

Impacts of Climate Change on Food Security in Bangladesh -- A GIS-based analysis

M.A. Siraj¹, M. N. Neema^{1*} and M.T.H. Shubho¹

¹Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh. *Email: mehernigar@urp.buet.ac.bd

Abstract-- Climate change has some conspicuous adverse impacts on food production. Bangladesh is confronted with a big challenge to cope up with the significant impact of climate change. In this context, an attempt has been made using GIS to analyze the impacts of climate change on Gross Domestic Products (GDP), rice cultivated area, food production and availability, crop production due to temperature and CO₂ rise, and ultimate food security due to natural calamities. This study includes the prevailing data on food sector, socio-economic and demographic information. Statistical and GIS analyses manifest that, the contribution of agricultural sector in GDP was reduced by 13.56 % from fiscal year 2003-04 to 2010-11 and arable lands of the country were declined especially for major rice of type-1 (Aus) and type-2 (Aman) by 64.24 % and 6.5 % respectively in spite of significantly increasing overall cultivated area due to increased cropping intensity of high yielding variety rice type-3 (Boro). On the other hand, the domestic production of different types of cereal and non-cereal crops was increased except wheat and pulses which reduced respectively 29.22% and 172.69% from fiscal year 1995-96 to 2009-10. Besides, due to temperature rise wheat, Aus and Boro production reduced by 27%, 61% and 62% respectively and due to climate change induced calamities, on an average almost 409077.5 metric tons food production are lost and 23.62 million hectares of agriculture lands are degraded every year. In addition, per capita consumption of people has found to be decreased due to the high population pressure and climate change induced different natural calamities. These results obtained thus can support decision makers, concerned authority and general citizens to realize the current food security aspects of Bangladesh and the government can undertake effective measures to ensure the food security..

Index Term-- Climate change, Food security, Cultivated area, GDP, GIS.

1. INTRODUCTION

Climate change is a phenomenon that is causing the earth to become warmer, which means that our climate and weather systems are changing towards a warmer state which affects a lot in survival [1]. Bangladesh, is recurrently known as one of the most vulnerable countries to climate change due to its geographic location, pressure of population, high level of poverty and high dependency on primary economic activities especially agriculture based activities and fisheries. Many of the probable undesirable affects of climate change, such as sea level rise, increasing temperatures, enhanced precipitation, and an increase in intensity and frequency of different natural calamities, will aggravate the existing stresses that already obstruct development in Bangladesh, particularly by reducing water and food security [2]. Food security refers to the physical and economic access to sufficient, safe and nutritious food to meet the dietary needs and food preferences for an active and healthy life [3]. Agriculture is always vulnerable to unfavorable weather events and climate conditions. The impacts of climate change on food security are global concerns, especially for Bangladesh, where livelihoods of

most of the people depend mainly on agriculture. Climate change affects plants, animals and natural systems in different ways. Changes in temperature and irregular precipitation that already affect the livelihood and production of a large number of rural families are expected to become more serious in the face of climate change. In the past 20 years, Bangladesh has achieved considerable progress in the agricultural sector. Cereal production contributed a large amount, especially the rice production even before the population doubled in last 40 years. However, Bangladesh's food production potential is likely to diminish due to the impact of climate change. Food insecurity therefore has also become a burning issue hindering people's access to food in terms of purchasing power and food distribution, and in terms of people's food preferences [4].

In this context, the main goal of this study is to demonstrate the impact of climate change on food security in Bangladesh with the help of GIS. In particular, this study focuses on rice cultivation, GDP growth, food production and availability. Impacts due to natural hazards on food security and food utilization as a negative effect of climate change and also some positive impacts of climate change on food security in Bangladesh are analyzed, quantified and visualized with GIS mapping and statistical extrapolation. This paper studies the phenomenon of climate change and its ineluctable impacts on food security more comprehensively which would help the decision makers to formulate new strategies towards increasing resiliency of the crops to climate change.

2. MATERIALS AND METHODS

In order to unfold the impact of climate change on food production of Bangladesh, the entire country was chosen as study area. The study was conducted on the basis of secondary information on various aspects related to agriculture and livelihood. Socio-economic statistical data and other relevant data were collected from Bangladesh Bureau of Statistics (BBS) and from different literatures. Crops considered for analyses are the three types of rice (type-1 (Aus), type-2 (Aman) and type-3 (Boro)) and wheat, data on which were collected from Agricultural Ministry of Bangladesh, Food and Agricultural Organization (FAO) of the United Nations in Bangladesh and BBS. Besides, this research accumulated data from different books, research papers and journals on climate change and food security. Collected data from different sources were compiled, tabulated and analyzed through Spreadsheet tools and GIS. ArcGIS 10.1 were used for mapping, analysis and comparison of collected information. The results of GIS and statistical analyses were also comprehensively presented in graphical and pictorial form.

3. RESULTS AND DISCUSSION

Agriculture is important for food security in two ways: first one, it produces the food people eat; and secondly, it is one of the primary sources of livelihoods, accounted for 36 percent of the world's total workforce [5]. The economy of Bangladesh is mainly agriculture based, with almost 70% of the population directly or indirectly relying on agricultural activities. However, agriculture is highly sensitive to climate change, particularly changes in temperature, rainfall patterns, increased carbon-dioxide, sea level rise and frequent natural disasters. These are mainly responsible for incessantly reduced crop yields in Bangladesh. Several studies have been conducted in Bangladesh to assess the vulnerability of food grain production to various climate scenarios. One such study shows if the temperature increases in Bangladesh, there would be about 28 percent reduction in rice and almost 68 percent reduction in wheat production [6]. This research manifests the bizarre impacts of climate change on agricultural sector under the following segments.

3.1 Impacts on GDP

The overall impact of climate change on agricultural production in Bangladesh is wide spread and devastating for the country's economy. Analyzing data on agricultural contribution to country's GDP, as shown by Figure 2(a), it is found that the GDP growth of Bangladesh in agriculture is declining over the years. In fiscal year 2003-2004, the contribution of agricultural sector in GDP was 23.08 percent which were the highest in last eight fiscal years. However, the contribution in fiscal year 2010-11 was 19.95 which declined almost 13.56 % from 2003-2004 for different climatic variation.

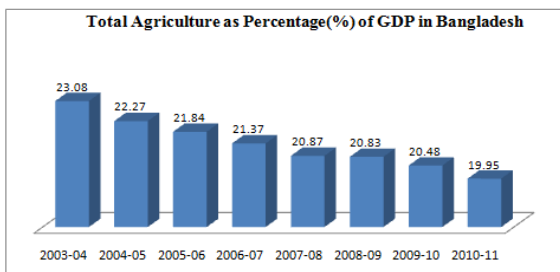


Figure 1(a)

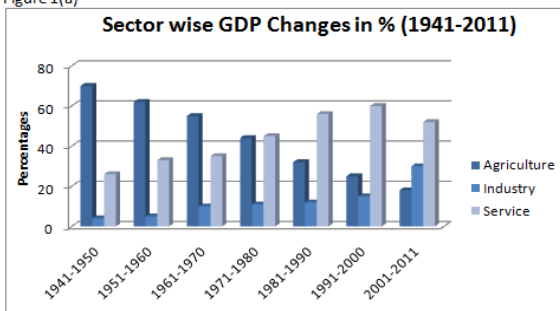


Figure 1(b)

Fig. 1. (a) Total Agriculture (%) of GDP in Bangladesh; (b) Sector wise GDP Changes in % from 1941-2011

In Figure 1(b), we see Agriculture sector's decreasing growth rate during 1941-2011; agriculture sector contributed 70% of total GDP in 1950. Now the contribution has decreased to 18% in 2011. It is very catastrophe for our country because most of our village people depend on

agriculture. Growth rate during 1941-2011, industry sector's contribution has been increasing which has a good impact on our economy and our movement towards the modern fast world. The sector jumped to 30% from 15% in 2001-2011. Now service sectors have increased to 52% of total GDP. The current share of agriculture to GDP is around 18%, although this share has been declining in the last seventy years These changes mainly happened due to the different types of devastating natural calamities especially cyclone and flood.

3.2 Impacts on Rice Cultivated Area

Rice is the most important crop in Bangladesh. Together with the reduction in Aman rice area (as a result of greater spatial extent and longer duration of flooding) and in the Aus rice area (due to constraints in irrigation), the total area suitable for rice production will decrease in future. Due to sea level rise along the southwestern coastal region of Bangladesh, Aman and Aus suitable areas would decrease significantly [7, 8]. Cultivated area under Boro has increased significantly from last twenty years. Due to the climate change impact, Aus cropped area has significantly declined over the years. From 1980-2010, the total Aus cropped area reduced 64.24 % (Figure 2a). Aman is the second largest crop in the country in respect of the volume of the production. But Aman cropped area has been declined significantly over the years. From 30 years it has been declined almost 6.5% Figure 2(b).

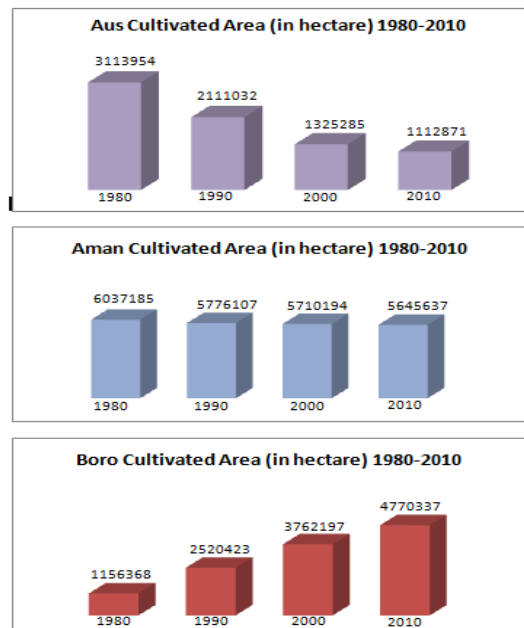


Fig. 2. Aus, Aman and Boro cultivated Area from 1980-2010

From last 20 years, Boro crop played the most important role in rice production and food security of Bangladesh. In 1980, it was cultivated only 1.15 million hectares but now it became 4.77 million hectare which increased 312.53% in 2010 (Figure 2c) because of HYV and temperature rising.

From GIS map analysis it is seen that, major changes of Aus cropped have been noticed in northwest and central

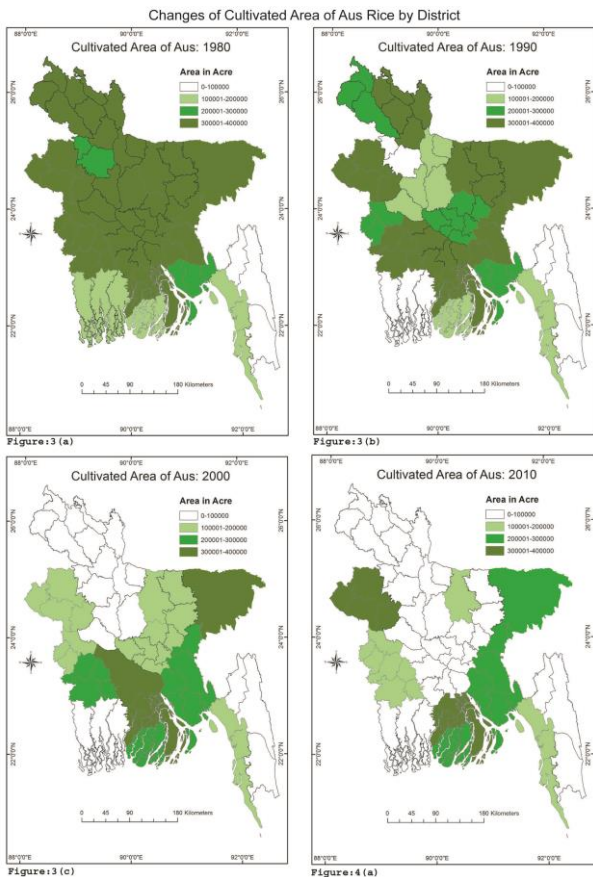


Fig. 3. Changes of Cultivated Area of Aus from 1980-2010.

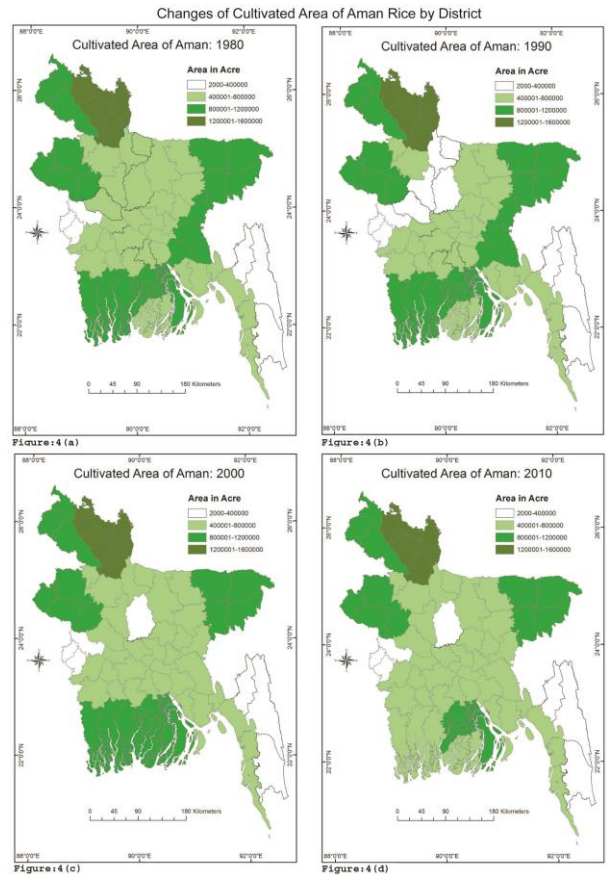


Fig. 4. Changes of Cultivated Area of Aman from 1980-2010.

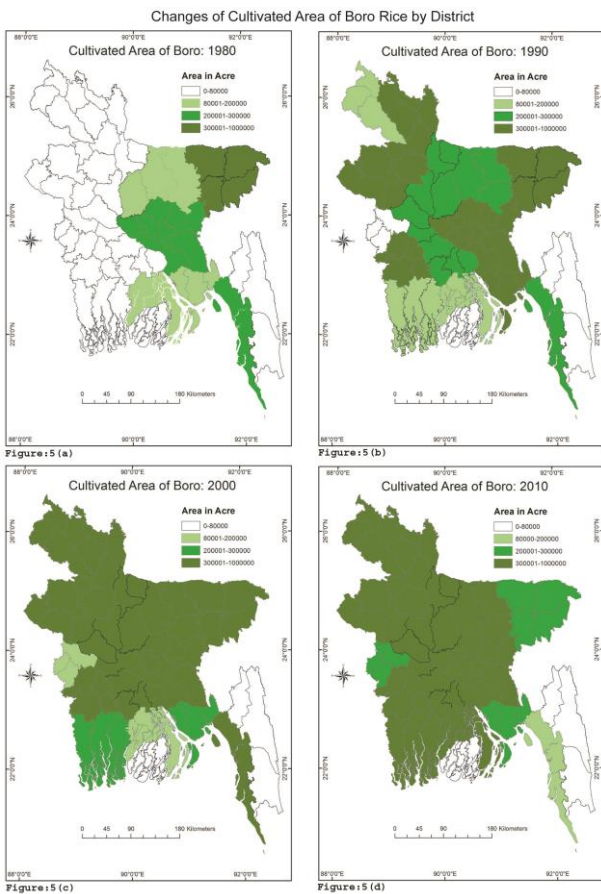


Fig. 5. Changes of Cultivated Area of Boro from 1980-2010.

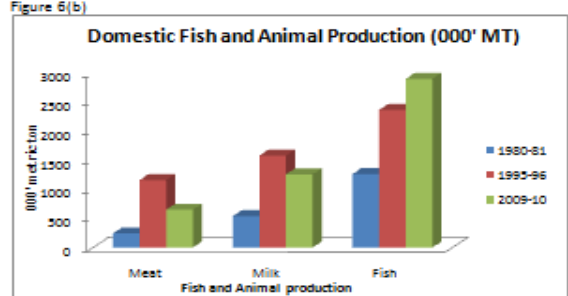
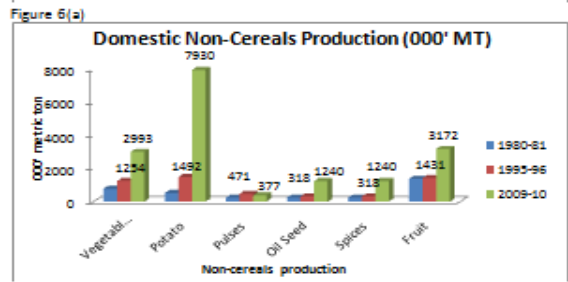
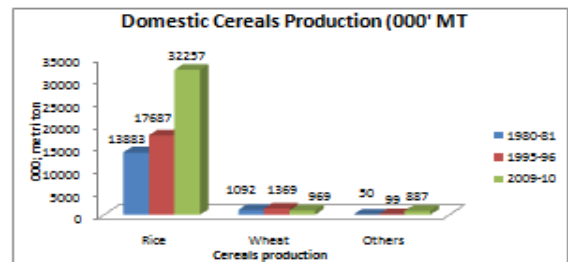


Fig. 6. Domestic production of different food menu

regions of Bangladesh (Figure 3) where different types of disaster especially climate induced cyclone, salinity intrusion and flood are mainly seen in this region. Figure 3(a) and 3(b) shows most of the cultivated area of Aus was 300001-400000 acres but in 2000 and 2010 it is significantly change and now most of the cultivated area of Aus 0-100000 acres (Figure 3c, 3d). GIS mapping shows that Aman cropped area has been declined significantly over the years and these changes in all over the country especially coastal region of southern part, flood prone and drought prone region of northern and central part of Bangladesh (Figure 4). These change occurs because of change of unusual behavior of climate and its elements. Figure 5 shows the changes pattern of cultivated area of Boro rice from 1980-2010. In 1980, most of the land were cultivated only 0-80000 acres but in 2010 it change a very significant way which converted into 300001-1000000 acres.

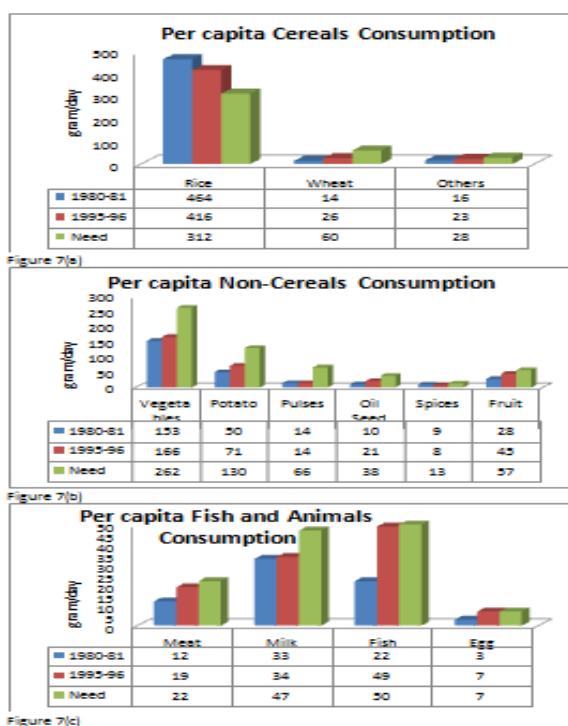


Fig. 7. per capita consumption of different food menu

3.3 Impacts on Food Production and Availability

Production of food and other agricultural commodities may keep pace with aggregate demand, but there are likely to be significant changes in local cropping patterns and farming practices. Climate change affects food production directly through changes in agro-ecological conditions and indirectly by affecting growth and distribution of incomes, and thus demand for agricultural produce [9, 10, 11, 12, 13]. As a major staple food, rice occupies 71 percent of the gross cropped area and accounts for over 94 percent of food grain production. Its contribution to total per capita calorie and protein intake is 74 percent [14]. Rice production continues to increase, but wheat production is showing a declining trend in recent years. Remarkable progress has been made in rice production during the last fifteen years. Spreadsheet analysis shows that, in 1995-96, rice production was 17.69 million tons, which has sharply increased to 32.25 million tons in 2009-10 (Figure 6(a)). Wheat production also

increased from 1.09 million tons in 1980-81 to 1.37 million tons in 1995-96. It then started declining and the production has come down to 0.97 million tons in 2009-10. Similarly, pulses and oilseed production steadily declined mainly because of the loss of areas under these crops to Boro rice and other associated winter crops. Production of non-cereals crops such as pulses, oilseeds, vegetables and fruits, which are the chief sources of protein, mineral and vitamin, still remains far below the actual requirements, and thereby making it difficult to provide balanced diet for all.

The production of meat, milk, fish and egg etc has increased significantly over the last thirty years. But the shortage is still wide. The current per capita intake of animal protein is less than 2 gm/day against the FAO recommendation of 28 gm/day, similarly, domestic milk production accounts for only 14% of the minimum requirement. Per capita availability of milk is approximately 30 ml/day against the FAO recommendation of 250 ml [15]. Accordingly, per capita availability of cereals (rice and wheat) has been found to decrease from 464.3 gm/day in 1999-96 to 416 gm/day in 2009-10 (Figure 7a). Sharp increase in per capita availability of potato, fruits and vegetables is seen in the last fifteen years, while the per capita availability of pulses and oilseeds has declined significantly. Availability of meat, milk and egg has also increased. So it is clearly seen that, through the production of different cereals and non-cereals crops increased significantly but it is not enough to meet the per capita consumption.

3.4 Impacts due to Temperature and CO₂ rise on crop production

Food availability is related with the crop production. This crop production is dependent on some elements. Temperature, CO₂ level and the rate of precipitation are the most important element among them. There are different types of crops. For every certain type of crops certain range of temperature is essential. Any types of changes in that temperature range can cause devastating impacts on the crop production. A GCM (Global Circulation Models) reported that, Aus production would suffer by 27 percent while wheat production would decline by 61 per cent under a moderate climate change scenario. Under a severe climate change scenario which is associated with 60% moisture stress, yield of Boro might reduce by 55 to 62 percent.. It is reported that, the effect of soil salinity on Aus production would be detrimental, and Aman, when grown under a severe climate change scenario, could suffer over two-fold yield reduction [16, 17].

3.5 Impacts due to Natural Hazards on Food Security

Bangladesh is already vulnerable to many climate change related extreme events such as flood, drought, cyclone, sea level rise etc. are the major climate induced natural disasters which cause loss of livestock, damage pasturelands, increase fodder scarcity, destroy shelters, decrease production, increase management cost through incidence of diseases etc. Fourth assessment report of IPCC supports that, sea level rise and rise of the sea surface temperature will cause an

intensification of tropical cyclone and storm surge which can greatly impact on live and livelihood pattern of the people.

Figure 9 shows loss of total crop production due to different natural calamities such as cyclone, storm surge,

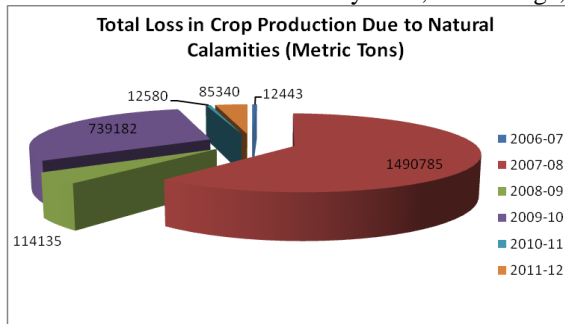


Fig. 9. Total Loss in Crop Production Due to Natural Calamities in the Years of 2006-07 to 2011-12.

flood and excessive rainfall over the last 6 years. Every year in our country almost average 409077.5 metric ton food production are lost due to different climate change related natural calamities. “In 2007 and 2012, wind based shocks affected Boro production in coastal and north-east regions and caused 6.35% and 10.65% loss in production respectively” [18].

3.6 Degradation of Agriculture Land

Every year lots of agricultural lands degraded due to the different types of climate change impact. The considerable extent of degradation of agricultural lands caused by soil erosion, river erosion, and soil fertility decline, depletion of soil organic matter, water logging, soil salinity, pan formation, acidification and deforestation (Table 1). During last three decades 170,000 hectare areas of agriculture lands have been affected by increased salinity intrusion [19, 20]. Table 1 shows that due to the ramification of climate change total 23.62 million hectares of land are by far affected by climate change induced upheavals. Among this enormous amount of affected cultivable land, only 2% and 34% land are very good and good respectively. 25% lands are of inferior in quality.

Table I
Causes of agricultural land degradation [19, 20].

Causes	Affected Area (million ha)	Category of Agricultural lands
Soil erosion	1.70	Very good (2%), Good (34%), Moderate (39%), Poor (16%) Very poor (9%).
River erosion	1.70	
Soil fertility decline	8.00	
Depletion of soil organic matter	7.50	
Water logging	0.70	
Soil salinity	0.84	
Pan formation	2.82	
Acidification	0.06	
Deforestation	0.30	

This research sets forth the causes behind this phenomenon. Frequent natural disasters (especially cyclone and flood), salinity intrusion, alarming rate of sea level rising and temperature rising (annually temperature increased by 0.8° Celsius during 1961-2007) and erratic rainfall etc. are playing the negative roles to ensure the food security. The World Bank estimates that sea level rise by 2020, 2050 and 2100 would be 10 cm, 25 cm and 1 m rise respectively and this rise would inundate respectively 2%, 4% and 17.5% of the total land [21, 22].

4. CONCLUSIONS

This research successfully divulges the impact of climate change on GDP, rice cultivated area, food production and availability, and food utilization of Bangladesh. Although, the overall rice production has increased, no attention has been made yet on the impacts of foreseeable climate change on food security. Results of statistical and GIS analysis, employed in this research, support that due to climate change and its induced calamities arable lands in Bangladesh are decreasing. From this study it is seen that, the production of the different crops (boro (type-3 rice), vegetables, potatoes) are increasing in Bangladesh along with significant decreasing in the production area of specific type-1 (Aus) and type-2 (Aman) rice crops. With decreasing cultivable lands, the country is going to be confronted with food insecurity problem in the upcoming years. In near future, it will pose a negative impact on cultivated area, agriculture production and overall the economy of Bangladesh. The impact of climate change on agriculture is undeniable and will most certainly worsen if governments and donors fail to take appropriate measures right now. Bangladesh urgently needs support to develop climate-resilient agriculture for its people to survive and prosper in the long term. In order to reduce the severity of impacts of climate change on food security alternate livelihoods may be introduced which are affected by climate change such as cultivation of high yielding crop. Shrimp cultivation is severely saline prone therefore shrimp can replace saline rice crop area. Besides, it is mandatory to keep up the flow of present production and taking the proper steps to increase the food production of the country and initiating the national food storage systems to tackle the food shortage situation in an adverse time. The results and analyses thus obtained would help to formulate effective a priori measures and decision making tools for government bodies, planners and relevant personnel.

REFERENCES

- [1] Yusuf, H. K. M. et al. (2008). “Climate Change: An emerging threat to agriculture and food security in Bangladesh”. FAO, Dhaka.
- [2] Huq, S., and Ayers, J. (2008). “Climate Change Impacts and Responses in Bangladesh”. International Institute for Environment and Development, London, UK.
- [3] FAO (1996). *Rome Declaration and World Food Summit Plan of Action*. Rome.
- [4] Ingram, et al. (2010). *Food security and global environmental change*, Washington DC.
- [5] ILO (2007). *Employment by sector: In Key indicators of the labor market (KILM)*, 5th edition. At: www.ilo.org/public/english/employment/strat/kilm/download/ki_lm04.pdf.

- [6] Litchfield, W. A. (2010). Climate Change Induced Extreme Weather Events & Sea Level Rise in Bangladesh leading to Migration and Conflict.
- [7] World Bank, (2000).“Bangladesh: Climate Change and Sustainable Development. Report No. 21104-BD”, Rural Development Unit, South Asia Region, the World Bank (WB), Dhaka, pp. 95.
- [8] CEGIS (2006). Impacts of Sea Level Rise on Land use Suitability and Adaptation Options, Draft Final Report. Submitted to the Ministry of Environment and Forest, Government of Bangladesh and United Nations Development Programme (UNDP) by Centre for Environmental Geographic Information Services (CEGIS), Dhaka.
- [9] Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Scenarios. Washington, DC: Island Press.
- [10] Porter, J.R. & Semenov, M.A. (2005).Crop responses to climatic variation. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360: 2021-2035.
- [11] Wheeler, T.R. et al, (2000).Temperature variability and the yield of annual crops. *Agriculture, Ecosystems and Environment*, 82: 159-167.
- [12] Schmidhuber, J., and Tubiello, F. N. (2007). *Global food security under climate change*,Columbia University, International Institute for Applied Systems Analysis. Vol. 104, No. 50.
- [13] Akanda, A. I. (2012). Agricultural growth verses food security and safe- food security. *New Age*, 25 June.
- [14] Hossain, M, et al. (2004). Food Security and Nutrition in Bangladesh: Progress and Determinants. FAO, Rome.
- [15] BBS, (2012).Bangladesh Bureau of Statistics, Ministry of Planning, Government of Bangladesh, Statistical Year Book, 2012.
- [16] Ahmed A. H. (2006). Bangladesh: Climate Change Impacts and Vulnerability.Climate Change Cell, Department of Environment, Comprehensive Disaster Management Programme, Bangladesh.
- [17] Habibullah, M., Ahmed, A.U. and Karim, Z., 1998, “Assessment of Food grain Production Loss Due to Climate Induced Enhanced Soil Salinity”,Kluwer Academic Publishers. pp 55-70.
- [18] Rahman. A. et al. (2009) “The Probable Impacts of Climate Change on Poverty and Economic Growth and the Options of Coping with Adverse Effect of Climate Change in Bangladesh”; General Economics Division, Planning Commission, Government of the People’s Republic of Bangladesh & UNDP Bangladesh.
- [19] Karim, Z. (2009). Background paper on food and agriculture: Crops, forestry, fisheries and livestock, Planning Commission, Ministry of Planning, Government of Bangladesh.
- [20] Karim, Z. and Iqbal, A. (2001).Impact of Land Degradation in Bangladesh (Changing Scenario in Agricultural land use). Bangladesh Agricultural Research, Farmgate, Dhaka 1215, Bangladesh. pp. 106.
- [21] Basak, J. K. (2008) “Climate Change Impacts on Rice Production in Bangladesh: Results from a Model”. Unnayan Onneshan, Dhaka.
- [22] Sarwar, G. M., and Khan, M. H. (2007).*Sea Level Rise: A Threat to the Coast of Bangladesh*. Internationals ASIAN forum, Vol. 38, No. 3–4, pp. 375–397.
- [23] <https://www.worldbank.org>.