Proceedings of the Australasian Conference on Business and Social Sciences 2015, Sydney
(in partnership with The Journal of Developing Areas)
ISBN 978-0-9925622-1-2

THE IMPACT OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTIVITY: EVIDENCE FROM PANEL DATA OF BANGLADESH

Kazi Iqbal
Bangladesh Institute of Development Studies, E-17 Agargaon, Sher-e-Bangla Nagar, Dhaka 1207, Bangladesh
kiqbal@bids.org.bd

Abu Siddique
University of Western Australia
35 Stirling Highway
Crawley WA 6009, Australia abu.siddique@uwa.edu.au

Abstract: This paper studies the impact of climate change on agricultural productivity in Bangladesh for the period 1975-2008 for 23 regions. First, the study relies on descriptive statistics and maps to explore the long term changes at both country and local level in climatic variables such as temperature, rainfall, humidity and sunshine. Second, it uses regression models to estimate the impact of climate change on agricultural productivity. Unlike the existing literature, this study exploits within-region time series variations (regional fixed effect) to estimate the impact of long term changes in climatic variables on agricultural productivity in order to control for regional differences, both observed and unobserved. The results show that long term changes in means and standard deviations of the climatic variables have differential impacts on the productivity of rice and thus the overall impact of climate change on agriculture is not unambiguous.

Key words: Agricultural productivity, climate change, Bangladesh

JEL Classification: O13, Q18, Q54

1. Introduction

Bangladesh is identified as one of the most vulnerable countries to climate change. There are numerous projections about temperature and sea-level rises and their potential impacts. IPCC estimated that a 0.5 degree Celsius increase in mean temperature and a 10cm rise in sea level could lead to inundation of 15 percent (approximately 750 km^2) of the Sundarban forest, the largest mangrove ecosystem in Asia (Intergovernmental Panel on Climate Change - IPCC, 2001). A World Bank study (2000) projects that by the year 2050, average temperature will increase by 1.8 degrees Celsius, precipitation will fluctuate 37 percent compared to 1990 in the dry season, and sea levels will rise by 50 cm in Bangladesh. Between 1972 and 2009, per capita carbon dioxide emissions in Bangladesh also increased by a factor of 6.68. There is also a clear trend of increasing emissions of methane (United Nations Environment Programme - UNEP 2013).

Since agriculture is highly dependent on climate in developing countries, changes in climatic variables are likely to impact agriculture more than other sectors such as services or manufacturing. Climatic variables such as atmospheric carbon dioxide concentration, rainfall, humidity, temperature, etc. are found to affect agricultural output (IPCC, 2001).The scientific models that forecast the impact of various scenarios of climate change on the production of cereal crops indicate that potential yields are projected to decrease for most projected increases in temperature changes in most tropical and subtropical regions (IPCC, 2001).

While the literature on the impact of climate change on agricultural productivity is fraught with numerous scientific models, the use of econometric models controlling for region and period specific unobserved heterogeneity is uncommon (see Table A_1 for details on literature review). To this end, this study compiles and uses a unique data set of 23 regions of Bangladesh for the period 1974-2008 (see Table A_2). We first use descriptive statistics and maps to

ISBN 978-0-9925622-1-2

track the changes in climatic variables and agricultural productivity. Second, we use region (agricultural zones) and year fixed effects to estimate the impact of changes in temperature, rainfall, humidity and sunshine on agricultural productivity. We use agricultural output per acre (only rice), and agricultural output per acre (only Boro rice), as measures of agricultural productivity. We consider Boro rice separately because it constitutes about two-thirds of total rice production in Bangladesh.

The descriptive statistics show that average temperature in the wet seasons has increased while dry seasons experienced more temperature fluctuations. Rainfall for both seasons has generally increased, but with more regional variation in the wet season. Average bright sun conditions for the country have declined over time for both seasons, while average relative humidity has generally increased, with both variables exhibiting regional variations.

Regional variations of the climatic variables are also very significant. Khulna and Rajshahi (eastern part of the country) have experienced some of the hottest temperatures throughout the entire period under study in wet season. On the other hand, in the dry season, the average maximum temperature is found to be higher in the south-western region of the country. Average rainfall in the dry season seems to have increased generally for the entire country with the eastern regions, Sylhet and Chittagong, having the greatest increases. In the wet season, average bright sun has decreased for the western half of the country over time. Average relative humidity has increased in general for the entire country over time, again showing some regional variations.

Regression results show that both average temperatures and temperature variability (standard deviation) affect rice output per acre significantly, though the effect is not unidirectional. The impact of temperature on rice productivity varies significantly with the inclusion of region and year fixed effects. While an increase in average minimum temperature increases rice productivity in the dry season, it has opposite impact in the wet season. Fluctuations in minimum and maximum temperature are found to have a negative impact on productivity. The impacts of rainfall, bright sun and relative humidity are found to lose significance when the year specific effect is controlled for. In the case of Boro rice, productivity decreases with fluctuation of maximum temperature.

This paper is structured as follows. Section 2 provides an overview of existing literature and examines some of the limitations that previous studies have faced. Section 3 describes the data chosen to represent changes in climatic conditions and agricultural productivity, whilst Section 4 displays descriptive statistics for this data. Section 5 describes the long-term variation in climate variables at the regional level, and Sections 6 and 7 describe the regression model and provide a discussion of the regression results.

2. Literature Review

Unfortunately, literature relating to the effects of climate change on agriculture in Bangladesh is sparse and decidedly qualitative. A number of papers on Bangladesh's risk, vulnerability and adaptations to climate change (Ali, 1999; Agrawala *et al*, 2003; Huq *et al,* 2004*;* Brouwer *et al,* 2007) have been policy focused and have lacked quantitative techniques to isolate the impact of climate change on agricultural productivity from other confounding factors.

Agrawala *et al* (2003) used a subjective ranking system to identify key vulnerabilities Bangladesh faces from climate change based on circulation models and previous studies[1] of the country. The authors assessed agriculture as having a medium "certainty of impact" risk, low-medium "timing of impact" risk, low-medium "severity of impact" risk and high "importance of resource" risk based on the studies identified on Bangladeshi agriculture and their relative assessment of the other risk areas (Huq *et al*, 1995; Islam *et al*, 1999). Interestingly, agriculture ranked last behind water resources, coastal resources and human health. Agrawala *et al* discounted the impact of climate change on agriculture because some of the possible beneficial and adverse effects of climate change on crop yield may

[1] This includes national communications, country studies and scientific literature.

offset each other: A higher frequency of extreme, potentially crop damaging weather events could be offset by higher crop yields with modestly warmer temperatures.

The effects of climate change are inherently region specific, inciting the need for region-based research on climate change. Ruttan (2002) noted this, saying rainfall and sunlight could potentially alter agricultural productivity but the gross effect was largely region-specific. Specifically discussing Bangladesh, Rashid and Islam (2007) identified droughts, floods, salinity and cyclones as the major extreme climatic events to which Bangladeshi agriculture is most vulnerable. Additionally, they identified a series of structural adaptations necessary to mitigate potential impacts of climate change on agriculture, including: crop diversification away from those most vulnerable to climatic changes; improving water efficiency; improving crop production strategies; investing in measures to mitigate the impact of cyclones and other natural disasters; reclaiming soil salinity by investing in cultivating Boro rice and sweet water shrimp; and investing in machinery to expedite farming operations.

Previous studies based on scientific models in Bangladesh have employed the CERES[2]-Rice and DSSAT[3] models (Karim *et al*, 1996; Mahmood, 1998; Mahmood *et al*, 2004; Basak *et al*, 2010) to assess climate change influence on agriculture. These models simulated the effects of rising temperature and CO2 concentration on rice.

Karim *et al* (1996) conducted a series of simulations using the CERES-Rice and -Wheat models for Aus, Aman and Boro rice, and wheat. They tested the sensitivity of the crops to three different levels of atmospheric carbon dioxide concentration (330, 580, and 660 parts per million) and two levels of temperature increases (2 and 4 degrees Celsius). They found that while higher concentrations of CO_2 increased yields with temperature unchanged, higher temperatures adversely affected yields even with higher CO_2 concentrations.

Basak *et al* (2010) concluded that climate change was likely to have predominately adverse impacts on the yield of Boro rice. They found that if climate change was to result in increased temperatures, ~~that~~ this would cause grain sterility during the growing season and hence a reduced yield. They also found that while changes to the level of atmospheric carbon dioxide and solar radiation might offset the impact of increased temperatures to some degree, that it would not be sufficient to mitigate it altogether. Mahmood *et al* (2004) observed that since rain-fed rice constitutes over 50% of total rice production in Bangladesh, production of this crop is extremely vulnerable to volatility in the supply of water. Early monsoon arrival can cause flood damage to rice seedlings in early growth stages, whilst late monsoon arrival can lead to water stress. Their application of the CERES-Rice model found that high water stress could lead to yield losses as high as 70% to rice plants in both flowering and maturing stages, suggesting potentially disastrous impacts for rice production from changes to seasonal monsoon occurrence caused by climate change.

Sarker *et al* (2012) performed time series analysis to assess this question for three major rice crops (Aus, Aman and Boro) in Bangladesh at the aggregate level using both Ordinary Least Squares and median quantile regression. However, this study did not account for regional variations and unobserved heterogeneity. The authors use maximum and minimum temperature and rainfall as climate variables and found a significant relationship between climate change and agricultural productivity. They found that minimum temperature was significant only for the Aman and Boro varieties, with a negative impact on output in the former case and a positive impact in the latter. Maximum temperature was found to be significant for all varieties, with a positive impact on output of Aus and Aman and a negative impact on Boro output. Finally, rainfall was found to be significant only for Aus and Aman, with a positive impact on output for both varieties.

[2]Crop Estimation through Resource and Environment Synthesis
[3]Decision Support System for Agrotechnology Transfer

ISBN 978-0-9925622-1-2

3. Data on climatic variables and agricultural output

Weather data

We collect monthly average rainfall, monthly average maximum and minimum temperature and monthly average humidity and average bright sun data for the period 1975-2008 from Bangladesh Agricultural Research Council (BARC).There are 32 weather stations in Bangladesh and hence weather data varies only across weather stations. Therefore, the challenge is to assign weather stations to each region. In some cases a region has multiple weather stations and we use a simple average of all stations' data. Table A_2 in the appendix shows the regions and their corresponding weather station(s).

The weather variables include mean and standard deviations of temperature (maximum and minimum), rainfall, bright sun and relative humidity. Since crops follow a seasonal calendar and weather varies significantly between seasons, we split a year into two seasons – dry (Oct- March) and wet (April-Sept). All weather variables are, thus, for two seasons. Not only the average but also the fluctuation of temperature in each season might have an impact on agricultural productivity. And in order to account for fluctuations we use the standard deviations of the relevant weather variables.

Average monthly rainfall data is available and based on these data, we create seasonal average rainfall for dry and wet seasons. And similarly seasonal data on bright sun and relative humidity conditions are created.

The average maximum and minimum temperatures during both the dry and wet seasons did not fluctuate much throughout the period under study and they were close to their mean values for the full sample. Both the maximum and minimum temperatures in the dry season tend to fluctuate although the variation is less for minimum temperatures while for the wet season fluctuations are high for both cases. For the case of rainfall in the country, both the averages for dry and wet seasons clearly show an upward trend over the years albeit with some fluctuations as depicted by their associated standard deviations. For the dry season, the standard deviation is mostly increasing over time although it dropped during the 1980s, while the wet seasons show much greater fluctuations over time. Recorded values for average bright sun[4]have clearly fallen over the years for both dry and wet seasons, while their standard deviations suggest greater variability with time. The average relative humidity[5] has been increasing for all years for the dry seasons while the trend for the wet season is less clear and both show fluctuations over time as their standard deviations are also found to vary.

Agriculture Data

This study considers only rice and it includes three types of rice - Aus, Aman and Boro. The source of agriculture data used is the Yearbook of Agricultural Statistics, BBS, which has been published regularly since 1974 except for the year 1990. The Yearbook reports agricultural data at the regional level. There are 23 agricultural regions defined by the BBS and each region is composed of one or more current administrative districts. The Yearbooks of Agricultural Statistics produce estimates of acreage, production and yield per acre for more than 100 crops grown in the country.

[4]Average bright sun conditions are measured as the average number of hours per day with bright sun in the dry and wet seasons.

[5]Humidity, the amount of water vapor in the air, has three types of measurements: absolute, relative and specific humidity. We use the Relative Humidity measure, which expressed as a percent, measures the current absolute humidity *relative* to the maximum for that temperature with absolute humidity being the water content of air.

ISBN 978-0-9925622-1-2

4. Long term changes in agricultural productivity

Table 1: Productivity of rice: 1975-2008 (tons per acre)

Rice	1975	1980	1990	2000	2008	Full samples
Aus	0.391 (0.134)	0.392 (0.083)	0.470 (0.091)	0.532 (0.112)	0.645 (0.140)	0.493 (0.140)
Aman	0.698 (0.826)	0.538 (0.146)	0.672 (0.127)	0.752 (0.130)	0.772 (0.180)	0.657 (0.220)
Boro	0.832 (0.214)	0.924 (0.156)	0.992 (0.154)	1.198 (0.000)	1.512 (0.186)	1.085 (0.265)
Rice	0.583 (0.430)	0.519 (0.112)	0.704 (0.103)	0.702 (0.118)	1.090 (0.206)	0.695 (0.225)

Note: standard errors in parentheses.

From Table 1, we find that the productivity of rice (in terms of ton per acre) has increased steadily over the years. In 1975, production of rice per acre was only 0.58 tons, which picked up sharply in the 1980s and 2000s. In 2008, production per unit stood at 1.09 tons per acre. This increase in productivity is largely due to Boro and Aus.

5. Long term regional variations of climatic variables

Table 2: Changes in climatic variables (means values for the regression sample)

Variables	1975	1980	1990	2000	2008	Full Sample
Avg. max temp. in dry season	28.658 (0.354)	28.595 (0.529)	28.006 (0.433)	28.53 (0.598)	28.267 (0.577)	28.635 (0.737)
Avg. min temp. in dry season	17.047 (1.504)	17.701 (1.234)	16.791 (1.038)	17.292 (0.959)	17.369 (0.962)	17.092 (1.151)
Avg. max temp. in wet season	32.115 (0.979)	32.014 (0.727)	31.804 (0.648)	31.873 (0.629)	32.626 (0.696)	32.189 (0.836)
Avg. min temp. in wet season	24.743 (0.396)	25.037 (0.462)	24.814 (0.465)	24.927 (0.371)	25.195 (0.37)	24.948 (0.528)
Sd. of max temp. in dry season	3.229 (0.315)	2.853 (0.334)	2.139 (0.472)	2.727 (0.41)	3.033 (0.423)	2.87 (0.495)
Sd. of min temp. in dry season	4.679 (0.422)	4.229 (0.363)	4.213 (0.376)	4.341 (0.318)	4.453 (0.44)	4.293 (0.418)
Sd. of max temp. in wet season	1.441 (0.538)	1.368 (0.421)	0.727 (0.173)	0.806 (0.316)	1.274 (0.412)	1.166 (0.434)
Sd. of min temp. in wet season	0.978 (0.449)	1.12 (0.423)	1.541 (0.429)	1.198 (0.419)	1.179 (0.373)	1.264 (0.493)
Avg. rainfall in dry season	33.255 (14.490)	37.210 (15.178)	76.7 (38.66)	66.876 (20.499)	70.252 (29.411)	47.837 (24.793)
Avg. rainfall in wet season	293.892 (106.698)	317.56 (76.819)	321.426 (107.401)	381.897 (100.622)	329.653 (80.622)	330.201 (100.423)
Sd. of rainfall in dry season	63.506 (27.327)	34.975 (16.319)	112.901 (68.293)	105.95 (41.246)	97.453 (57.587)	72.92 (46.528)

ISBN 978-0-9925622-1-2

Sd. of rainfall in wet season	201.532 (80.700)	188.295 (46.068)	178.047 (80.094)	160.725 (71.384)	228.946 (62.151)	187.343 (76.188)
Avg. bright sun in dry season	8.974 (0.324)	8.061 8.061	7.013 (0.331)	7.307 (0.495)	6.551 (0.488)	7.519 (0.77)
Sd. of bright sun in dry season	0.900 (0.193)	0.524 (0.246)	0.964 (0.347)	1.28 (0.195)	0.862 (0.275)	0.866 (0.333)
Avg. bright sun in we t season	6.138 (0.318)	5.726 (0.343)	5.219 (0.464)	4.782 (0.486)	5.243 (0.339)	5.461 (0.62)
Sd. of bright sun in wet season	2.451 (0.090)	1.542 (0.281)	1.526 (0.154)	1.633 (0.352)	2.16 (0.258)	1.745 (0.362)
Avg. relative humidity in dry season	72.587 (3.975)	72.867 (2.580)	78.899 (1.63)	78.487 (1.495)	79.352 (1.812)	75.436 (4.059)
Sd. of relative humidity in dry season	7.134 (1.928)	6.719 (2.990)	3.995 (0.805)	5.271 (0.738)	4.148 (0.938)	5.882 (2.062)
Avg. relative humidity in wet season	81.561 (2.501)	81.108 (2.242)	84.005 (1.274)	85.397 (1.108)	82.944 (1.873)	82.626 (2.47)
Sd. of relative humidity in wet season	7.197 (2.623)	7.563 (2.931)	3.64 (0.89)	4.054 (1.036)	5.884 (1.089)	5.642 (2.365)

Note: standard errors in parentheses.

Both average maximum and minimum temperatures in the dry and wet seasons show some fluctuations over the years around their mean value for the period under consideration. For both seasons, average maximum and minimum temperatures are found to decline slightly in 1990 but then increased again afterwards. Overall average temperatures in both seasons generally show an upward trend. Fluctuations in the minimum and maximum temperatures, as measured by the standard deviations, in both seasons show a declining trend from 1975 to 1990 but afterwards follow an increasing trend. An exception to the above mentioned pattern of fluctuations is found in the minimum temperature in the wet season. It shows an upward trend up to 1990, declines afterwards, but maintains a general upward trend. Average rainfall in the dry season has almost doubled in value from 1980 onwards while average rainfall in wet season generally shows an upward trend with some fluctuations over the period. Fluctuations in rainfall have been generally increasing for the dry season while showing greater variation in the wet season but increasing overall. Average bright sun shows a clearly decreasing trend over time for the dry season with generally declining fluctuations, while almost similar trends are also seen in the case of the wet season. Over time average relative humidity has generally followed an upward trend in both seasons but with reduced fluctuations.

Change in weather in Bangladesh by region: 1980—2008

Since we exploit the regional variations in weather variables in order to explain the variations in agricultural productivity, we have created some maps of Bangladesh that will capture how the climate has changed over time in different parts of the country.

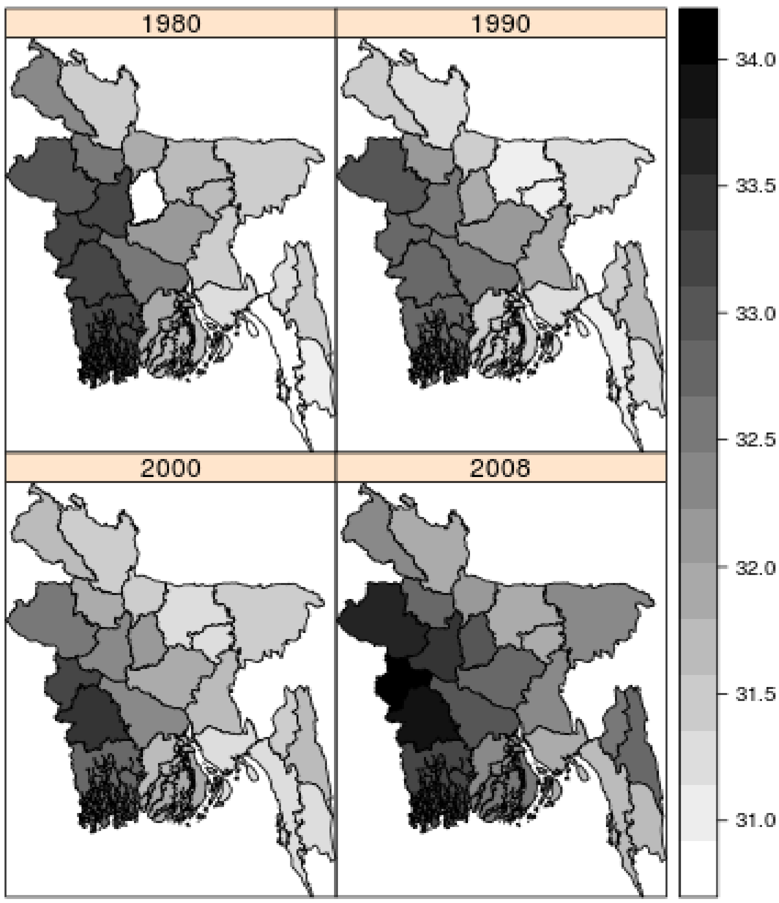
The maps below show the changes in the region wise variation in the average maximum temperature in the wet season. They track changes in the average maximum temperature in the wet season from the 1980s to the 2010s. In 1980, Khulna and Rajshahi were among the hottest areas in the wet season with an average maximum temperature of around 34^0C while Sylhet and parts of Chittagong were the coolest with an average of around 31^0C. In 1990, parts of Dhaka, Rangpur and Barisal became colder while some parts of Chittagong turned warmer. This trend is found further in 2000 with Barisal and Sylhet and parts of Rangpur getting even warmer. More recently, in 2008, Dhaka grew much warmer and joined Khulna and Rajshahi's range of average maximum temperature in wet season while

ISBN 978-0-9925622-1-2

Barisal, Sylhet, Rangpur and parts of Chittagong also followed the upward trend in temperature. The general picture is that the pattern of change of average maximum temperature across the country is heterogeneous.

i. Average Maximum Temperature in Wet Season

Map 1: Average maximum temperature, wet season

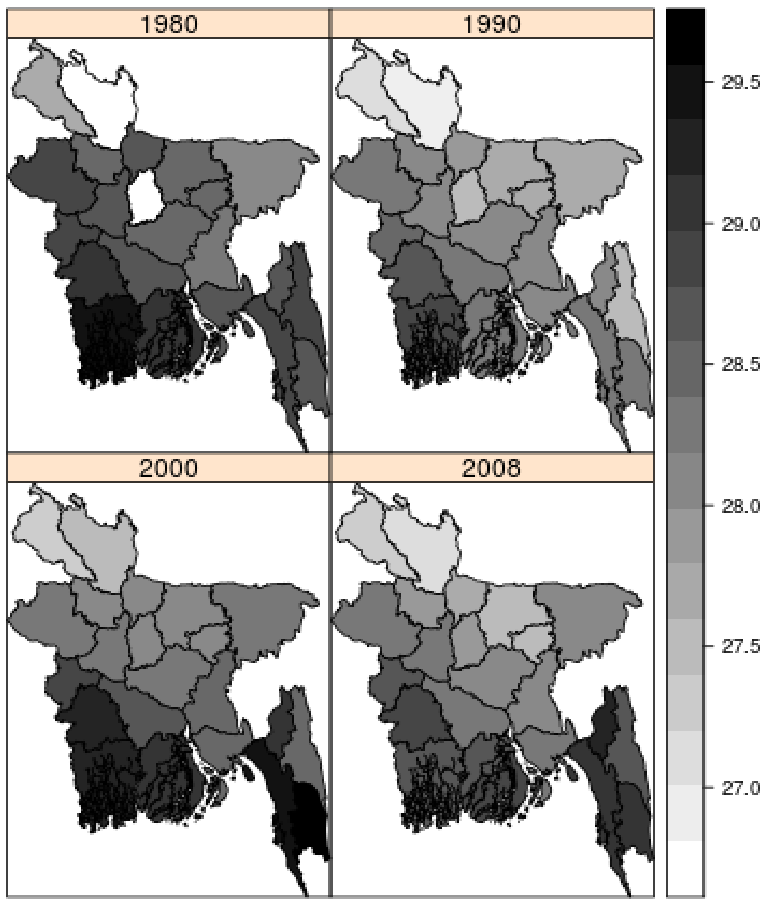


Source: Created by authors.

ISBN 978-0-9925622-1-2

ii. Average Maximum Temperature in Dry Season

Map 2: Average maximum temperature, dry season



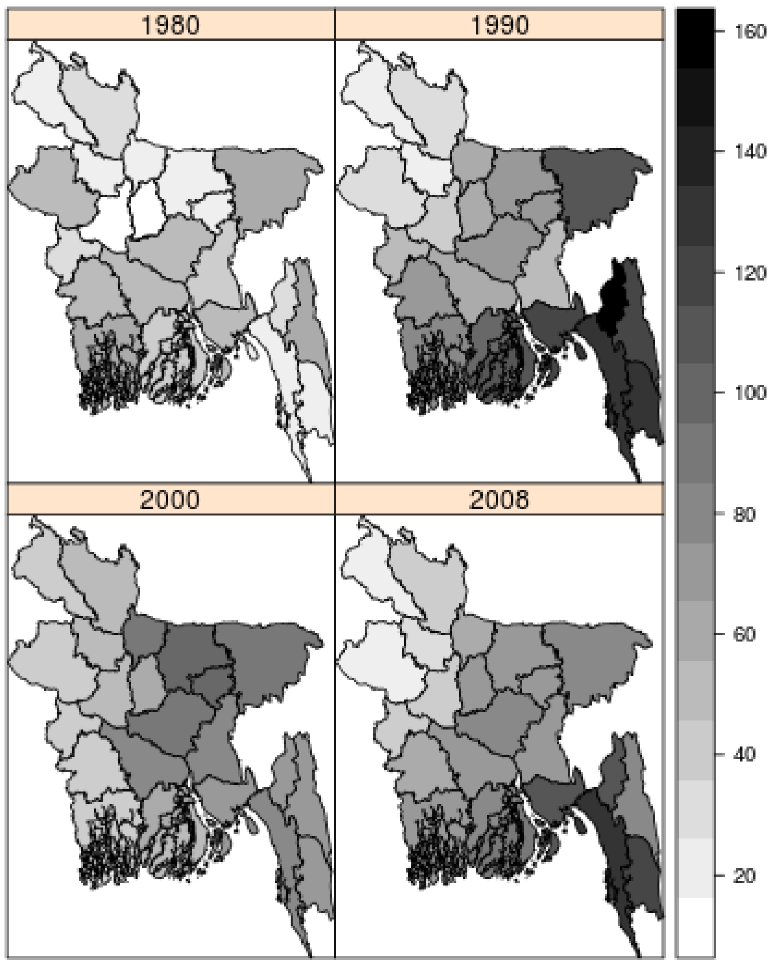
Source: created by authors.

Now we turn to the case of regional changes in the average maximum temperature in the dry season. For 1980 the picture is somewhat similar to that of the wet season with Khulna, Barisal and parts of Rajshahi and Chittagong being the warmest, having a temperature of around 29^0C. Rangpur had the coolest average in the dry seasons with an average temperature of around 27.5^0 C, with the rest of the country in between with an average of 28.4^0C. The whole country, with the exception of Khulna, experienced a reduction in the average dry season temperatures in 1990 but it did not continue in 2000. Barisal, Sylhet and parts of Chittagong and Dhaka grew warmer, returning to their average temperature in 1980, but Rangpur's average temperature for the dry season did not change. In 2008, along with Rangpur and Sylhet, parts of Dhaka are found to be getting cooler while parts of Chittagong, Khulna and Barisal remained warm.

ISBN 978-0-9925622-1-2

iii. Average Rainfall in Dry Season

Map 3: Average rainfall, dry season

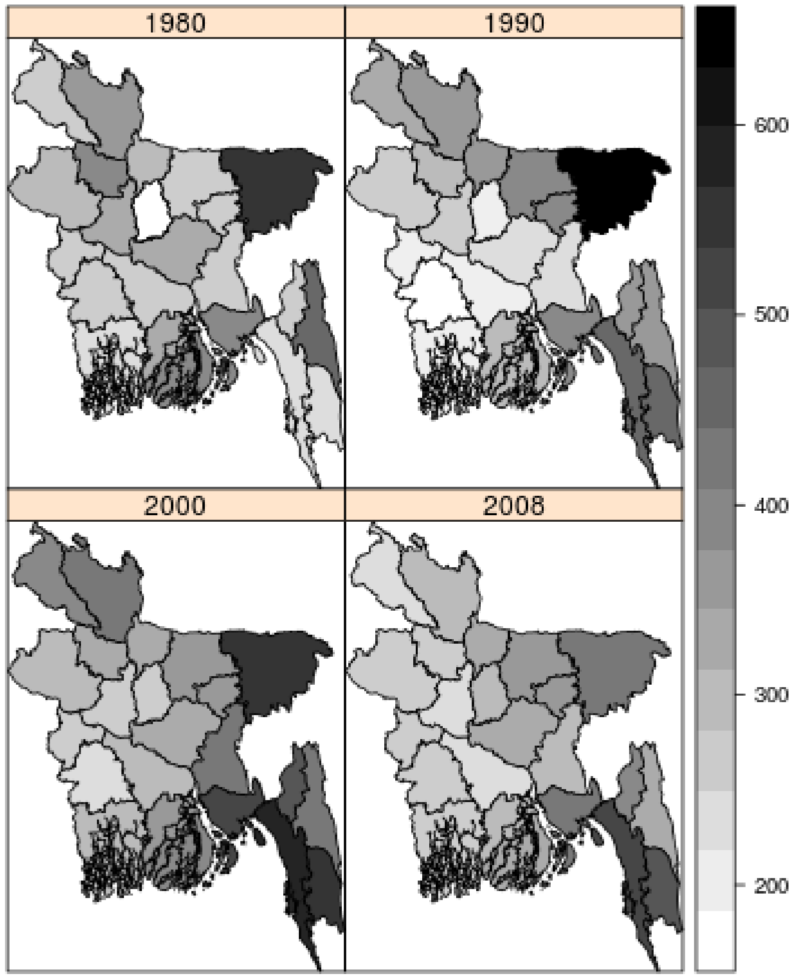


Source: created by authors.

Average rainfall in the dry season in 1980 shows some regional variations with rainfall in parts of Khulna and Chittagong getting heavier compared to Rangpur and parts of Dhaka, and the rest experiencing moderate rainfall. In 1990 we see that rainfall in Chittagong, Barisal and Sylhet increased significantly, along with moderate increases in parts of Dhaka and Khulna. In 2000, the pattern of rainfall in the dry season changed with Dhaka getting heavier rain than before and rainfall in Chittagong and Barisal decreasing. In 2008, although Sylhet and parts of Dhaka continued to get heavy rain and rainfall in Chittagong and parts of Barisal increased once again, but Rangpur and Rajshahi experienced lower rainfall than in 2000.

iv. Average Rainfall in Wet Season

Map 4: Average rainfall, wet season

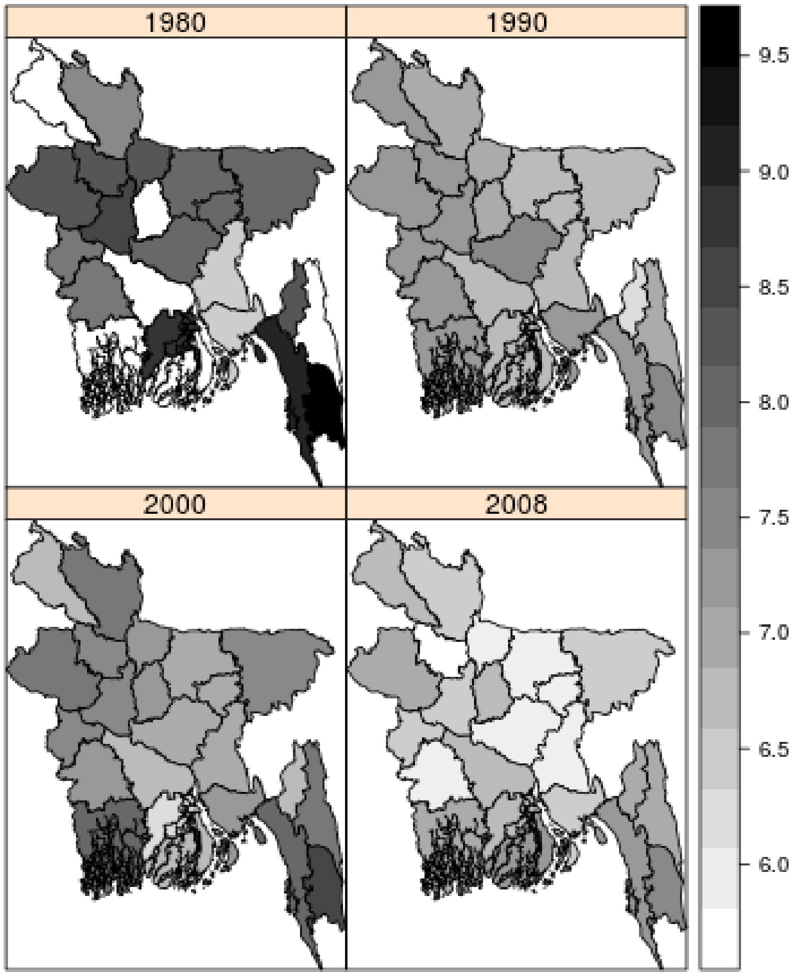


Source: created by authors

In 1990, average rainfall in the wet season was the highest in greater Sylhet and parts of Barisal (with an average of around 510 mm) while Chittagong, along with parts of Khulna, Dhaka and Rangpur, had the least (average of around 226 mm).The rest of the country experienced an average rainfall of 332 mm. In 1990 a major portion of the country (Khulna, Dhaka, Rajshahi and Barisal) experienced reductions in rainfall in the wet season, although it increased for some parts of Chittagong and Dhaka. In 2000, rainfall increased for most parts of the country with Rangpur, Chittagong and parts of Barisal having the larger share. This pattern of regional variation in wet season rainfall is also found to exist in 2008 but with Rangpur and parts of Chittagong and Barisal now having less rainfall.

v. Average Bright Sun in Dry Season

Map 5: Average bright sun, dry season



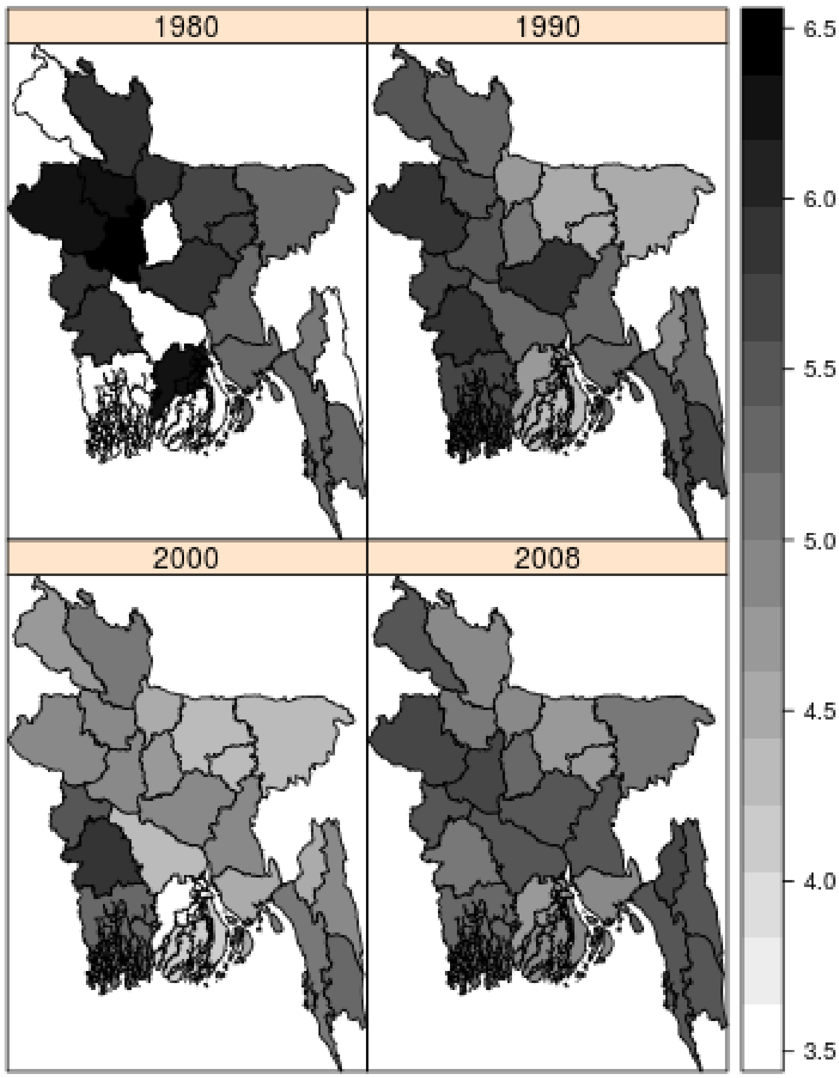
Source: created by authors

The majority of the country, with the exception of some parts of Chittagong and Rangpur, experienced high bright sun conditions in the dry season (average of around 6.27 units) in 1980. But the scenario changed greatly in 1990 when no part of the country experienced bright sun in excess of 7.74 units, with the greatest reduction occurring in Barisal and parts of Dhaka and Chittagong. In 2000, the situation improved somewhat with parts of Khulna and Chittagong experiencing bright sun over 7.74 units and moderate increases for parts of Rangpur, Rajshahi, Dhaka and Chittagong. In 2008, the regional pattern in the average bright sun conditions in the dry season changed again with the majority of the country getting less bright sun than in 2000. Although it did increase for parts of Barisal and Chittagong, for the rest of the country it either decreased or stayed constant.

ISBN 978-0-9925622-1-2

vi. Average Bright Sun in Wet Season

Map 6: Average bright sun, wet season

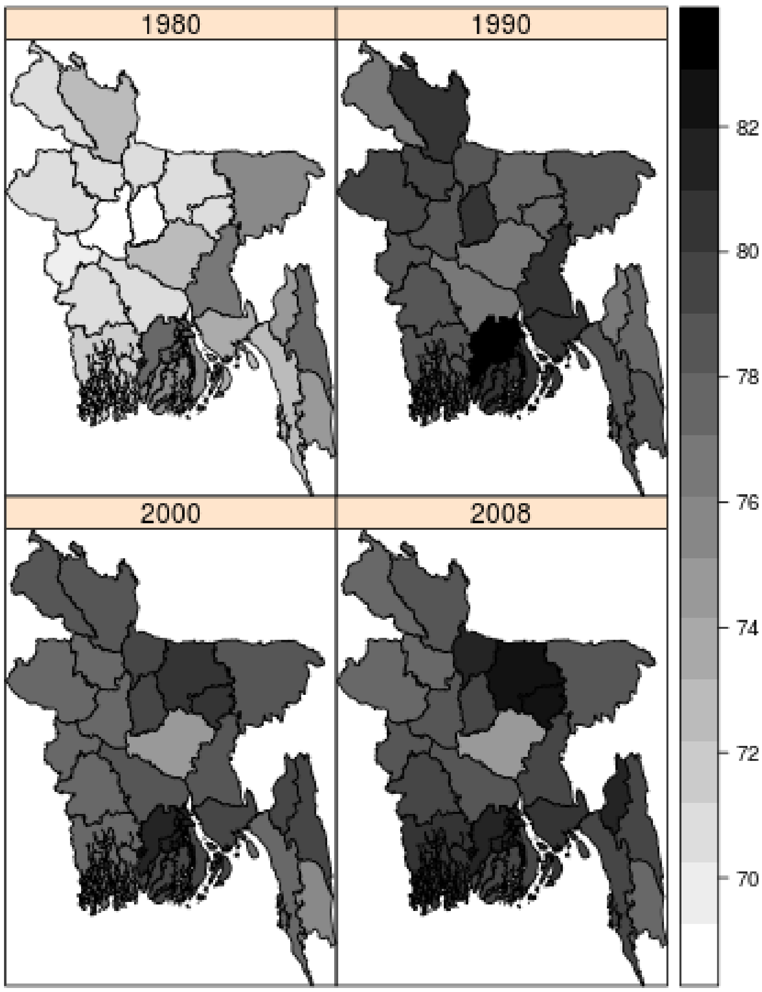


Source: created by authors

Similar patterns of change in the average bright sun conditions can also be found in the case of the wet season. In 1980, half of the country experienced high bright sun conditions (an average of around 6 hours) but with the exception of Sylhet and parts of Chittagong and Dhaka. In 1990 average bright sun conditions generally decreased for the country, except for some parts of Khulna, Rajshahi, Dhaka and Chittagong, where it remained more or less constant. This trend continued in 2000 when it decreased further, generally with the exception of some parts of Khulna. But in 2008, a reversal of the trend is observed as the overall country is found to have experienced increased bright sun conditions except for some parts of Dhaka.

vii. Average Relative Humidity in Dry Season

Map 7: Average relative humidity, dry season



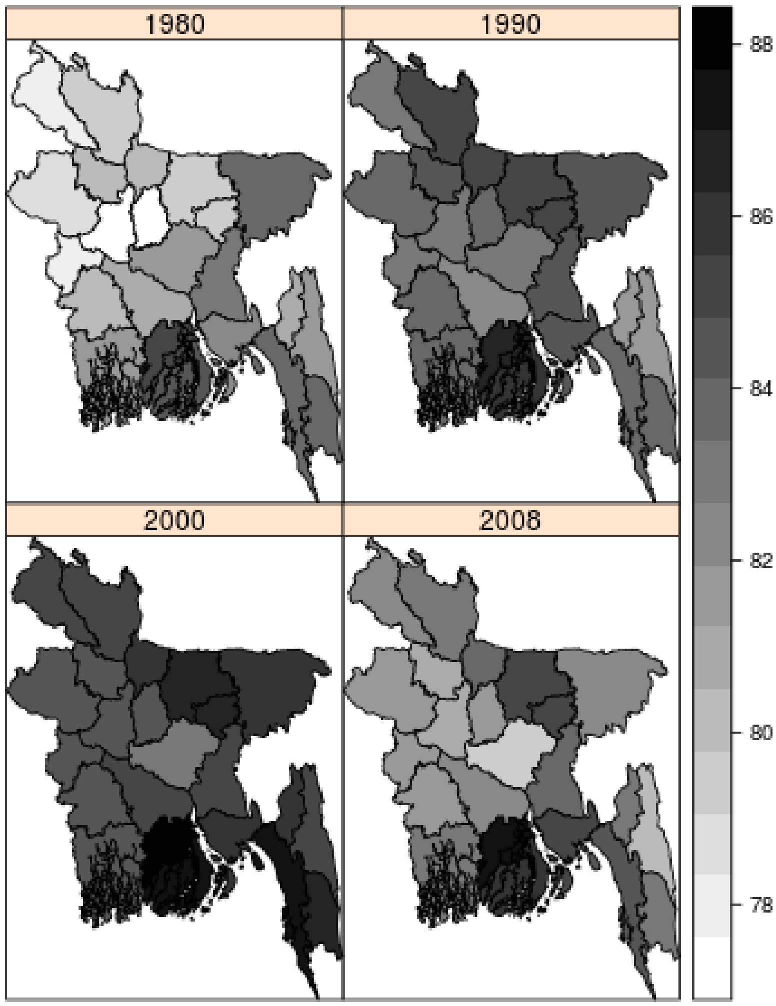
Source: created by authors

From the above maps, we find that compared to 1990, average relative humidity was lower in 1980 with the vast majority of the country having an average of 72.75 units except for some parts of Chittagong and Barisal. But in 1990 both the variation and magnitude of relative humidity in the dry season increased with an average of 79.6 units for the overall country. The greatest increases were for parts of Barisal, Chittagong and Rangpur, followed by Khulna, Rajshahi and Sylhet with moderate increases in parts of Dhaka. In 2000, average relative humidity generally decreased for the whole country except for parts of Barisal, Chittagong and Dhaka. But in 2008, we again observe increases in overall relative humidity in the dry season with most increases in parts of Khulna, Barisal and Dhaka.

ISBN 978-0-9925622-1-2

viii. Average Relative Humidity in Wet Season

Map 8: Average relative humidity, wet season



Source: created by authors

The variations over time in the relative humidity in the wet season are somewhat similar to that of the dry season. Relative humidity was generally lower in 1980 compared to 1990. In 2000, changes in relative humidity in the wet season followed an upward trend with about half of the country experiencing an average humidity of 86.4 units, with most increases in parts of Chittagong and Sylhet. The humidity data for 2008 shows that relative humidity again decreased generally for the overall country with some exceptions.

6. Empirical analysis

6.1. Regression model and identification issues

The model is specified as follows:

$$Agriculturalproductivity_{i,t} = \beta_0 + \beta_1 \cdot Weathervariables_{i,t} + \beta_2 \cdot Regiondummy_{i,t} + \beta_3 \cdot Yeardummy_{i,t} + u_{i,t}$$

We use two dependent variables: (i) log of agricultural output per acre of three kinds of rice (Aus, Aman and Boro), and (ii) log of agricultural output (only Boro rice) per acre. The indices *i* and *t* denote region/agricultural zone and year respectively. The weather variables include mean and standard deviations of maximum and minimum temperatures, average rainfall, bright sun, and humidity conditions for both dry and wet seasons.

The unobserved characteristics of the regions might influence agricultural productivity. Time invariant district specific characteristics such as soil quality can impact agricultural productivity. Regions also vary with respect to altitude and physiography (e.g., flood plains, basin, beels, tract, hills and terrace).These and other characteristics specific to regions may have an impact on the agricultural productivity of that area. At the same time we need to control for shocks or effects that are specific to certain years such as disasters, supply side interventions such as government incentives (e.g. subsidies or tax reductions) provided to farmers during certain years, or major improvements in technology that became available in a certain year etc. Therefore, we also control for unobserved spatial and temporal effects using regional and year dummies respectively.

Since it is highly likely that the errors are correlated over time, that is, the assumption of i.i.d. errors does not hold, we need a more realistic error structure. We assume that errors are correlated within regions but not across regions. Therefore, in order to capture these within-region correlated errors we cluster the errors around region to get unbiased estimates of standard errors.

6.2. Empirical Results

Regression results are presented in Tables 3-4. Table 3 reports the OLS and FE regression results of the effect of various weather variables on agricultural productivity (measured as the log of agricultural output per acre for three kinds of rice: Aus, Aman and Boro). The specifications vary with the extent of control for the various weather variables and unobserved effects. The first specification (model 1) only includes the temperature variables while the second specification (model 2) also includes the variables related to rainfall; the next two specifications (models 3 and 4) further include ‘bright sun’ and ‘humidity’ conditions. The fifth specification (model 5) only controls for unobserved spatial effects using regional dummies while the sixth specification (model 6) further uses year dummies to control for unobserved temporal effects.

From Table 3, we find that average minimum temperature in the dry season is significant in all models run, which implies that this variable has a significant and robust effect on overall productivity of rice in Bangladesh. The size of the coefficient varies from 0.037 to 0.116, implying that an increase in the average minimum temperature in the dry season by one unit increases per acre rice output by 3.7% to 11.6%.The impact of average maximum temperature in the wet season is positive and highly significant for the first five models. When we control for year specific heterogeneity, the significance vanishes. Average minimum temperature in the wet season is also found to have a negative and significant impact even after controlling for region and year fixed effects.

ISBN 978-0-9925622-1-2

Standard deviations of maximum temperature in both dry and wet seasons are found to have a negative impact on agricultural productivity, though the impact in the wet season loses its significance after controlling for the year fixed effect.

The impact of average rainfall in the dry season, and standard deviation of rainfall in dry and wet seasons was highly significant for models 2-5 but insignificant in model 6 when the year specific effect is controlled for. It is interesting to note that the fluctuation of rainfall in both seasons has a positive impact on agricultural productivity. However, the fluctuation of humidity in the wet season is found to have a negative impact on rice productivity.

Table 3: Dependent variable: Log of Agricultural output per acre (only rice)

VARIABLES	model 1	model 2	model 3	model 4	model 5	model 6
Avg. max. Temp. in dry season	-0.079***	-0.096***	-0.034	0.021	0.008	-0.014
	(0.021)	(0.022)	(0.023)	(0.025)	(0.023)	(0.023)
Avg. min. Temp. in dry season	0.106***	0.116***	0.097***	0.042**	0.062***	0.037*
	(0.020)	(0.021)	(0.020)	(0.020)	(0.020)	(0.020)
Avg. max. Temp. in wet season	0.227***	0.281***	0.220***	0.117***	0.138***	0.001
	(0.023)	(0.025)	(0.026)	(0.029)	(0.030)	(0.027)
Avg. min. Temp. in wet season	-0.121***	-0.104***	-0.116***	-0.050*	-0.037	-0.077**
	(0.030)	(0.029)	(0.028)	(0.029)	(0.031)	(0.033)
Sd. of max. Temp. in dry season	-0.079**	-0.064**	-0.077**	-0.049	-0.039	-0.084***
	(0.033)	(0.032)	(0.031)	(0.031)	(0.027)	(0.030)
Sd. of min. Temp. in dry season	-0.031	-0.004	0.005	-0.007	0.045*	0.027
	(0.033)	(0.032)	(0.030)	(0.029)	(0.026)	(0.035)
Sd. of max. Temp. in wet season	-0.235***	-0.279***	-0.220***	-0.126***	-0.088***	-0.016
	(0.031)	(0.029)	(0.030)	(0.032)	(0.029)	(0.024)
Sd. of min. Temp. in wet season	-0.013	0.043	0.063*	0.047	0.001	-0.073**
	(0.036)	(0.036)	(0.035)	(0.033)	(0.033)	(0.034)
Avg. Rain in dry season		-0.004***	-0.005***	-0.005***	-0.004***	0.000
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Avg. Rain in wet season		0.000	0.000	0.000	-0.000	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sd. of Rain in dry season		0.003***	0.003***	0.003***	0.002***	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sd. of Rain in wet season		0.001***	0.001***	0.001***	0.001***	0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Avg. Bright Sun in dry season			-0.139***	-0.098***	-0.128***	-0.003
			(0.018)	(0.018)	(0.017)	(0.017)
Sd. of Bright Sun in dry season			0.107***	0.054*	0.009	0.037
			(0.031)	(0.030)	(0.027)	(0.025)
Avg. Bright Sun in wet season			0.051**	0.034	0.017	0.013
			(0.022)	(0.022)	(0.020)	(0.018)
Sd. of Bright Sun in wet season			0.054*	0.053*	0.056*	0.005
			(0.032)	(0.032)	(0.028)	(0.029)
Avg. Relative Humidity in dry				0.038***	0.028***	0.004

ISBN 978-0-9925622-1-2

season						
				(0.005)	(0.005)	(0.004)
Sd. of Relative Humidity in dry season				0.012*	0.011*	-0.003
				(0.007)	(0.006)	(0.005)
Avg. Relative Humidity in wet season				-0.057***	-0.018*	-0.009
				(0.010)	(0.011)	(0.009)
Sd. of Relative Humidity in wet season				-0.038***	-0.029***	-0.015**
				(0.009)	(0.008)	(0.007)
Constant	-3.607***	-5.851***	-4.560***	-1.768*	-4.880***	1.581
	(0.802)	(0.894)	(0.875)	(0.994)	(1.217)	(1.223)
Region fixed effect	No	No	No	No	Yes	Yes
Year fixed effect	No	No	No	No	No	Yes
Observations	782	782	782	782	782	782
R-squared	0.167	0.277	0.364	0.432	0.593	0.800

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4 shows the results of the regression analysis when the dependent variable is the log of Boro rice output per acre. In this case we only consider the weather during the Boro season, i.e. from December to May.

In the case of Boro rice, the only variable that is significant for controlling region and year specific heterogeneity is the standard deviation of maximum temperature in the Boro season. Average bright sun is found to have negative impact on the productivity of Boro rice, though it loses significance with the inclusion of the year fixed effect. On the other hand, average relative humidity is also found to impact productivity positively, but with no significant impact when the year fixed effect is controlled for.

Table 4: Dependent variable: Log of agricultural output per acre (only Boro rice)

VARIABLES	model 1	model 2	model 3	model 4	model 5	model 6
Avg. max. Temp in Boro season	-0.009	-0.009	0.032**	0.049***	0.065***	0.004
	(0.014)	(0.014)	(0.014)	(0.014)	(0.017)	(0.022)
Avg. min. Temp. in Boro season	0.023**	0.022*	0.005	-0.026**	-0.005	-0.038
	(0.011)	(0.011)	(0.011)	(0.012)	(0.017)	(0.031)
Sd. of max. Temp. in Boro Season	0.047**	0.045**	0.028	0.052***	0.004	-0.056*
	(0.019)	(0.020)	(0.019)	(0.019)	(0.021)	(0.029)
Sd. of min. Temp. in Boro season	0.021	0.019	-0.014	-0.036	0.018	-0.000
	(0.029)	(0.029)	(0.029)	(0.028)	(0.029)	(0.039)
Avg. Rain in Boro season		-0.000	-0.001*	-0.002***	-0.001	-0.000
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Sd. of Rain in Boro season		-0.000	0.000	0.000	0.001	0.000

ISBN 978-0-9925622-1-2

		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Avg. Bright Sun in Boro season			-0.112***	-0.082***	-0.110***	-0.025
			(0.014)	(0.014)	(0.015)	(0.021)
Sd. of Bright Sun in Boro season			0.037	0.005	0.007	-0.018
			(0.030)	(0.031)	(0.029)	(0.032)
Avg. Relative Humidity in Boro season				0.018***	0.020***	-0.001
				(0.003)	(0.003)	(0.004)
Sd. of Relative Humidity in Boro season				-0.002	-0.003	-0.012*
				(0.007)	(0.007)	(0.007)
Constant	-0.394	-0.338	-0.142	-1.601***	-2.381***	0.950
	(0.317)	(0.366)	(0.364)	(0.467)	(0.604)	(0.883)
Region fixed effect	No	No	No	No	Yes	Yes
Year fixed effect	No	No	No	No	No	Yes
Observations	782	782	782	782	782	782
R-squared	0.024	0.024	0.111	0.169	0.313	0.501

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Boro season is from December to May

7. Conclusion

Climate change is no longer a myth, but a scientific observation. The Word Bank (2013) shows that the world is now 0.8°C warmer than pre-industrial levels, and it also predicts that a scenario in which the world is 2°C warmer is highly likely in one generation. It is predicted that Bangladesh's drought-prone areas are warmer and drier than 50 years ago, and current projections suggest that Bangladesh will become hotter and will face frequent droughts due to increased rainfall variability. These changes of climatic variables will have strong adverse impacts on agricultural productivity, poverty and food security.

However, there is no robust estimate of the impact of the changes in climatic variables on agricultural productivity. Though there are some studies estimating the impact, they did not take into account regional and temporal variations. In this study, we have created a unique data set for 23 regions for the period 1975-2008. Using regional and year fixed effects, we estimate the impact of the changes in climatic variables on the productivity of rice (Aus, Aman and Boro) and only Boro. We found that when regional variations are considered, it significantly changes the sign and size of the estimates. The impact differs significantly with the choice of weather variables – mean vs. standard deviation (fluctuation), minimum vs. maximum, dry vs. wet seasons. For example, the impact of an increase in one unit of minimum temperature and maximum temperature on rice productivity are different in the same wet season. The choice of weather variables should be driven by scientific knowledge, which the current literature lacks.

This study informs scientists and policymakers about the robust estimates of the impact of climate change on agricultural productivity for forecasting different scenarios under different climatic prognoses.

ISBN 978-0-9925622-1-2

References

Agrawala, S., Ota, T., Ahmed, A.U., Smith, J., and van Aalst, M., 2003, 'Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans', OECD Development and Climate Change Project.

Ali, A., 1999, 'Climate change impacts and adaptation assessment in Bangladesh', *Climate Research*, 12, pp. 109 - 116.

Bangladesh Bureau of Statistics (BBS), *Yearbook of Agricultural Statistics.*

Basak, J.K., Ali, M.A., Islam, M.N., Rashid, M.A., 2010, 'Assessment of the effect of climate change on Boro rice production in Bangladesh using DSSAT model', *Journal of Civil Engineering*, 38, pp. 95–108.

Brouwer, R., Akter, S. ,Brander, L., and Haque, E., 2007, 'Socioeconomic Vulnerability and Adaptation to Environmental Risk: A Case Study of Climate Change and Flooding in Bangladesh', *Risk Analysis*, 27(2), pp. 313-326.

Huq, S., Ali, S.I., and Rahman, A.A., 1995, 'Sea-level rise and Bangladesh: a preliminary analysis', *Journal of Coastal Research*, pp. 44-53.

Huq, S., Reid, H., Konate, M., Rahman, A. , Sokona, Y. ,and Crick, Y., 2004, 'Mainstreaming adaptation to climate change in Least Developed Countries', *Climate Policy*, 4(1), pp. 25-43.

Intergovernmental Panel on Climate Change (IPCC) (2001), Climate Change 2001 - IPCC Third Assessment Report.

Islam, S.R., Huq, S., and Ali, A., 1999, 'Beach erosion in the eastern coastline of Bangladesh', In Karim, Z., Hussain, S.G., and Ahmed, A.U. *Vulnerability and adaptation to climate change for Bangladesh*. Netherlands: Springer, pp. 71-92.

Karim, Z., Hussain, S., Ahmed, M., 1996, 'Assessing impacts of climate variations on food grain production in Bangladesh', *Water Air Soil Pollution*, 92, pp. 53–62.

Mahmood, R., 1998, 'Air temperature variations and rice productivity in Bangladesh: a comparative study of the performance of the YIELD and CERES-Rice models', *Ecological Modelling*, 106, pp. 201–212.

Mahmood, R., Legates, D.R., Meo, M., 2004, 'The role of soil water availability in potential rainfed rice productivity in Bangladesh: applications of the CERES Rice model', *Applied Geography*, 24, pp. 139–159.

Rashid, M.H., Islam, M.S., 2007, 'Adaptation to Climate Change for Sustainable Development of Bangladesh Agriculture', *Bangladesh Country Paper*, APCAEM, November, 2007.

Ruttan, V.W., 2002, 'Productivity Growth in World Agriculture: Sources and Constraints', *The Journal of Economic Perspectives*, 16(4), pp. 161-184.

Sarker, M.A.R., Alam, K., & Gow, J., 2012, 'Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data', *Agricultural Systems*, 112, pp. 11-16.

United Nations Environment Programme (UNEP) (2013), *Annual Report 2013*

World Bank (2000), 'Bangladesh: climate change and sustainable development', Report No. 21104, Dhaka.

World Bank, (2013), 4^0 Turn down the heat: climate extremes, regional impacts, and the case for resilience, Washington DC.

Table A1: Summary of relevant literature

Source	Research type	Context of Climate Change	Geo-focus	Methodology	Brief outcomes
Agrawala, Ota, Ahmed, Smith, and van Aalst (2003)	Review and application of literature.	Risk factors and vulnerabilities.	Bangladesh	Qualitative: Subjective ranking system	Agriculture is ranked as having a medium “certainty of impact” risk, low-medium “timing of impact” risk, low-medium “severity of impact” risk and high “importance of resource” risk. Agriculture risk is ranked lowest amongst; flooding, costal resources and human health due to a mix of beneficial and adverse impacts.
Ali (1999)	Model applications	Impacts and adaptation, use of cyclone data.	Bangladesh	Quantitative and qualitative: numerical model and scenario analysis	Severity, not frequency of cyclones is increasing. Bangladesh doesn’t contribute largely to greenhouse gases but is very susceptible to the climate change they may cause. Coastal erosion could lead to a loss of between 13750 and 252000 metric tons of grain.
Almaraz, Mabood, Zhou, Gregorich, Smith (2008)	Methods-Model applications	Climate variability and crop yields.	Quebec, Canada	Quantitative: Multiple regression analysis	The agriculture of nations at higher altitudes will be more affected by climate change. Crop production will be affected by climate change in many important regions of the world.
Basak, Ali, Islam, Rashid (2010)	Model applications	Weather variables and crop yields.	Bangladesh	Quantitative: DSSAT model and PRECIS	With modeled climate change: 20% and 50% reduction in yield of Boro (BR3 and BR14) rice by 2050 and 2070 respectively. Increases in daily minimum and maximum temperatures are mainly responsible.
Brouwer, Akter, Brander, and Haque (2007)	Methods-Model applications	Socioeconomic vulnerability and adaptation, flood risks.	Bangladesh	Quantitative and qualitative: analytical model and survey	Positive relation exists between poverty, risk and vulnerability People facing the highest risk of flooding are often the poor who are least prepared and carry the most environmental risk.
Chen, McCarl, Schimmelpfennig , (2004)	Methods-Model applications	Crop yield variance.	United States	Quantitative: Stochastic production function	Rainfall and temperature increases raise sorghum yield and variability. Precipitation and temperature increases lower corn yield and variability.

ISBN 978-0-9925622-1-2

Table A1: Summary of relevant literature

Source	Research type	Context of Climate Change	Geo-focus	Methodology	Brief outcomes
Huq, Ali, Rahman (1995)	Effects of scenario	Sea level rise and coastal flooding.	Bangladesh	Qualitative: Analysis of topographical and thematic maps	A one meter rise in the sea level will result in: Inundation of 25,000km^2 (over 17.5% of land area). 13 million people could be displaced (over 11% of population). Ecosystem and agricultural effects also discussed.
Huq, Reid,Konate, Rahman, Sokona, Crick (2004)	Discussion-Opinion-Examples	LDC's vulnerability and adaptation to climate change.	Bangladesh and Mali	Qualitative: Analysis of climate change adaptation for LDC's and potential policy options	LDCs are most vulnerable to climate change and adaptation is needed. LDCs contribute least to greenhouse gases. Bangladesh has some disaster response systems and strategies to deal with freshwater shortages. Research must be translated for policy makers using understandable language and applying the correct time scale.
Isik, Devadoss (2006)	Methods-Model applications	Wheat, barley, potato and sugar beets - crop yield mean, variance and covariance. Climate variables.	Idaho, USA	Quantitative: Stochastic production function	Expects climate change to have "modest effect" on crop yield. Climate change will cause a significant reduction in variance and covariance of crop yields. Allocations of land to crop types could differ with climate change.
Joshi, Maharjan, Luni(2011)	Methods-Model application	Crop yield of rice, wheat, maize, millet, barley and potato. Climate variables.	Nepal	Quantitative: Multiple regression analysis	The current trend of climate change has a negative effect on summer crops (except paddy). Rainfall is decreasing during winter months but temperature rises has helped increase winter crop yield. Maize and potato affected most by climate change and need first attention.

ISBN 978-0-9925622-1-2

Table A1: Summary of relevant literature

Source	Research type	Context of Climate Change	Geo-focus	Methodology	Brief outcomes
Karim, Hussain, Ahmed (1996)	Model application	Crop yield for Aus, Amana and Boro rice, and wheat.	Bangladesh	Quantitative: Simulation with CERES models	Temperature rises offset any yield gain from CO2 rises in the model. Wheat more susceptible to temperature increases than rice varieties.
Kimand Pang (2009)	Methods-Model applications	Rice yield and climate variables.	Korea	Quantitative: Stochastic production function	Positive relationship between average rice yield and temperature. Increase precipitation has a negative effect on average rice yield. Temperature and precipitation increase yield variability. With an expectation of increase temperature and precipitation, larger market price risk is likely.
Lobell, Cahill, and Field(2007)	Methods-Model applications	Analysis of 12 major crops, min, max temperature and precipitation.	Californian , USA	Quantitative: Regression equations developed specifically for each crop.	Climate may influence crop yield through crop infection, pollination and dormancy. Climate change has so far had differing effects on the 12 crops discussed.
Lobelland Field(2007)	Model application	Average crop yields for 6 major crops, monthly min, max temperature and precipitation.	Global	Quantitative and Qualitative: Empirical and regression.	Estimate that growing season temperatures and precipitation explain at least 30% of variations in crop yields. Estimate that $5 billion per year worth of crop (40Mt), since 1981, has been lost due to climate trends. As at 2002.
Mahmood, R., 1998)	Model comparison	Boro rice productivity and air temperatures.	Bangladesh	Quantitative: YEILD model and CERES-Rice Model.	Strength and weakness of each model are discussed. Both rely on different assumptions and as such are more applicable in different studies.

ISBN 978-0-9925622-1-2

Table A1: Summary of relevant literature

Source	Research type	Context of Climate Change	Geo-focus	Methodology	Brief outcomes
Mahmood and Legates(2004)	Model application	Impact of soil water stress on rainfed rice during monsoon season.	Bangladesh	Quantitative: CERES-Rice model	Potential yield loss estimates for regions and Bangladesh are made for flowering and maturing seasons. Climate change and its effects on monsoon season have the potential to significantly impact crop yields in Bangladesh and other parts of Asia susceptible to monsoons.
Olesen and Bindi (2002)	Review and application of literature	European agricultural policy for climate change.	Europe	Qualitative: Identifying effects on agricultural productivity and suggesting policy for adaptation and mitigation.	New crops, higher productivity, more cultivatable land, are potential benefits of climate change. Plant protections, nutrient leaching, water shortages and a higher increase of extreme weather events are possible costs of climate change.
Rashid and Islam (2007)	Discussion-Opinion-Review of literature	Identified impacts and adaptations for sustainable development of agriculture with climate change.	Bangladesh	Qualitative: Discussion and suggestions for adaptation.	Identified droughts, floods, soil salinity and cyclones as the extreme climatic events that could affected agricultural production adversely. Changes in behavioural patterns, human practices and international actions are suggested as anticipatory adaptive measures in the study.
Reilly, Paltsev, Felzer, Wang, Kicklighter, Melillo, Prinn, Sarofim, Sokolov, and Wang (2007)	Methods-Model application	Economic consequences of climate, CO2 and ozone via crop productivity.	Global	Quantitative: MIT IGSM , TEM and EPPA updated models.	Effects of climate and CO2 are generally positive. Ozone damage could offset these benefits. Intra- and inter-country resource allocation can strongly affect the estimated economic effect on agriculture.
Ruttan (2002)	Discussion-Opinion-Review of literature	Sources and constraints of agricultural productivity growth.	Global	Qualitative: Discussion and perspective on sources and constraints of agricultural productivity.	Effects of climate on agriculture are largely region specific. There is potential for growth in agricultural productivity where land and labour have not neared their scientific and technical frontiers, i.e. developing nations.

ISBN 978-0-9925622-1-2

Table A1: Summary of relevant literature

Source	Research type	Context of Climate Change	Geo-focus	Methodology	Brief outcomes
Sarker, Alam and Gow (2012)	Model applications	Effect of min, max temperature and precipitation on three rice yields.	Bangladesh	Quantitative: OLS and Quantile regression	Significant relationship between climate change and agricultural productivity. Climatic variables have varying significance over the three varieties of rice. The sign of the relationship can also vary.

ISBN 978-0-9925622-1-2

Table A2: Agricultural zones (regions) and corresponding weather stations

Regions	**Weather Stations**					
1.Bandarban	Chittagong					
2.Barisal	Barisal	Bhola				
3.Bogra	Bogra					
4.Chittagong	Chittagong	Cox's Bazar	Kutubdia	Sandwip	Sitakunda	Teknaf
5.Comilla	Comilla					
6.Dhaka	Dhaka					
7.Dinajpur	Dinajpur					
8.Faridpur	Faridpur	Madaripur				
9.Jamalpur	Tangail	Mymensingh				
10.Jessore	Jessore					
11.Khagrachhari	Sitakunda					
12.Khulna	Khulna	Satkhira	Mongla			
13.Kishoregonj	Mymensingh					
14.Kustia	Ishurdi	Rajshahi				
15.Mymenshing	Mymensingh					
16.Noakhali	MaijdeeCourt	Feni	Hatiya	Chandpur		
17.Pabna	Ishurdi					
18.Patuakhali	Patuakhali	Khepupara				
19.Rajshahi	Rajshahi					
20.Rangamati	Rangamati					
21.Rangpur	Rangpur					
22.Sylhet	Sylhet	Srimangal				
23.Tangail	Tangail					