Effects of Increasing Temperature and Population Growth on Rice Production in Bangladesh: Implications for Food Security

উন্নয়ন অন্বেষণ
Unnayan Onneshan
The Innovators
centre for research and action on development

Effects of Increasing Temperature and Population Growth on Rice Production in Bangladesh: Implications for Food Security

Author
Jayanta Kumar Basak

Acknowledgement:
The manuscript is an output of a research programme of Environment Unit, undertaken by the Unnayan Onneshan-The Innovators, a center for research and action on development, based in Dhaka, Bangladesh. I cordially thank Mr. Rashed Al Mahmud Titumir for his constant support, careful supervision and guidance, keen interest, valuable criticism, active co-operation, suggestions and encouragement to conduct this research work. I am extremely indebted to Dr. M. Ashraf Ali and Dr. Md. Jobair Bin Alam, Professor, Department of Civil Engineering, BUET, Dhaka and Dr. Jiban Krishna Biswas, Chief Scientific Officer (CSO); Dr. Md. Abdur Rashid, Principal Scientific Officer (PSO); Md. Abdus Salam, Scientific Officer (SO), Bangladesh Rice Research Institute (BRRI) Gazipur and Palash Kanti Das for their kind support throughout this study. The report is copy edited by Rashed Al Ahmad Tarique.

For orders and request please contact:

Unnayan Onneshan-The Innovators
House: 19A, Road: 16 (New), Dhanmondi, Dhaka-1209, Bangladesh
Tell: +(880-2) 815 82 74, 911 06 36; Fax: + (880-2) 815 91 35
E-mail: info@unnayan.org; Web: www.unnayan.org

Table of Contents

Executive Summary

Potential increase in global temperature due to climate change and population growth and their impact on rice productivity, above all food security, has been a major concern in recent years. Every year a huge amount of rice production is lost to a changing climate, which eventually threatens food security in Bangladesh. The purpose of this paper is to build the interfaces among Boro rice production, increasing temperature and population growth and their effects on total rice production in Bangladesh.

Population growth rate in Bangladesh is two million people per year and the population will reach 233.2 million by 2050, going by the current trend. Bangladesh will require more than 55.0 million tons of rice per year to feed its people by the year 2050. In 2007-2008, Boro rice production contributed 58% to the total rice production, T.Aman 34% and Aus rice only 7%. Therefore, the rice production depends disproportionately on Boro rice production in the country.

The effects of temperature on yield of Boro rice have been assessed using the DSSAT (Decision Support System for Agrotechnology Transfer, version 4) model for the years 2020, 2030, 2040 and 2050. The study has been conducted on the basis of IPCC Fourth assessment report and has found a considerable yield reduction (1.5%, 2.5%, 4.4% and 5.4% respectively) which will directly affect the total rice production in the country. Rice shortage of 35% may occur due to population growth (two million people per year) whereas it may be 50% for growing population and increasing temperature within 2050 compared to the total rice production in 2006-07. Rice demand for a single people was 580 gm per day or 211.73 kg per year in 2006-07. More than 6.5 crore people would be deprived of their rice requirement by the year 2050, which is more than 45% compared to the total population in 2006-07 owing to the combined effects of increasing temperature and population (35% due to population growth alone).). Consequently, Taka 1.06 thousand crore would be lost which is 2% of the total Agricultural and Forestry GDP in the fiscal year 2007-08 (Tk. 0.80 thousand crore for the increasing population in 2050). Bangladesh will face a substantial food shortage in the next few years and it will turn into a critical issue around 2050, if the current trend continues. Increasing the Boro and the T.Aman production and preventing the declining yield of Aus rice production and developing more heat tolerant rice varieties and management practices would be vital in increasing rice production in Bangladesh.

Section 01

1.1 Introduction

Agricultural production in Bangladesh is highly influenced by different seasonal climatic variables such as high fluctuations of day and night temperatures, changing rainfall patterns, high carbon dioxide concentrations, humidity and day-length. It is also adversely affected by different climatic disasters such as floods, droughts, cyclones, storm surges, and sea level rise. For example, two rounds of floods and devastating cyclones Sidr in 2007 and cyclone Aila in 2009, severely damaged agricultural production, especially the rice production and resulted in a severe food crisis.

Food security refers to the availability of food and one's access to it. A household is considered food secure when its occupants do not live in hunger or fear of starvation. According to the Food and Agricultural Organization (FAO, 2002), food security exists when all people at all times have physical, social, and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. To achieve food security, four components such as availability, accessibility, stability and utilization must be sufficient. These components are often dependent on natural events, such as flood, cyclone, water conservation, degradation due to erosion, and drought.

In the coming decades, agriculture of Bangladesh will face a great challenge to feed its growing population as the food demand will increase with increasing population. Bangladesh, as a whole, still has a very low level of average nutrition. Many households and individuals cannot have a balanced diet, even in good production years. According to the World Bank, approximately 33 million of the 150 million people in Bangladesh cannot afford an average daily intake of more than 1800 kilocalories (the minimum standard for nutrition as set by the World Food Program). For most people in developing countries, the daily average calorie intake is 2,828 kilocalories. On the contrary, in Bangladesh, that average is only 2,190 kilocalories (Foshol, 2009).

Therefore, it is imperative to increase rice production in order to meet the growing demand for food emanating from population growth. However, there have been ups and downs in the domestic production of food grains. Diverse climatic phenomena like cyclone, drought, changing rainfall patterns and temperature caused significant loss in food grain production every year. So the challenges faced by the agricultural sectors from the adverse climatic conditions and population growth require systematic integration of environmental and economic development measures for sustainable agriculture growth.

1.2 Objectives of the Study

- Assessment of Population and Rice production (Boro, Aus and T.Aman) Trend in the year of 1971-2006
- Projection of Possible Population and Rice production in the years 2020, 2030, 2040 and 2050
- To identify the state of food security in the realm of changing climatic conditions, mainly focusing on temperature rise, and population growth on rice production in Bangladesh
- Assessing the effect of food security on human rice demand and economic conditions in Bangladesh in the years 2020, 2030, 2040 and 2050
- The study proposes policy recommendations for yield improvement to attain food security needed to feed the country's population

Section 02

2.1 Present Status of Population and Rice Production in Bangladesh

Rice production systems make a vital contribution to the reduction of hunger and poverty in Bangladesh. Total rice production in Bangladesh was 10.32 million tons in the year 1975-76 when the country's population was only 79.90 millions and cultivated rice area was 10.32 million ha. However, the country is now producing 27.32 million tons in 10.71 million ha rice area to feed more than 140 million people (BBS and DAE, 2007). This indicates that the growth of rice production was much faster than the growth of population and the cultivable rice area change is not very significant between the years

1975 and 2007. This increase in rice production has been possible owing largely to the adoption of modern rice varieties on around 73% of the cultivated rice land which contributes to about 85% of the country's total rice production, modern rice cultivation technology, improvement irrigation facilities and applications of fertilizer and pesticides (BBS, 2006).

T. Aman had a vital role in increasing the total rice production till 1995-96; after 1995-96, Boro rice is playing a significant role in the total rice production. Boro rice production gradually increased due to increase in cultivation area, high yield varieties, modern technology and improvement in irrigation facilities during winter season. In 2007-2008, Boro rice contributed to more than 58% of the total rice production, whereas, T. Aman 34% and Aus rice only 7%. From this analysis, it is clear that the rice production of this country depends on a considerable part on Boro rice production.

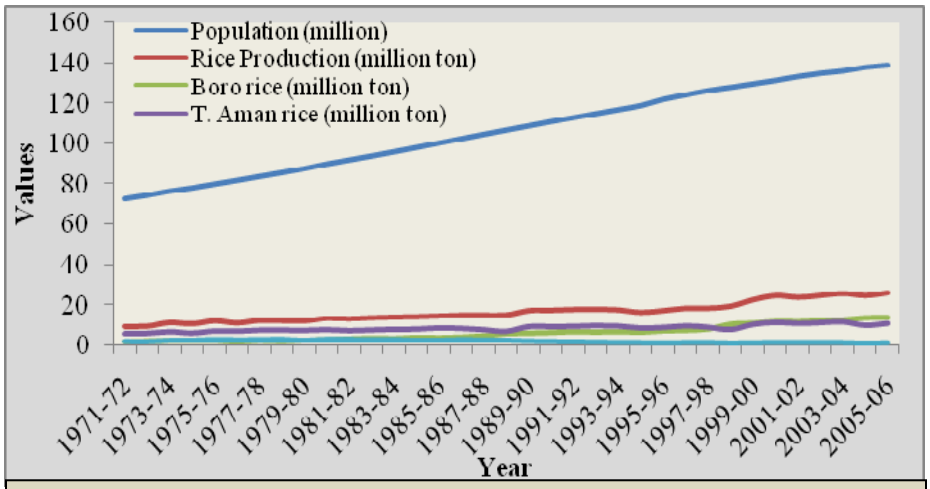

Figure 1: Population and rice production in Bangladesh (Year wise)

The rice cultivation area has mostly remained unchanged over the last few decades but there is a good sign to increase Boro rice area because it makes an important contribution to increase the overall rice production and the main source of livelihood for the farming community in Bangladesh. Rice areas of T. Aman and Aus have gradually decreased after the year 1989-90 (Fig. 2).

Population of Bangladesh is increasing at a rate of two million every year and the total population will be 233.2 millions in the next 40 years if the current trend continues. Therefore, Bangladesh will require more than 55.0 million tons of rice to feed its people by the year 2050. During this time, total rice area will have shrunk due to pressure from cultivating high value crops, urban and industrial development and expansion of human settlement area.

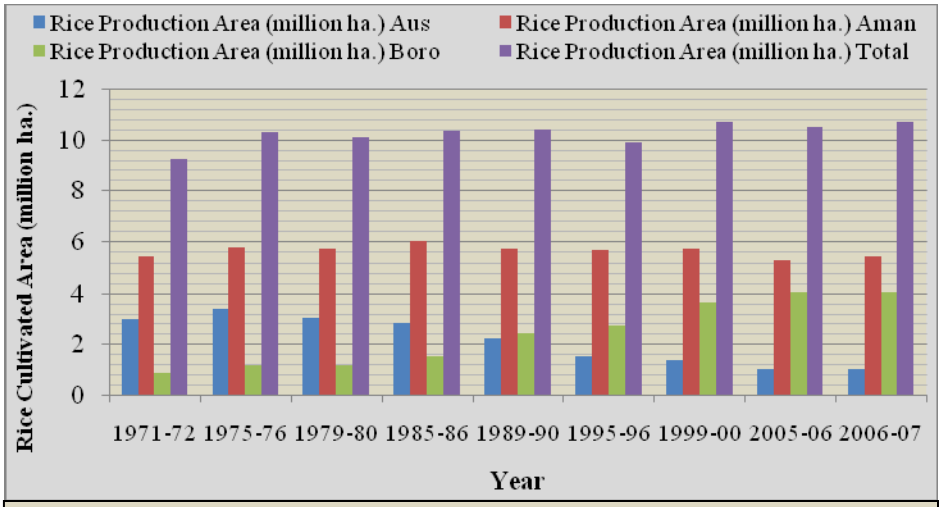

Figure 2: Area under rice production in Bangladesh

2.2 Potential Impacts of Temperature on Rice Production in Bangladesh

Temperature greatly influences not only the growth duration, but also the growth pattern and the productivity of rice crops. During the growing season, the mean temperature, and the temperature sum, range, distribution pattern, and diurnal changes, or a combination of these may be highly correlated with grain yields (Basak et al., 2009). Rice plant has nine growth stages with its three distinct growth phases and every stage has an optimum temperature range for its proper development. The critical temperatures for the development of the rice plant at different growth phases (vegetative, reproductive and ripening) are shown in Table 1. These critical temperatures differ according to variety, duration of the critical temperature, diurnal changes and physiological status of the plant (Yoshida, 1981). Extreme temperatures, whether low or high, cause injury to the rice

plant. High temperatures are a constraint to rice production and cause a significant yield reduction. When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep decline in net growth and yield (Rosenzweig and Hillel, 1995).

Table 1: Critical temperature for the development of rice plant at different growth stages

Growth stages	Critical temperature (^{0}C)		
	Low	High	Optimum
Germination	16-19	45	18-40
Seedling emergence	12	35	25-30
Rooting	16	35	25-28
Leaf elongation	7-12	45	31
Tillering	9-16	33	25-31
Initiation of panicle primordia	15	-	-
Panicle differentiation	15-20	30	-
Anthesis	22	35-36	30-33
Ripening	12-18	>30	20-19

(Source: Yoshida, 1978)

A number of modeling studies (e.g., Basak et al., 2009; Mahmood et al., 2003; Mahmood, 1998; Karim et al., 1996) have been carried out to assess the impacts of climate change and variability on rice production in Bangladesh. DSSAT model has predicted significant reduction in Boro rice yield due to climate change. Yield reductions of over 20% and 50% have been predicted for the years 2050 and 2070 respectively (Basak et al., 2009). Karim et al., argued that a significant yield reduction may occur in rice and wheat (35% and 31% respectively) due to changing climatic conditions in the future. Therefore, there is a great threat to both rice and wheat production (main food grains in Bangladesh) which may directly affect the food security and also pose a social security problem for developing countries like Bangladesh.

2.3 Future Rice Demand for Food Security

Huge population size, extreme population density and high levels of poverty impose significant challenges towards sustainable food security in Bangladesh. From the analysis of population data from the last 35 years (1971-2005), it was observed that population increased at a rate of 2.042 million per year. Similarly, rice production increased at a rate of 0.4582 million tons per year (rice production data, 1971 to 2005), Boro rice production increased at a rate of 0.3654 million tons per year, T. Aman production increased at a rate of 0.1388 million tons per year, whereas Aus rice production decreased at a rate of 0.0463 million tons (Fig. 1). The statistical data indicates that rice production will largely depend on Boro rice production in future. If this rate continued for a few years such as 2020, 2030, 2040 and 2050, then there will be a huge shortage (5.08, 6.02, 7.80 and 10.50 million tons respectively) compared to the requirement of total population in the aforementioned years (Table 2 and Fig. 3). These projected results of rice production will only be possible if there are great developments in new rice varieties, improved management practices, increased rice areas, and above all strengthen the government policies in agricultural sectors. Projected values of population and rice production (included Boro, T.Aman and Aus rice) on the specified years (2020, 2030, 2040 and 2050) are calculated by simple trend line equation

Y=mX+C

Where, **Y**-Projected value (population or rice production) for a specific year

m- Slope (rate of change per year)

X-Interval between two periods (initial to projected year) and

C-Constant

Equations used to calculate projection values are **Y=2.0418X+69.876** (population), **Y=0.4582X+8.7376** (rice production), **Y=0.3654X-0.4721** (Boro rice production), **Y=0.1388X+5.946** (T. Aman rice production) and **Y= -0.0463X+3.268** (Aus rice production).

The study used the standard formula developed by Abdullah et al., 2006 to estimate rice consumption for the targeted years, is as follow

$$X_{t+n} = (1+r)^n Q_t$$

Where, X_{t+n}-volume of targeted year,

r-Average growth rate (average growth rate 1.41% for Bangladesh, source: BBS, 2006)

Q_t-Volume of base year (2006)

n-Total number of years ahead

The projected values represent that rice production will not be sufficient compared to its population and it will be more acute in 2050. About 10.50 million tons rice shortage is estimated for its total population demand in 2050 which is about 38.43% compared to the total rice production in Bangladesh in the year of 2006-07 (rice production in 2006-07 was 27.32 million tons). From the analysis, it is also clear that Boro, T.Aman and Aus rice production would fall short in all targeted years compared to the growing population. T.Aman and Aus rice production shortage are significantly higher than Boro rice production. Therefore, food insecurity will not only occur for Boro rice production, but it may also be more vulnerable for the reduction of Aus and T.Aman production.

Table 2: Projected Total Population and Rice production in Bangladesh

Year	Population (million)	Total Rice Production (million tons)		
		Requirement	Production	Achievement/Shortage
2006-07*	140.60	29.77	27.32	-2.45
2020	171.97	36.73	31.65	-5.08
2030	192.38	42.25	36.23	-6.02
2040	212.80	48.60	40.81	-7.80
2050	233.22	55.90	45.40	-10.50

(*Source: BBS, 2006-07 and Author's own calculation)

Year	Boro Rice Production (million tons)			T. Aman Rice Production (million tons)			Aus Rice Production (million tons)		
	Req.	Prod.	Ach. /Short.	Req.	Prod.	Ach. /Short.	Req.	Prod.	Ach. /Short.
2006-07	16.31	14.96	-1.35	11.82	10.84	-0.98	1.64	1.51	-0.13
2020	20.12	17.80	-2.32	14.58	12.89	-1.70	2.02	0.95	-1.07
2030	23.15	21.45	-1.70	16.77	14.27	-2.50	2.33	0.49	-1.84
2040	26.62	25.10	-1.52	19.30	15.66	-3.64	2.68	0.03	-2.65
2050	30.63	28.76	-1.87	22.20	17.05	-5.50	-	-	-

(Source: Author's own calculation)

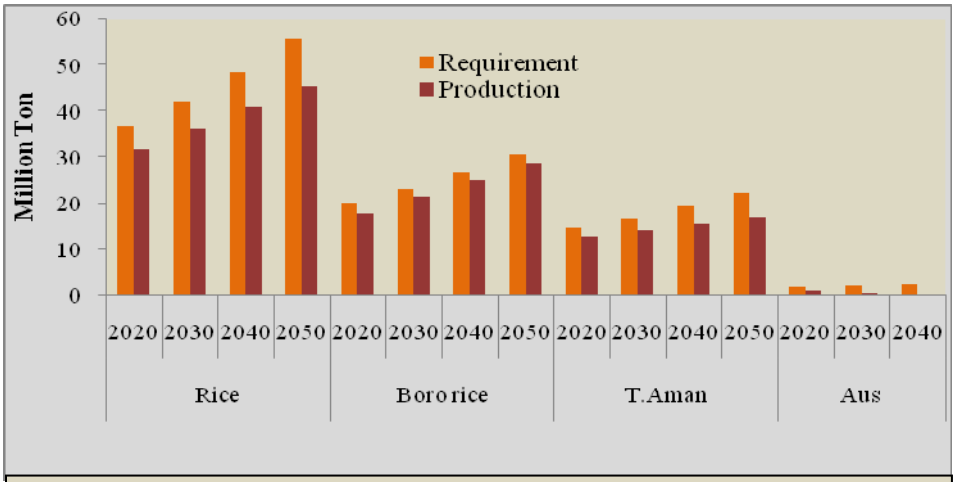

Figure 3: Rice production and requirement in Bangladesh

2.4 Impacts of Temperature on Rice Production Associated with Food Security

It has already been mentioned that during 2007-08, Boro rice contributed to more than 58% of the total rice production in Bangladesh. To see the effects of temperature on Boro rice yield and consequently rice production in Bangladesh, a modeling study (Decision Support System for Agrotechnology Transfer, version 4) has been conducted specifically for Boro rice to observe the effects of temperature, on the basis of IPCC Fourth assessment report (temperature is projected to rise by between 1.8°C to 4.0°C by 2100) for the following assumptions (Table 3). It should be also noted that the other climatic phenomenon such as changing solar radiation and rainfall patterns, cyclones, floods, and drought are not considered in the present study.

Boro rice production is expected to reduce by 1.5%, 2.5%, 4.4% and 5.4% (base year 2008) in the years 2020, 2030, 2040 and 2050 respectively. Therefore, a considerable amount of Boro production might decline, which will directly affect the total rice production of this country. Rice and Boro rice production, requirement, shortage and achievement for the targeted years (2020, 2030, 2040 and 2050) are shown in Table 4.

Table 3: Year wise assumptions carbon dioxide concentrations and temperature data		
Year	IPCC	CO_2
	Average Temperature	379 ppm in 2005
2008 (Base)	**0.042 ^{0}C/year**	**1.9 ppm/year**
2020	0.67	409
2030	1.09	428
2040	1.51	447
2050	1.93	466

Table 4: Effects of Temperature on Rice Production						
Year	**Total Boro Rice Production (million tons)**			**Total Rice Production (million tons)**		
	Req.	**Prod.**	**Ach. /Short.**	**Req.**	**Prod.**	**Ach. /Short.**
2006-07	16.31	14.96	-1.35	29.77	27.32	-2.45
2020	20.12	17.53	-2.59	36.73	29.05	-7.68
2030	23.15	20.91	-2.24	42.25	34.00	-8.25
2040	26.62	24.00	-2.62	48.60	38.20	-10.40
2050	30.63	27.20	-3.43	55.90	41.97	-13.93

(Source: Author's own calculation)

Temperature influences rice production significantly. From the modeling study it is found that there will be a small amount of Boro production shortage in the years 2020, 2030, 2040 and 2050 (Table 2); but when the temperature effects are considered, there is a considerable shortage (2.59, 2.24, 2.62 and 3.43 million tons respectively) in the amount of Boro production which directly affects the total rice production in Bangladesh. Rice production shortage of about 13.93 million tons in 2050 is predicted, which accounts for about 50.10% of the total rice production in the year 2006-07 (Table 4). As a result, more than 11.50% (3.14 million tons) rice shortage may occur only due to temperature and its effect on Boro rice production during 2050 (38.43% rice shortage may occur for increasing population and 50.10% for increasing population and temperature effect in 2050, compared to 2007) (Fig. 4).

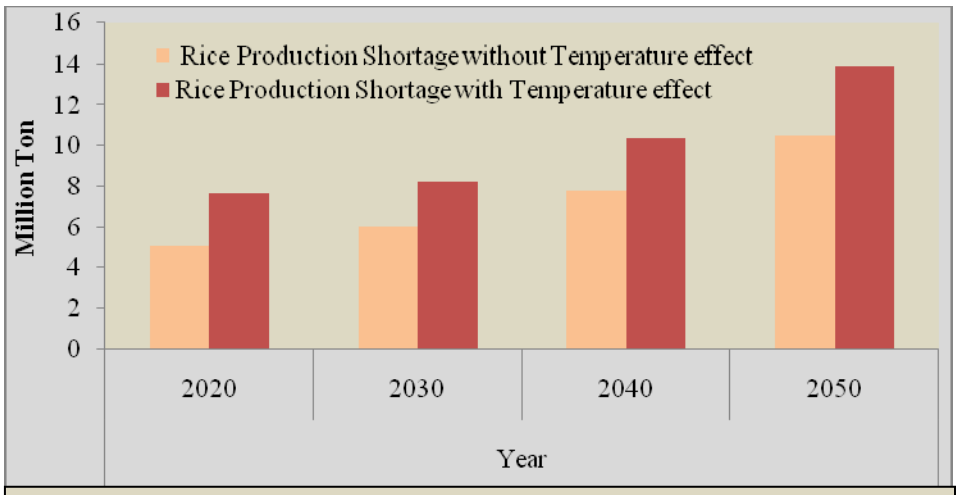

Figure 4: Impacts of Temperature on rice production in Bangladesh

2.5 Impacts on Human Rice demand

In Bangladesh rapid population growth makes it difficult for rice production to keep pace with the rising demand for food. According to the BBS 2006-07, the total rice demand in Bangladesh was 29.77 million tons, whereas production was only 27.32 million tons, corresponding to the total population of 140.60 million. More than 2 million tons rice shortage occurred in 2006-07. Therefore, a huge segment of the population in Bangladesh is partially or fully deprived from their basic rice demand and this condition will be more hostile in the future due to pressure from increasing population. Climate change will complicate the scenario further.

Rice demand for a single people was 580 gm per day or 211.73 Kg per year in 2006-07, but the rice production was insufficient in that year. From the previous analysis (Table 2), it was found that rice shortages are predicted to be 5.08, 6.02, 7.80 and 10.50 million tons in the years 2020, 2030, 2040 and 2050 respectively. These shortages arise only due the huge population's growing rice demand in the corresponding years. About 10.50 million tons of rice shortage may occur in 2050 and if it is converted to rice demand for people, more than 4.5 crore people would be completely deprived from rice, which accounts for about 35 % of the total production of 2006-07. When the temperature effects are considered with population growth (Table 4), rice shortages of 7.68, 8.25, 10.40 and 13.93 million tons respectively are projected. Therefore, more than 6.5 crore people may

be fully deprived from their rice requirement within 2050, which is 45 % increment on 2006-07 statistics (Table 5).

Table 5: Population growth and Temperature effect on Food Security in Bangladesh

Year	Population Growth			Population Growth and Temperature		
	Rice Shortage million tons	People deprive from rice million	% of Population	Rice Shortage million tons	People deprive from rice million	% of Population
2020	5.08	24.00	17.07	7.68	36.27	25.80
2030	6.02	28.43	20.20	8.25	38.96	27.71
2040	7.80	36.84	26.20	10.40	49.12	34.94
2050	10.50	49.60	30.92	13.93	65.80	46.80

(% of population is counted by comparing to the total population in 2006-07)

2.6 Impacts on Economic Conditions in Bangladesh

Agriculture remains the most important sector of the Bangladesh economy. It contributed 20.83 % to the national GDP and employs 48.1% of the population. In 2007-08 fiscal years, agricultural sector contributed 6.99% ages of the total export earning. In the first nine months of 2009, exports were 651 million USD, which accounted for 5.59% of the total export earnings over the period (Bangladesh Economics Review, 2009).

According to the Bangladesh Economics Review 2008, the total GDP in 2007-08 fiscal years was more than five thousand billion Taka (Tk. 5458.2 billion), whereas the contribution of Agricultural and Forestry sectors was more than fifty thousand crore Taka (Tk. 50157 crore) and the GDP growth rate on that fiscal years was 6.19%. In the analysis of the last few years' data, it was observed that GDP growth rates followed an increasing trend and it was more than 5.5% from 2001. In this study, GDP in the fiscal years 2000 to 2008 were used to find the possible GDP in the targeted years 2020, 2030, 2040 and 2050 by using polynomial method (Table 6). From the previous study (Table 4 and Table 5), it was found that considerable rice shortages may occur in the specified years due to both increasing temperature and growing population. These rice shortages are calculated in terms of money (Taka in thousand crore) by using the following formula:

$$Q = q(1+r)^n$$

Where, **Q** = Rice price for those specified years

q = Rice price in base years (Assume, rice price Tk. 32 per Kg. in 2008-09)

r = Average rate of inflation in 2008-09 is 7.84 %

n = Total number of years ahead

These rice shortages may have a significant impact on the country's economy in the long run and may cause a substantial dent in the GDP. Almost 0.10% of the total GDP and 0.60% of Agricultural and Forestry GDP will be wiped out due to population growth by 2050. Accordingly 0.12% of the total GDP and 0.80% of the Agricultural and Forestry GDP will decrease due to increasing temperature and population. About 0.80 thousand crore Taka would be lost in 2050 due to rice shortage. In comparison, it is equal to about 0.15% of the total GDP and 1.5% of Agricultural and Forestry GDP in the fiscal year 2007-08. On the other hand, about 1.06 thousand crore Taka may be lost due to increasing population and temperature which accounted for more than 0.2% of the total GDP and 2% of the Agricultural and Forestry GDP in the fiscal year 2007-08. It should also be noted that the percentages values are estimated from a study of Boro rice is considered to see the effects of increasing temperature on its production and overall it impacts on rice production and the human rice demand and economic conditions in this country. These figures are expected to be higher, if other crops (T. Aman and Aus rice), wheat, potato, and other agricultural sectors such as fisheries and forestry are considered which directly or indirectly affected by changing climatic conditions.

Table 6: Population growth and Temperature effect on Food security, consequently Bangladesh Economy

Year	Total GDP (Taka in Th. Crore)	Ag. GDP (Taka in Th. Crore)	Population Growth				Population Growth and Temperature			
			Rice Shortage (million tons)	Rice Shortage (Taka in Th. Crore)	% of Total GDP	% of Ag. GDP	Rice Shortage (million tons)	Rice Shortage (Taka in Th. Crore)	% of Total GDP	% of Ag. GDP
2020	613.00	90.00	5.08	0.040	0.007	0.04	7.68	0.061	0.01	0.07
2030	696.00	102.00	6.02	0.101	0.015	0.10	8.25	0.140	0.02	0.14
2040	794.00	118.00	7.80	0.280	0.04	0.24	10.40	0.373	0.05	0.32
2050	880.00	134.00	10.50	0.800	0.10	0.60	13.93	1.061	0.12	0.80

(Th. : Thousand)

Section 03

3.1 Adaptation Strategies

Bangladesh is one of the most vulnerable countries to climate change due to its economic, social and geological construct. Individual dependence on agriculture, widespread poverty, inadequate technology and lack of political power are likely to exacerbate the impacts of climate change and food security on this country. Improving Boro and T.Aman production and restraining the declining rate of Aus rice production and developing more heat tolerant rice varieties and management practices would be vital in increasing rice production.

Adaptation involves adjustments to decrease the vulnerability of rice production to climate changes. Field level adaptations include changes in planting and harvesting dates, tillage and rotation practices, substitution of crop varieties or species more appropriate to the changing climate regime and improved irrigation and drainage systems. There are a range of technological options that are currently available, which can be properly used for enhancing the rice production systems and the ability to adapt and to mitigate the effects of climate change. Crop scientists should place more emphasis on the development of heat and drought resistance varieties and the feasibility of manipulation through modern genetic techniques.

The Government of Bangladesh can also facilitate adaptation to climate change through water development projects, agricultural extension activities, incentives, subsidies, provision of insurance, emphasis on the agricultural research organizations and above all strengthening the polices on the agricultural sector.

3.2 Conclusion

Impacts of climate change on food production and food security are global concerns, but it is more so for a country like Bangladesh. Agriculture is under the gun mainly due to increasing demand for food from the growing population. The prospects of global climate change make this problem a priority for Bangladesh.

Higher temperatures and water stress due to heat would result in a significant decline in rice production. Increasing population also affects food security in the future. The combined effect would be more acutely felt in 2050. Economic conditions of this country are directly linked with the combination of these factors. Economic growth rate in future will be hampered. The study shows, Boro rice production shortage is considerable, significantly due to the effect of temperature alone, which directly affects the total rice production. From the trend line analysis, it is observed that T.Aman production has slightly increased, whereas Aus production decreased at a significant rate. This study also indicates that the rice cultivation area has not considerably changed in the last few decades. From the study, it is clear that food security in future will mainly depend on Boro rice production. If rice production is inadequate to meet the demand, a major part of our population will be deprived from food and will be enforced to lead a hungry life with their families and suffer from malnutrition. Consequently, our next generation is going to face a great challenge in getting their daily food due to changing climatic conditions and the huge population.

Sustainable increase of rice production for food security will require efforts to enhance the capacity of the rice production system to adapt to global climate change as well as to mitigate the effects of rice production on global warming. Technical options for adaptation and mitigation are available, which should be properly applied in the agricultural sector. Policy support to rice research and development to develop and transfer appropriate and efficient technologies, will be vital for the realization of such measures for sustainable rice production. Above all public awareness of the impact of climate change on the agricultural production deserves consideration as a priority.

References:

Abdullah ,A.B., Ito, S. and Adhana, K. 2006. Estimate of Rice Consumption in Asian Countries and the World Towards 2050. Proceedings for Workshop and Conference on Rice in the World at Stake, 2. School Lunch Programs and Rice Consumption Behaviors: International Comparison.

Bangladesh Economics Review, 2009. Government of the People's Republic of Bangladesh. Ministry of Finance, Dhaka.

Bangladesh Economics Review, 2008. Government of the People's Republic of Bangladesh. Ministry of Finance, Dhaka.

Basak, J.K., Ali, M.A., Islam, M.N. and Alam, M.J.B. 2009. Assessment of the effect of climate change on boro rice production in Bangladesh using CERES-Rice model, Proceedings of the International conference on Climate Change Impacts and Adaptation Strategies for Bangladesh, 18-20 February 2009, p. 103-113.

BBS (Bangladesh Bureau of Statistics), 2006. Statistical Year Book of Bangladesh. Planning Division, Ministry of Planning Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics), 2007. Statistical Year Book of Bangladesh. . Planning Division, Ministry of Planning Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics), 2008. Statistical Year Book of Bangladesh. . Planning Division, Ministry of Planning Government of the People's Republic of Bangladesh, Dhaka.

DAE (Directorate of Agricultural Extension), 2007. Government of the People's Republic of Bangladesh. Ministry of Agricultural, Dhaka.

Food and Agriculture Organization (FAO), 2002. The State of Food Insecurity in the World 2001. Food and Agriculture Organization ,Rome.

http://www.foshol.org/EC%20Food%20Security/current_conditions.htm

Karim, Z., Hussain, S. G. and Ahmed, M. 1996. "Assessing impacts of climatic variations on foodgrain production in Bangladesh". Kluwer Academic Publishes, Netherlands.

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 Modeling, 106, 201-212.

Mahmood, R., Meo, M., Legates, D. R. and Morrissey, M. L. 2003. The Professional Geographer, 55(2), 259-273.

Rosenzweig, C and Hillel, D. 1995. "Potential impact of climate change on agriculture and food supply", Consequence, 1(2).

Yoshida, S. 1981. Fundamentals of Rice Crop Science. International Rice Research Institute. Los Banos, Philippines. pp. 269.

Annex I

Selection of study area:

The simulation study was conducted in six major rice growing locations in Bangladesh. Among them, Rajshahi was selected from Rajshahi division; Mymensingh was selected from Dhaka division; Satkhira from Khulna division; Barisal from Barisal division; Comilla from Chittagong division; and Sylhet district from Sylhet division. It has also been mentioned that the weather and soil data were also collected for those selected locations.

Data Collection:

Crop management data required by the DSSAT model include planting method, transplanting date, planting distribution, plant population at seedling, plant population at emergence, row spacing, plants per hill, fertilizer application dosage and irrigation application and frequency were collected from Bangladesh Rice Research Institute (BRRI, 2009). The major crop management input data was used in the model for all simulations.

Soil data (percentage of clay, silt and stones, organic carbon, cation exchange capacity, pH in water, etc) were collected from Soil Resources Development Institute (SRDI), Dhaka and Bangladesh Rice Research Institute (BRRI), Gazipur.

Weather data including average daily maximum and minimum temperatures, daily precipitation, carbon dioxide in 2008 were collected from BMD. First, the simulation study is conducted for 2008 to predict boro rice yield for the major six rice growing locations under 2008 climatic parameters.

The model uses a detailed set of crop specific genetic coefficients, which allows the model to respond to diverse weather and management conditions. Therefore, in order to get reliable results from model simulations, it is necessary to have the appropriate genetic coefficients for the selected cultivar. The Boro rice variety BR3 has been selected in the present study because genetic coefficients for this variety are available in the DSSAT modeling system. Although this variety is not widely used at present, the effects of climate change and variability on this variety provides insights into possible impact of climate change on Boro rice yield in the future. In order to assess the effect of climate change on the rice varieties currently being grown in Bangladesh, it is necessary to determine their genetic coefficients through carefully controlled field and laboratory experiments for 1 to 2 years.