Minimum temperature is risk increasing for Boro rice and risk decreasing for the Aus and Aman varieties. Finally, rainfall is risk increasing for Aman rice whilst risk decreasing for Aus and Boro rice. Moreover, future climate change is expected to increase the variability of rice yield for all three rice crops. Disaggregated level analysis, thus, provided more information than aggregate level analysis. However, the disaggregated level data is unable to show how individual farmers are affected by climate change which necessities a farm level analysis of impact and adaptation.

The farm level analyses employed data from a survey of 550 farm households in a severely drought-prone area of Bangladesh. Descriptive statistics reveal that net revenue and production loss from Aman rice vary between different subsamples of farmers. For example, mean profit was significantly higher for large and medium farmers compared to small and landless farmers while the latter group of farmers faced higher mean production losses. Integrated farms have higher net revenue compared to rice only farms. Moreover, production losses for highly irrigated farms are lower than for less irrigated farms. Further, results from both mean and median regression on the determinants of profit and production loss indicate significant variables that can be targeted to increase profit or decrease production loss. These include age, years of schooling of household head, household yearly total income, household assets, land tenure, access to agricultural extension services, weather information, electricity and subsidy, percentage of land under irrigation, crop selling at local market, and distance to local or nearby urban market. Government policy initiatives should include support for integrated farming, increasing the provision of education, providing regular weather forecasts, giving subsidies to very

small and landless farmers, distributing government owned fallow lands to small farmers, and adopting water saving irrigation technologies.

Farmers have taken some adaptation strategies to reduce these adverse effects on rice production. The major adaptation strategies include higher levels of irrigation, cultivation of short-duration rice varieties, changing planting dates, agro forestry, use of different crop varieties and cultivation of non rice crops. Estimates from a multinomial logit model specify that age, gender and education level of household head, household annual total income, household assets, farm size, tenure status, farming experience, access to agricultural credit, availability of subsidies, electricity at home, and farmer-to-farmer extension services all affect adaptation choices. Therefore, policy makers should target these determinants to boost farmers' adaptation and thereby diminish the adverse effects of climate change.

The analytical framework used in this study has produced robust results. It should be replicated in other developing countries experiencing adverse climate change and having similar characteristics to Bangladesh.

Certification of dissertation

I hereby certify that the work embodied in this dissertation is the result of my own research. I also declare that it has not been submitted for a higher degree to any other institution or university.

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Name and Signature of Candidate Date

Endorsement

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Name and Signature of Principal Supervisor Date

Professor Jeff Gow

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Publications from this research

Journal Papers

1. Sarker, MAR, Alam, K, Gow, J (2012), 'Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data', *Agricultural Systems,* vol. 112, pp. 11-16.

2. Sarker, MAR, Alam, K, Gow, J (2012), 'How does the variability of Aus rice yield respond to climate change in Bangladesh?', *Journal of Agronomy and Crop Science* (Accepted).

3. Sarker, MAR, Alam, K, Gow, J (2012), 'Assessing the determinants of rice farmers' adaptation strategies in Bangladesh', *International Journal of Climate Change Strategies and Management*, (Accepted).

4. Sarker, MAR, Alam, K, Gow, J (2012), 'Performance of rain-fed Aman rice yield in Bangladesh in the presence of climate change', *Crop and Pasture Science* (Under review).

Conference Paper

1. Sarker, MAR, Alam, K, Gow, J (2012), 'A comparison of the effects of climate change on Aus, Aman and Boro rice yields in Bangladesh: Evidence from panel data', Proceedings of the 41st Australian Conference of Economists, July 8-11, 2012, Melbourne.

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Dedication

In fond memory of my father, the late Abdul Mazid Sarker and my eldest brother, the late Abdul Khaleque Sarker.

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List of abbreviations and acronyms

ADF	Augmented Dickey Fuller
AEO	Agriculture Extension Officer
AEZ	Agro-ecological Zone
AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
AWD	Alternate Wet and Drying
BADC	Bangladesh Agricultural Development Corporation
BBS	Bangladesh Bureau of Statistics
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BIC	Bayesian Information Criterion
BMD	Bangladesh Meteorological Department
BMDA	Barind Multipurpose Development Authority
BRRI	Bangladesh Rice Research Institute
CGE	Computable General Equilibrium
cm	centimetre
CO_2	Carbon Dioxide
CV	Coefficient of Variation
DAE	Department of Agricultural Extension
DOE	Department of Environment
DTW	Deep Tube Well
FAO	Food and Agriculture Organisation
FGLS	Feasible Generalised Least Squares
GCM	General Circular Model
GDP	Gross Domestic Product
GOB	Government of Bangladesh
HBT	High Barind Tract

HYVs	High yielding varieties
IFPRI	International Food Policy Research Institute
IIA	Independent of Irrelevant Alternatives
IPCC	Intergovernmental Panel on Climate Change
Kg	Kilogram
MLE	Maximum likelihood estimates
mm	millimetre
MNL	Multinomial logit
MNP	Multinomial probit
MOEF	Ministry of Environment and Forest
NAPA	National Adaptation Programmes of Actions
NGOs	Non-Government Organisations
OLS	Ordinary least squares
PP	Philips and Perron
ppm	parts per million
PVC	Polyvinyl Chloride
QR	Quantile regression
RRR	Relative risk ratio
SAAOs	Sub-Assistant Agricultural Officers
T. Aman	Transplanted Aman
UNDP	United Nations Development Programme
VIF	Variance Inflation Factor
WB	World Bank