* 1. **Introduction**

Rice is the basic diet of over 135 million inhabitants of Bangladesh. It supplies roughly 48 percent of rural livelihoods, almost two-thirds of overall calorie consumption, and about one-half of the entire dietary protein of an average individual in the nation. The rice sector generates one-half of the agricultural gross domestic product and one-sixth of the national revenue in Bangladesh (BRKB 2004). Rice is the major grain in Bangladesh, contributing to around 75 percent of the country's total arable land usage (Zakaria et al., 2014). Rice is the staple crop in Bangladesh, making about 90 percent of the country's overall crop yield and taking up roughly 45 percent of the country's total planted land (MoP, 2011).

However, crop cultivation, particularly rice, which is the most important leading grain, is particularly vulnerable to the effects of environmental issues and fluctuation. The quality and quantity of agricultural goods has a strong connection to climatic parameters such as precipitation, solar radiation, temperature, and atmospheric carbon dioxide, amongst others. Consequently, low crop yields would be a serious social problem due to changing weather patterns since there is a substantial amount of crop yield potential that may be hindered by only fluctuations in those climatic parameters. This is because the production of rice is dependent on a number of meteorological conditions, including temperature, rainfall, and humidity (Basak, 2010). Since the climate is the primary factor responsible for the year-to-year variation in rice productivity, any changes in the environment will lead to an increase in the degree of skepticism around rice production (Sarker, 2012). In order to combat and mitigate the effects of unpredictable environmental issues, Bangladesh is up against a number of obstacles. As per the Third Evaluation Report of the IPCC, South Asia is the region of the world that is the most susceptible to the consequences of environmental issues (McCarthy, 2001). The global community is aware of the fact that Bangladesh is highly ranked on the list of nations that are most susceptible to the effects of climate change (Climate Change Cell, 2008c). It is predicted that climate change will have a negative effect on crop yield in the 21st century as a result of warmer concentrations, extra varying rainfall, and extreme weather events such as catastrophic flooding, tropical storms, dry spells, and sea-level rise. Crop farming is extremely susceptible to climate change (Molua 2002; Isik & Devadoss 2006; IPCC 2007; WB 2010).

One of the nations that is most susceptible to the consequences of climate change is Bangladesh. The primary causes of its susceptibility are (i) its orientation in the tropics, (ii) the prevalence of floodplains, (iii) its low elevation from the ocean level, and (iv) its massive population concentration. All of these factors contribute to the region's susceptibility. However, it also has minimal adaptability skills as a result of inadequate economic capacities and limited technical competence (MOEF 2005; DOE 2007; Shahid & Behrawan 2008; Pouliotte et al. 2009; Hossain & Deb 2011). Both of these factors contributed to the country's current predicament. Severe weather, such as large flooding, dryness, and storms, happens virtually yearly, or perhaps even more than once per year. This has a negative impact on the agricultural industry, notably on rice output (MOEF 2005; Yamin et al. 2005).

* 1. **Rice of Bangladesh**

By around 11.54 million hectares of land dedicated to rice production, Bangladesh is the fourth biggest rice-producing nation in the world. Rice alone accounts for about 95.4 percent of the nation's total cereal output. Rice is the most important cereal crop in the country (BBS 2006). Rice has long been considered the nation's primary source of nutrition, and now, the production of rice takes up over 70 percent of the nation's arable land. Rice is farmed in Bangladesh throughout the three local seasons, which are locally known as Aus (hot season), Aman (rainy season), and Boro (cold season). Rice is cultivated between the months of April to August for the summer variety, July to December for the monsoon variety, and December to May for the winter variety. When it is in its reproductive phases, the primary rice crop known as Aman is subjected to heavy rains during the monsoon season when it is also transplanted. In the future, there will be more rainfall, which will have a greater impact on it. Food shortages in Bangladesh, which may be caused by either a lack of rainfall or an excess of it, is already placing a huge pressure on the country's socioeconomic system, and this burden is only going to become worse in the years to come.

* + 1. **Aman Rice**

Aman is a kind of paddy that develops during the rainy season and is virtually entirely dependent on rain for its water supply. However, it does need supplemental irrigation during the sowing phase and occasionally during the blooming stage, and this is dependent on the amount of rainfall that occurs. Temperature is another factor that might affect Aman output since there is a strong correlation between precipitation and temperature. Because of these factors, increasing Aman cultivation requires having enough understanding of the meteorological situation of Bangladesh and the shifting trend of its climate. In order to accomplish this goal, GIS technology needs to be implemented. This technology must be able to manage both geographic information and characteristic data in order to provide the tools necessary to display data in the form of maps in a way that facilitates improved visualization, comprehension, and decision making.

* + 1. **Aus Rice**

The Aus crop seems to be either sown or transplanted, depending on whether or not the circumstances are rainfed or flooded. It is harvested in the late summer to the middle of August [Xiao 2006], having been sowed in March or April. The phenology of Aus rice may be broken down into three separate stages, which are the formative stage, the reproduction stage, and the maturity stage. The seed implantation (germination) and the beginning of the panicle initiation mark the beginning and conclusion of the vegetative period, which is regarded as the crucial phase for maximum yield. Up until the middle of the 1980s, Aus rice was one of three types of rice crops that went into the manufacture of food. The other two were Aman and Boro. Rice production takes place throughout the following seasons: Kharif— I (April–July), Kharif—II (July–November), and Rabi (November–April), in that order: Aus, Aman, and Boro rice. As farmers gradually began turning their focus to the cultivation of irrigated Boro rice, which was encouraged by the better yields that it provided, the significance of Aus rice began to decline. After reaching a peak of 30 lakh acres in the early 1980s, the area harvested during the Aus season has since dropped to 10 lakh ha. In comparison to the early 1980s, when rice production was above 30 lakh tons, the Aus season only produced 17 lakh tons, a decrease of nearly half. At the same time, both the amount of land used to grow Boro rice and the amount of rice produced increased by many times. As the seed sowing and transplanting periods for Aus rice occur between the months of March and April, when fields of Boro rice are still present, there is less area available for Aus rice production, which is one of the reasons why Aus rice output has decreased. According to BRRI (2011), farmers who grow Aus rice do not have access to sufficient time or land to cultivate rice.

* + 1. **Boro Rice**

Rice is the primary and most important crop grown in Bangladesh. Boro rice accounts for approximately 56 percent of the total amount of rice grown in Bangladesh during the dry winter season (December to April), while the other two varieties of rice (Aman and Aus) are cultivated during the other months of the year. Bangladesh is home to the cultivation of three distinct types of rice. In the western part of Bangladesh, the most important crop is Boro rice. According to Shahid and Hazarika (2010), between the months of December through April, almost 70 percent of the land in the north-western section of the nation is used for the cultivation of Boro rice, despite the fact that only 6 percent of the annual rainfall falls during that period. In addition, the yield of Boro rice is severely affected by a lack of water during the blooming period, which occurs between the months of March and April. As a result, crop output suffers when drought occurs during this time. Rice production is concentrated in western Bangladesh, notably in sections of the nation that are known for their production of Boro rice. The high yielding variety (HYV) known as Boro rice is the primary factor in Bangladesh's overall rice output. This study focuses primarily on the Boro rice fields that have been negatively impacted by the risk of drought in recent years, and it describes those fields in great detail(Rukaiya et al. 2020).

* 1. **Climate Change**

The issue of global warming is referred to as a "wicked dilemma." In the spirit of Sandra Batie's most recent address to the Fellows of the Agricultural and Applied Economics Association (AAEA), we use this phrase (Batie 2008). In her research, she makes a distinction between "wicked" issues and "tame" problems, the former of which have unambiguous definitions and the latter of which have obvious conclusions. Problems that are not very challenging may be easily classified as either solved or unsolved. On the other hand, when it comes to the issue of climate change, there is no consensus even on a suitable characterization of the problem, much alone an effective remedy. A successful involvement by economists in the analysis of climate change requires broad interaction with other fields of study and with community at large (Toman 2006). This is due to the magnitude of the issue, as economics has played an integral part in evaluating impacts of global warming and alternative prevention measures.

We are well aware of the fact that agriculture is not the only sector that may be affected by the effects of climate change; this is something that we simply admit. Damage to infrastructure, including highways, retail and social facilities, and homes that might be caused by natural calamities could have negative effects that are more concentrated but nevertheless felt by the community as a whole. However, when explored in a concentrated way, the nexus between climate change and agriculture produces useful insights that may be exploited for climate change reduction efforts and for development policy. These insights are best appreciated when examined in this manner (Thomas et al. 2010).

Farming is always susceptible to being harmed by poor weather conditions and climatic occurrences. The weather and environment continue to be important variables in agricultural output, despite technical developments such as better crop types and irrigation systems. The connection between these major elements and production losses is often quite clear, but there are occasions when the connection is not as straightforward. The consequences of climate change on agricultural productivity are a matter of concern on a worldwide scale, and they are of critical significance for Bangladesh.

Rice production in Bangladesh has to be increased in order to fulfill the rising needs of the growing population that is a direct result of the country's expanding population. Nevertheless, the effects of climate change provide a feasible obstacle to the accomplishment of this goal. As a result, it is of the utmost need to have an understanding of the impact that climate change would have on rice production, particularly the manufacturing of Aman (Basak et al. 2010). Bangladesh is already one of the most sensitive nations to the effects of global warming and will continue to be one of the most sensitive nations in the future (Islam et al., 2011). In the next years, it is anticipated that natural disasters such as flooding, hurricanes, tropical storms, and water shortages would become more often and catastrophic (Sarker et al., 2014). People living in Bangladesh's arid and semi-arid regions, as well as the coastal areas, have already seen the effects of global warming on their way of life and their ability to make a living (MOP, 2011).

* 1. **Season Shifting**

The growth seasons are moving in a different direction. The beginning of spring is coming around sooner, winters are becoming shorter, and there are less days when it freezes over. Precipitation may occur at any moment these days; there is no set schedule for when it will happen. The schedule of various events that occur throughout a life cycle, including when flowers bloom or when pollinators appear, is altered as a result of these shifts. Alterations in the timetable of these events, such as the spring thaw or the transition of songbirds, for example, can have negative consequences on the environment. This is due to the fact that various organisms may respond to various environmental cues, which can lead to an imbalance between organisms that may depend on one another.

Shifting seasons are a clear result of rising average temperatures around the globe. A moderate shift in heat is all that is required to bring forward the start of the spring thaw and push back the onset of the first frost until much later in the autumn. Because of these changes in the climate, many trees and spring wildflowers bloom much sooner than they normally would. As a direct consequence of this, winters are shorter, spring comes sooner, summers are longer, and the beginning of autumn occurs later. The United States Environmental Protection Agency (EPA) utilizes leaf and bloom dates as an indicator of climate change. These dates represent national patterns in phenology. The scientific community is quite certain that recent rising temperatures in the climate of the whole planet are to blame for the earlier onset of springtime occurrences. The natural order of these occurrences might be thrown off, which can have a range of consequences for habitats as well as for human culture. For instance, an earlier spring might result in longer growing seasons, an increase in the number of exotic species and pests, and earlier and longer seasons for those who suffer from allergies. It is possible for unusually mild weather in the late winter to generate a "false spring," which causes the primary germination to initiate too early, leaving the plants susceptible to any future frosts. This is a tendency that has been increasingly documented across the United States.

Changes in temperature and precipitation have been seen to a noticeable degree in Bangladesh, just as they have been in many other regions of the globe. For instance, Islam (2009) reported that in Bangladesh, mean surface temperatures have risen by about 1°C over the past half-century, while a number of studies (for instance, Choudhury et al. 1997; Quadir et al. 2003) reported the major shift of annual precipitation for the recent decades.

* 1. **Parameter of Climate Change: Rainfall**

The country of Bangladesh is very susceptible to the effects of climate change, particularly extreme weather events such as droughts and floods. According to the National Encyclopedia of Bangladesh (2012), Bangladesh has been hit by around 20 droughts during the previous fifty years. In other years, the destruction that was brought on by a lack of rainfall was much worse than the devastation that was brought on by floods. The entire quantity of rice that was lost as a result of dryness in 1982 was about 53,000 tons, while the quantity of rice that was lost as a result of severe flooding was 36,000 tons (Ramasamy and Baas 2007). In some regions of Bangladesh, yield losses occur virtually annually as a result of flooding. Even though the impacts of the flood were less severe during the winter, they nevertheless represented 10% of the total damage that was inflicted by floods between 1974–1975 and 1998–1999. This loss occurred during the time period between 1974–1975 and 1998–1999.

Rice farming in Bangladesh is dependent on a number of variables, including the time of the beginning of the rainy season and the length of the rainy season. According to the findings of Islam et al. (2002), the inter-annual fluctuation in agricultural output is mostly attributable to the fluctuation in the quantity and patterns of precipitation experienced by the crop at various stages of its life cycle. The presence of moisture constraint during the germination phase resulted in a delay in the appearance of the leaves, a reduction in leaf area growth and splitting, and ultimately a decrease in the amount of assimilate produced (Wopereis 1993). Rice production was considerably hampered by a lack of water, especially during the grain-filling phase (Islam 2010).

According to the findings of Agrawala et al. (2003), it is anticipated that the amount of precipitation in Bangladesh would drop by 1.2, 1.7, and 3.0 percent for the years of 2030, 2050, and 2070, correspondingly. During the 2007–2008 agricultural year in Bangladesh, cold weather agricultural output accounted for 58.4 percent of the overall rice output, whereas rainy season production of rice accounted for just 34 percent, and summertime crop yields accounted for only 7 percent (BBS 2009). Including a very large upward trend of 0.37 million tons per year from 1971–2005, this contribution of winter rice demonstrated the enormous significance of winter rice in Bangladesh.

The paddy production grown with natural rainwater is highly reliant on the availability of water during the wetter months of the year, with the frequency and volume of rain being particularly important factors (Mahmood et al. 2004). Flooding may be caused by both an early start to the rainy season and an enormous amount of precipitation, both of which are detrimental to the growth of new rice seedlings. On the other side, arriving late often results in a significant amount of water tension. In order to get the best possible yield, enough precipitation during the growth period is also required. The unpredictable nature of the rain that falls during the rainy period often leads to significant floods and the destruction of crops. Rice seedlings are periodically replanted by producers in an effort to stave off food scarcity and make up for the harvests that were destroyed as a result of floods.

The amount of precipitation that falls on the nation is very unpredictable and has shown signs of being more unevenly distributed (Ahsan et al. 2011). Even while the overall yearly precipitation is very much about the same, there are more and more days going by without any sign of precipitation. This irregular pattern of precipitation results in severe occurrences such as droughts and floods, both of which have a discernibly negative effect on rice harvests. For instance, as a result of the dryness that took place in the northwestern area in 2006 (UNDP 2007; GOB & UNDP 2009), Aman rice output dropped by anywhere from 20 to 30 percent.

Rice production suffers greatly when there is an abnormal range of precipitation, which might manifest as either flooding or dry spells. According to Rosenzweig et al. (2002), Reid et al. (2007), and Roudier et al. (2011), crop reductions caused by floods are increased when the amount of precipitation is larger and/or heavier. In contrast, inadequate precipitation leads to a rise in the frequency and severity of dryness, while increasing evaporation results in the total loss of any crops that were planted (Reid et al. 2007; Liu et al. 2010).

* + 1. **Effect of Rainfall on Agriculture**

Rainfall is consistently regarded as one of the most essential aspects of climate. There is a clear connection between agricultural production and climate, and there is also a direct connection between rainfall and agricultural production. Therefore, changes in rainfall patterns have an influence that is immediately felt across the world's farming trends. Again, as a consequence of the ozone layer being depleted, there will be even more substances in the atmosphere that absorb heat. According to climate models, this would cause significant changes to the dynamics of rainfall and precipitation in two primary ways. The first change involves reinforcing the existing patterns, which would result in the already rainy parts being more wetter and the already dry regions becoming much dryer. This is due to the fact that warmer air holds more moisture from the air as a consequence of global warming, and experts expect that this more moisture will fall in areas of the globe that are already saturated with water. The second difference is sensitive to variations in the rotation of the atmosphere, which would lead storm tracks to migrate away from the equator and toward the poles. Storm tracks are defined as narrow zones in seas and oceans along which storms travel while being propelled by the predominant winds. According to Hossain and Dev (2011), irregular monsoons as well as an increased frequency of both floods and droughts pose an increasing risk to rain-fed rice production. This risk is expected to continue to grow.

Precipitation is the primary element in the expansion and development of food crops, both during the phase of fertilization and the phase of seed maturation. This is an essential point that has to be understood in respect to the interaction between precipitation and farming. However, as a result of changes in the climate throughout the globe, temperatures will increase, and in certain locations, there will be an increase in the amount of rainfall. The amount of precipitation will decrease in certain other locations. It is anticipated that natural occurrences such as coastal flooding would diminish the quantity of land that is suitable for agricultural use. This is in addition to the impact that extremes of rainfall on cropping patterns will have. Farmers are already finding it increasingly difficult to adapt to these changes in the climate since practically all crops are reliant on the specific seasons and the amount of rainfall they get. The changes in temperature and rainfall that are a direct result of climate change are likely to have additional reactions with other factors that influence plant development, such as atmospheric gases, fertilizers, insects, plant diseases, weeds, and the organic matter in the soil. Again, unforeseen reactions are to be anticipated as a result of this.

* + 1. **Effect of Rainy Season Shift on Agriculture**

Immediately after the end of the rainy season, farmers in Bangladesh harvest Aman rice. As a kind of subsistence agriculture, the majority of Bangladeshi producers tend to cultivate three different crops each year. Cultivating throughout the year, on the other hand, often does not provide farmers the opportunity to access land in adequate time to prepare it for the 'Aman' rice transplantation process. In light of this, the earliest month in which Bangladeshi farmers are allowed to transplant rice is July, despite the fact that the specific date of when rice may be transplanted varying from area to region. In general, yield loss is the consequence of late transplanting of 'Aman' rice, which is caused by soil moisture constraint during the blooming and maturation of the crops. On the other hand, farmers are often obliged to plant rice at dates that are later than they would want because of early season water stress or floods, or they must replant rice at a later date because of crop damage. This optimal management may prevent part of the production loss by ensuring that there is enough water available throughout the transplanting period, delivering the appropriate quantity of agrochemicals, and beginning the transplanting process as soon as possible. In Bangladesh, a numerical geographical scale systematic substantial yield evaluation has not been finished for a series of implanting dates and under conditions of end-of-the-growing-season moisture stress, despite the fact that it is common knowledge that end-of-the-season water deficit lessens yield. This is due to the fact that end-of-the-season terminal drought lowers yield. This research focuses on the monsoon season in Bangladesh and studies the timing of rain, shifting pattern of rainy season, and the connection between the monsoon season and agricultural productivity (of rice).

* 1. **Objectives**

The following categories have been taken into consideration during this study:

1. To investigate the climatic conditions of the research regions based on the rainfall data;

2. To forecast and estimate the quantity of rainfall that will occur over the next five years;

3. To determine the trend in the changing of the seasons in Bangladesh based on the monsoon season;

4. In order to ensure that farmers sow rice seeds at the appropriate time, to give suggestions in the form of recommendations for those responsible for making policy.