Chapter II

Introduction

This chapter tries to link the long term climate change incidences with the agricultural sector in globally and Indian context. Climate change affects the livelihood, society and agriculture directly and indirectly, but the agriculture is also one of the very important contributors of greenhouse emission at global scale which causes the long term global climate change. Therefore, it is an urgent need to understand the link between agriculture and climate change and find out the solution to reduce the agricultural contribution of greenhouse emission at global scale. Because we cannot stop doing agriculture and keeping livestock, but we can find a solution to low contribute green house emission globally. If we cannot reduce the climate change effects then this would negatively affect the agriculture production, and the entire globe will suffer from the major food security problem.

2.1: An Overview on Impact of Climate Change on Agriculture

The agricultural processes, industrial development, burning fossils and fuels, nuclear tests and other actions caused by human and nature are the main causes behind the increase in earth temperature, resulting in global climate change. Increase in the percentage of carbon dioxide through various gas emissions in the earth's surface is also one of the major causes of global climate change. The Intergovernmental Panel on Climate change (IPCC) observed that agriculture contributes 13.5 percent of global greenhouse gas emissions (2004). According to Greenpeace, if calculated, both direct and indirect emissions from the food system, i.e. agricultural contributions could be as high as 32 percent. Now the world is at risk due to Climate change and increase in earth temperature. Global temperature has risen by 0.6 ^{0}C over the last thirty years. This rise in global temperature has lead to a huge impact on a wide range of climate related factors. Increases in the levels of carbon dioxide, methane and nitrous oxide gases are mainly results of human activities since carbon dioxide is being dumped in the atmosphere at an alarming rate. Also though industrial revolution, people have been pumping out huge quantities of carbon dioxide, resulting in raising carbon dioxide by 30 percent, while the burning of fossil and fuels is partly responsible for this huge increase. Land use changes such as deforestation and desertification, together with use of fossil fuels, are the major anthropogenic sources of carbon dioxide; agriculture itself is the major contributor to increasing methane and nitrous oxide concentrations in earth's atmosphere.

Also agriculture has been found to produce significant effects on Climate change primarily because it produces and releases greenhouse gasses, mainly carbon dioxide, methane and nitrous oxide and it is also responsible for altering the earth's land cover, which can change its ability to absorb or reflect heat and light, thus contributing to radioactive forcing.

Agriculture is also one of the very important contributors of greenhouse emission at global scale (Paustian et al, 2006). Agriculture land used in 1990s was responsible for approximately 15 percent of all GHG emission (Organic Consumer Association, 2008). Another report produce by OECD (2001) stated that agriculture contributes to over 20 percent of global anthropogenic gas emissions. According to the World Bank (2008), agriculture contributes about half of the global emissions of two of the most potent non-carbon dioxide greenhouse gases i.e. nitrous oxide and methane. Livestock manure, nitrogenous fertilizers and irrigated paddy are said to be responsible for producing most agricultural nitrous oxide and methane emissions. These non-carbon GHGs have more powerful greenhouse effects and have greater longevity than carbon dioxide. (Research Institute of Organic Agriculture, 2008)

Nitrous oxide emission not only contributes to the greenhouse gas effect but also to the depletion of stratospheric ozone. Almost 90 percent of the global atmospheric N2O is formed during the microbial transformation of nitrate (NO2-) and ammonia (NH4+) in soil and water. Globally, agriculture contributes 65-80 percent of N2O, mainly from nitrogenous fertilizers on cultivated soil, cattle and feed lots. Especial agricultural soils, elevated N2O production depends on the nitrogen fertilization level. Agriculture is believed to account for roughly two-thirds of the total man-made methane (CH4) emissions, mainly from paddy rice fields, burning of biomass and ruminants (enteric fermentation and animal waste treatment). Aerobi agricultural soil, however are considered sinks for atmospheric CH4.

Besides implementation of irrigation system, high yielding varieties seeds (HYV) and better markets for farm production, genetically modified seeds (GMS), which were earlier considered to be a threat, have now been accepted as giving better margins to farmers and this has improved the nation’s agriculture scenario. On the front of national policies, credit facilities too seem to have a positive impact on the agricultural scene. All these may portray that the agriculture and allied activities sector of the economy achieved the growth rate of 3.7 percent during Eleventh Five Year Plan, but fails to achieve the targeted growth rate of 4 percent. The government has been taking concerted effort to deliberate on floods that damage crops or the varying temperatures that disrupt normal agricultural production. Climatic change has been one big reason for upsetting a nation's agricultural scene. Increase in pests, reduction in water availability, or intensifying soil erosion are all related to climate change, and directly affect the productivity of the farms. At the national level, food security is threatened, while at the farmer level, there are widespread income losses due to crop failure and livestock deaths. The rising temperature will slow down the production of rice, wheat, maize and bajra.

Again weather is an atmospheric condition that has an important impact on agriculture (ICIMOD/ UNEP, 2007). Increase in temperature leads to direct erratic rainfall effecting agriculture and food supply. Thus the rainfall especially during monsoon plays a major role in agriculture production. Since agriculture is sensitive to short-term changes in weather, thus food crops are mostly effected. Also insufficient rain and increasing temperature not only causes drought, but intense rain in a short period reduces ground water recharge, accelerating run off and floods. Thus, both the situations induce negative effects on the agriculture affecting food supply. The climate change also causes disruption in normal weather patterns changing intensity and duration of monsoon (Mala, 2008). One of the recent most burning issues in agriculture has been low monsoon rainfall due to global warming. This low monsoon rains have become a threat to small and medium farmers, who invest their time, capital and labour to gain profits but instead due to monsoon failure are left with nothing. Ironically, in India every year many farmers commit suicide due to this heavy loss.

The IPCC (Inter Governmental Panel on Climate change) had stated that if global temperatures are to be prevented from rising beyond the danger mark of an additional two degrees centigrade, then industrialised nations would have to cut their greenhouse gas levels between 25 and 40 percent further below the 1990's levels by 2020. IPCC in 2007 reported that the average global temperature would rise 4.5^0C by 2050, resulting in deliberate climate changes. There is a growing confidence among atmospheric scientists that increased greenhouse gas concentration will result in increased global temperatures. However, there is much less confidence on how the climate will change at regional or at local scale, which is the scale where socio-economic impacts will be felt (Baethgen et al, 2003). Therefore here the researcher proposes to consider the impact of global climate change in agricultural production as a whole.

Climate change impacts are however dependent on latitudes, longitudes, altitudes and types of crops. There have been noticeable impacts in plant production, insect, disease and weed dynamics, soil properties and microbial composition in farming system. According to IPCC

2007, temperature changes in tropical areas in general had a negative impact on food production and it was estimated that food production within South Asia would decline by 50 percent by 2050.

Climate Change however is a natural process but the recent trends are alarming mainly due to anthropogenic reasons. Climate change has already disturbed people, their livelihood, ecosystem and presents a great challenge for the global community in general, and particularly for the poor people living in developing countries.

Agricultural intensification happened mainly in developed countries after World War II and it has consumed heavy amounts of fossils, fuels and other inputs have contributed significantly to GHG emissions. The doubling of GHG production during the last 35 years was associated with a 6.9 fold increase in nitrogen fertilization, a 3.5 fold increase in phosphorus fertilization and a 1.7 fold increase on irrigated land (Food and Agriculture Organization, 2008). The increase of chemical fertilizers contributed to substantial amount of GHGs emissions.

The production of food depends on many factors and climate is one of several important factors. The productivity of the soil, availability of water for irrigation, technological developments of the regional agriculture, management skills of the farmers, and capital for support of technology are also important. During the temperate latitudes in the late 20th century, except where population pressures were great people generally were well fed. North America, Europe and Northern Asia were able to maintain calorie and protein levels well above the accepted requirements. Only in the tropical regions of the world, where soils are frequently infertile, agriculture development retarded, and/or population pressures had chronic shortages of calorie and protein supply. In present times this further growth in populations will intensify and expand the areas where deficiencies prevailed. In order to provide food for these deficient areas, foreign trade must occur. Paddock and Paddock (1967) call the U.S., Canada, Australia, and Argentina ‘the granary’ of the world. These countries supply virtually all of the wheat exports. Besides U.S. and Canada together supply 65 percent of the total wheat export. Although the U.S. exports a significant amount of rice (about 20 percent of the world export), the primary supply for foreign trade (about 60 percent) comes from Burma and Thailand. Food commodities required by the deficit countries are supplied from the granary surplus countries of the world. In near future the adverse weather conditions in the world's ‘granary’ will affect the diets of people from the food deficient regions. It has been often seen that a region or country with permanent or temporary deficits in calorie and protein supply cannot shop at the world's market place because of lack of foreign credits. In absence of grants-in-aid from the affluent nations, insufficient credits make foreign trade virtually impossible. Countries are not free to withdraw from the world ‘granary’ unless they have other resources to pay for the trade. With a free market, world trade redistributes commodities from surplus regions to other deficit regions.

Global warming threatens to undermine the stability of the earth's climate system, disrupting the human population and ecosystem that depend upon it (IPCC 2001). Africa is no exception. The continent has warmed in the last 100 years and faces possible future increase of 2-6^{0}C (Hulme et al. 2001). Indeed, Hare (2003) recently observed that Africa seems to be consistently among the regions with high to very high projected damages' across a range of global warming scenarios. These changes will tend to impact the most vulnerable population first. Home to semi-arid regions where crops are already near their thermal maxima, higher temperatures will depress yields and place increasing limitations on pasture, yields and water availability in semi-arid regions. Increased air temperature will also raise rates of evapotranspiration and crop water requirements in regions, where rainfall is already scarce. More frequent occurrences of extreme hydro-climatic events are foreseen as well. These changes imply increased occurrence of crop failure and livestock losses due to lack of sufficient pasture and water resources and, consequently, greater food insecurity among subsistence farmers as well as pastoral and agro-pastoral households which are highly vulnerable to such shocks. Rural Africa will have to adapt in order to withstand the effects of changing climate.

Tieszen et al. (2004) has shown that promotion and adoption of natural resources management practices can help mitigate the impacts on subsistence farmers. Stemming the loss of woody biomass while increasing fallow, manure applications and water conservation practices can increase soil’s organic carbon and lead to positive intensification of agriculture instead of destructive intensification. The benefits of increased carbon sequestration are threefold; food and water supplies are enhanced, greenhouse gas emissions are mitigated and desertification is reversed. These practices will have to be part of a broad spectrum of adaptive measures. Timely identification of such measures, however, requires basic climate data and information to identify and quantify trends. Unfortunately, in many countries of Africa and Asia, climate data networks, data management systems, telecommunications and model-ling capacity are not adequate to meet the challenge. In fact, in the last 40 years there has been a major decline in the number of active stations (IRI, 2005). Priority must be given to investments that will empower African climate scientists and engineers with the technology they need in order to fully apply their knowledge to meet the challenges at hand (Washington et al. 2004). Indeed, this is an international responsibility under the implementation plan for the global climate observing system (WMO, 2004). Ethiopia is an extreme case and faces the same general problems that confront sub-Saharan Africa, as described above, but has acute problems of its own. It is in the midst of an ongoing food security emergency, where 8-10 million people were and will not be able to meet their minimum food requirements in the upcoming year without external assistance. The last 10 years have seen massive increases in destitution due to multiple causes. In the beginning of 1997, the world price for coffee began to decline, reducing employment opportunities that formerly provided a prime coping mechanism for withstanding crop and livestock losses. The El Nifio of 1997/1998 brought floods and crop losses, as well as outbreaks of rift valley fever. The disease caused livestock losses and more importantly led to a seven-year export ban which undermined the principle mechanism that pastoral households used to access food-the sale of livestock to purchase cereals. The disruptions of the 1998-2000 war with Eritrea were compounded by drought that was felt especially hard in pastoral areas. Then, a bumper crop in 2000 led to a market crash and by 2001 poor market infrastructure and lack of effective demand in lead to food deficit in effected areas. Farmers responded by reducing planted area in 2002, only to be struck by the worst drought in 40 years. An unprecedented food security crisis took place in 2002/2003, where 13.2 million people required emergency food aid (22 percent of the population). Since then recovery from that crisis has been slow. Ethiopia now has 5.1 million people who are chronically food insecure, and another 3.7 million who will need emergency assistance in the coming years another millions or more might become food insecure in the months ahead.

2.2: Agriculture and Climate Change in Indian Context

In the backdrop of a burgeoning population where food and nutritional security is a constant challenge, agriculture has emerged as a key component for the growth of the Indian economy. With a contribution of approximately 15 percent to India’s GDP and approximately 10 percent to the total exports in 2008-09 (Annual report, 2010) and the fact that it provides employment to 58.2 percent of the population, a consistent growth of this sector is vital to meet other challenges as well. In India, agriculture is substantially dependent on the south-west monsoon. This is evident from the fact that the net irrigated area of the country is 60.9 million hectares from a total net sown area of 140.3 million hectares. Thus, a large part of the net sown area is rain-fed, thereby making the agriculture sector in India very sensitive to any changes in the patterns of rainfall. For instance, the impact of overall deficit of 23 percent in rainfall during the south-west monsoon in 2009-10, adversely affected kharif production, and was reflected in the agriculture GDP growth rate which showed a decline of 0.2 percent as against the previous year's growth rate of 1.6 percent.

According to Ray (1971), the economic geography of Indian agriculture suggests that the rainfall distribution pattern is primarily responsible for differences in land uses, cropping patterns, settlement and density of population in different parts of the country. When viewed in the light of the country's limited irrigation potential, the influence of rainfall on crop output will sustain and perhaps will be more pronounced as production increases at a faster rate. The uncertainties in rainfall will cause the same old concern and instability will continue to plague Indian agriculture.

The production of a particular crop in any region is the resultant of the acreage and the yield per acre. Yield and acreage can be expressed as a function of a number of controlled variables like fertilisers, pesticides, irrigation, prices, etc. and uncontrolled variables comprising the various climatic factors like rainfall, temperature, run of dry days, humidity, day length etc. Variations in agricultural production can thus be man-made or made by nature. Even if the climatic factors follow some repetitive pattern, the production fluctuations would not be proportional unless the relative magnitudes of the effects of these factors on production remain constant over time. The physical frame of reference in agriculture is, however, not invariant with respect to time; men can influence it through technological advances. The variables which are currently exogenous can be made endogenous to the system through human skill and knowledge at a later period. Theoretically and conceptually, it is possible to practically eliminate the unexpected variation in production due to natural factors (for example, on an experimental plot, water, temperature, day length, humidity, wind velocity etc. can be kept at desired levels through artificial techniques). This idealised proposition is however, difficult to conceive if the production function of a region or, for that matter, even a plot on the cultivator's field is considered. Physical factors appear as constraints on the production surface; their basic differences from region to region leads to differences in land use and cropping pattern. Studies carried out in many countries to examine the effects of various climatic factors on crop output have singled out rainfall and temperature as the most important influencing factors while the various other factors which affect the crops are largely rainfall or temperature dependent. However, in India, temperature does not appear to be responsible for fluctuations in crops output. An analysis of data pertaining to about 50 meteorological stations of India, published in World Weather Records, indicated that month-wise variations in temperature over the years (data series ranging from 30 to 90 years) were not significant (some hilly areas were exceptions to those remarks). Also, some factors like snowfall, intensity of light etc. which generally affects crops output in western countries, pose practically no constraints in Indian agriculture.

The effects of rainfall on crops output at any location are very difficult to measure precisely. For, it is not only the volume of rainfall but also its distribution at different stages of the plants growth which influences the total output. The adequacy and timeliness of the rainfall at sowing affects the sown acres. Similarly, the volume and distribution of rain at the time of sowing, flowering, maturing and harvesting affects crops yield. Consideration of these issues would necessitate introduction of a large number of explanatory variables into the crop-rainfall relationship. The problem is the short production data series of less than 20 years which is available but does not provide scope for such rigorous analysis. Use of a large number of explanatory variables in the structural equation will reduce the precious degrees of freedom for estimating the parameters with adequate level of confidence. Again, the crops calendar is not same throughout the country. For example, rice produced in India is sown and harvested in the different states at different periods and is, therefore, influenced by the adequacy and timeliness of rainfall in the different states during the crop's growth. Taking account of all these differences, the result poses a serious problem in statistical estimation, unless the various factors are reduced to a manageable limit. Consequently, aggregation of the rainfall data from different parts of the country into some suitable rainfall indices at the state and national level becomes essential.

2.3: Northeastern Climate

Northeast India is located between the latitudes 22^o N and 29.5^o N. The tropic of cancer passes along its southern part through Tripura and Mizoram. Therefore, it has essentially a tropical climate. At the same time, being within the monsoon belt of South and Southeast Asia, the region is under the tropical monsoon climate. But its location and topography is encircled on three sides by high mountain ranges and the presence of a precipitous plateau (Meghalaya) athwart the course of the incoming southwest monsoon wines, have rendered its climate somewhat different from that of the other parts of India. The factors influencing the region’s climate may be listed as follows:

2.3.1: Factors Influencing the Climate of Northeast India

1. The situation and alignment of the hills, plateaus and mountains in the region.

2. The seasonal change in the pressure condition over the Bay of Bengal on the one hand and over the northwestern landmass of India on the other.

3. The tropical oceanic (southwest monsoon) air masses that blow over this region.

4. Occasional visit of the westerly (Mediterranean) lows in winter.

5. Presence of local mountain and valley winds.

6. Presence of numerous and vast water bodies and extensive forests and development of local cyclones.

The Himalayas in the north, the Patkai and other hills and mountains in the east and the Meghalaya Plateau in the middle have affected the general tropical warm climate of the region. Many of these hills and mountains are high enough (sometimes between 1 km to 5 kms) rendering the climate cool. Besides, the Himalayan mountain chain, the Patkai and the high hills ranges along Manipur and Mizoram borders with Myanmar prevent the rain bearing monsoon winds from escaping off this region. Further, these ranges do not allow the dry and cold winds of central Asia to enter the Northeast region. The Meghalaya plateau, standing athwart the course of the southwest monsoon winds, makes them rise ornographically, causing the heaviest rainfall in the world in its southern margin. The Himalayan and eastern hill ranges also cause ornographic rise of the monsoon winds with consequent heavy rainfall in Northeast India. Another very important effect of the encircling hills and mountains on the climate of the region is that in summer while the plains become hot, the air over the hills and mountain remain relatively cool. Thus local low pressure systems are built up over the valleys. These low pressure systems over the Brahmaputra and Barak valleys obviously modify the climate in this region.

the climate of the region can be understood clearly with the help of the following description. In winter an extensive high pressure system prevails over central Asia and the northern part of India. There then exists a low pressure over the sea/ ocean in south of India. As winter passes, the landmass becomes warm quickly and by about late March and April, a low pressure is built up over northern India. The air mass over the ocean being heated up slowly, there prevails a relative high pressure over the sea/ ocean. With the northward migration of the sun, the land mass of India becomes very hot in April and May and the pressure gradient between northern India and the southern sea becomes very steep. A low pressure system thus envelops the lower altitudes of northeast Indian region. The winds then begin to blow from the south and southwest of the region brings about a significant change in the weather conditions of this region. Such a condition results in the occurrence of thunder showers squalls and occasional rains. This is one of the reasons why temperature is never very high in the northeastern region.

The Mediterranean lows, which reaches the upper Indus valley and the upper Gangetic plain in winter, sometimes travel as far as east of Brahmapurta valley, causing overcast sky, drizzle and rain.

The important local phenomena that affect the climate of the region are (1) the mountain and valley winds, (2) the dust storms, (3) the haze, mist, fog and (4) the cyclones. The valley winds begin to blow from the plains lower down to hills and mountains from about 10 o'clock in the forenoon to about 10 o'clock in the evening. Conversely, the mountain wind blows down the slope to the plains from about midnight to about 9 o'clock in the morning. The cool valley winds check the rise of temperature over the hills in summer during daytime, but in winter they further lower the temperature over the hills. On the other hand, the cool mountain winds drop the night temperature of the plains both in summer and winter. The effects of the mountain winds are however, limited to the foothill plains alone.

The occurrence of dust storms is another important feature of the spring weather in the western half of the Brahmaputra valley. The local winds, caused due to the heating of the ground in February and March, results in the ascent of the ground level air, sweep the ground at a moderate to high speed, spread sand dust all over the lower level of the atmosphere. Under such a situation the humidity decreases and visibility is reduced.

The presence of haze, mist and fog is still another characteristic of the region. As the region experiences heavy rainfall in the monsoon period, its atmosphere remains impregnated with water vapor while its rivers, streams, lakes swamps and other low lying areas remain full of water. In the month of October, when temperature falls in general, the saturated atmosphere give out haze and mist, especially at late night and early morning. With the passage of time, as the temperature falls, dense fogs appear in December and January, which hang over ground till late forenoon.

It should be noted that the occurrence of storms is also common in Northeast India, especially in the two plains of Assam. Most of these storms have their origin in the tropical cyclones of the Bay of Bengal. Being not very far from the tip of the Bay, the plains experience cyclonic storms that reach them after blowing over the Bangladesh plain. Some of the storms, especially the ones experienced in spring are due to local thermodynamic conditions.

2.3.2: Seasons of Northeast India

Considering the temperature, pressure and humidity conditions in their temporal distribution, the weather conditions of Northeast India in a year can be divided into the following four seasons.

2.3.2a: Winter Season: With the southward migration of the sun after September 23, temperature fall over Northeast India and winter sets in towards the later part of November and it continues up to the end of February. The weather during this period is influenced by the high-pressure system of central Asia, the sub-tropical jet stream and the high pressure centers over upper Myanmar. The temperature falls down over the high hills and mountains often to 0^{o} C. In fact the high Himalayan areas of Arunachal experiences a temperature below 0^{o} C especially at night. The hills of Nagaland, Manipur and Mizoram experience a minimum temperature of 4^{o} C. Meghalaya, similarly has a very low temperature with Shillong experiencing a minimum of 1^{o} C. Tripura, because of the low altitude of its hills and its southerly location, experiences a minimum of 12^{o} C. The Brahmaputra and Barak Plains show an average temperature of 13^{o} C. Within the Brahmaputra valley itself, the eastern upper valley experiences a lower minimum of 7^{o}-8^{o} C while in the western part it is about 10^{o}-12^{o} C.

December is the driest month of the year. During this period a local low pressure sets in the Brahmaputra valley. This along with the Mediterranean lows can bring about cloudy and drizzly weather. Besides, the cold northeast trade winds occasionally blow over eastern Arunachal, Nagaland, Manipur, Meghalaya and Mizoram hills, bringing down the temperature of these areas. An important feature of the weather of this period is the presence of thick fog all over the region. The hills have thick fog in the evenings, while the plains have it early in the mornings. In the Brahmaputra Valley fogs are more common in the south bank than on the north bank. This is became the mountain winds coming down the Himalayan slope drive the fog to the south bank. In the Barak Valley also fogs are more common in the southern part than in the northern part. The total number of foggy days in the two valleys varies between 60 to 100 days.

The rainfall is normally scanty during this period. While the northeastern part of the region, i.e. the Arunachal foothills and the upper Brahmaputra plain receive an average rainfall of 10cm, while the rest of Northeast India receives 5cm. during this period. The normally clear and sunny sky, cool and gentle breeze and morning fog together make the winter weather pleasant.

2.3.2b: Pre-Monsoon Season: With the end of February, temperature begins to rise in the region. March, April and May become sufficiently hot and the rains are yet to come in their full form. Thus, the pre-monsoon is a transitional season between the dry, cool winter and warm, rainy monsoon seasons. The important characteristics of this season are the rapidly increasing temperature, disappearance of fog and not infrequent occurrence of thunder, showers and hail storms.

With the northward migration of the sun, the temperature increases rapidly in the region especially, over the plains. Thus the pressure decreases rapidly and the gradient of pressure between the hills and plains becomes steep. This, not only facilitates incoming of the Mediterranean lows from the west and tropical cyclones from the south, but also gives rise to local cyclonic conditions. All these do bring storms and rains. The average temperature in this season rises to 25^0 C over the plains and 20^0 C over the hills. The amount of rainfall varies from 15.6cm in western Assam to 23.13cm in eastern Assam. Over the hills the rainfall is less, but in the Barak Valley it becomes as high as 32.5cm.

It has been found that Guwahati and its surrounding areas experience on the average 8 stormy days and almost 13 numbers of 6cm of rainfall in the month of April. Of late the amount of rainfall in April has been found to be increasing. For example, the Borjhar meteorological centre recorded a total of 16.3cm in April, 1988, 18.5cm in April 1989 and 34.8cm in April 1990.

The diurnal range of temperature during this period is very high, while the late nights are pretty cool and the afternoons very hot. However with the passage of time, the temperature range decreases, both days and nights becoming hot and the frequency of rainy days increases. The rains normally occur in the afternoons. Sometimes hail storms come along with such rains. Since these storms appear to come from the west in the eastern part of India, locally they are known as 'Bardoichila' in Assam and 'Kal Baishakhi' in West Bengal. These storms are said to be the result of the joint actions of the Mediterranean lows progressing from the west and tropical cyclones from the south. The eastward progressing Mediterranean lows in eastern India attracts the moisture laden cyclonic current from the Bay of Bengal. When these two currents meet, full-blown cyclones occurs carrying hail storms and thunder showers. Sometimes these storms move at a velocity of 50-65 km. It is this cyclonic storm that causes immense destruction in coastal Bangladesh, West Bengal and Orissa. In Northeast India they occur with a slightly lesser intensity. However, quite a few cyclonic storms pass over the plains during this period.

It has been noticed that with the advancement of the seasons, the number of rainfall also increases. For example, the average number of rainy days increases from 6 in March to 12 in April and further to 14 in May. At the beginning of this season i.e. in March, dust storms occur in the western part of the Brahmaputra valley. After dry winter when the low level sweeping winds blow over hot ground, dust is blown every afternoon bringing down visibility and making the atmosphere uncomfortable.

2.3.2c: Monsoon Season: The season of monsoon prevails over Northeast India during the months of June, July, August and September. With the northward migration of the sun the landmass gets heated and a low pressure system is established firmly over India.

The low pressure system, which builds up in the north India plain, prevails over the Northeast India also. If the polar or sub-tropical jet streams withdraw from all over India to central Asia the moisture laden southwest monsoon winds from the southern seas also rush in. This is because the low pressure over north India attracts the winds from the relatively high pressure belt over the southern sea. The southwest monsoon winds from both the Arabian Sea and the Bay of Bengal strikes Meghalaya first and then movers further north to strike against the Himalayan foothills. As these winds are within less than 5 km from the surface they strike against the southern hills slopes and rise up. In this process the rising air masses lose heat at wet adiabatic rate. The moisture contained is condensed and rainfall occurs in the windward side of the hills, especially in the Meghalaya Plateau, Himalayan foothills and the foothills of the eastern ranges.

The southwest monsoon winds, laden with moisture, reaches Northeast India towards the middle of June or the beginning of the Indian month of Ashara. However, the whole of the region is prevailed upon by the monsoon winds by about June 20 and rains begin.

2.4: The Monsoon Winds Enter Northeast Through Two Routes

The monsoon enters Northeast India from the south of Bay of Bengal and the other from the southwest Arabian Sea. The Bay of Bengal current being obstructed by Arakan Yoma moves northward and causes rainfall in Tripura, Mizoram and Barak plains. And then it strikes against the southern face of the Meghalaya Plateau and then rises causing orographic rainfall at the southern part of the Plateau. That is why this part (Cherrapunji Mowsynram region) receives one of the highest average annual rainfalls in the world. The actual reasons for which this region receives such a high rainfall are as follows: A part of the moisture bearing air current from the Bay of Bengal and a part of another similar current from the Arabian sea meet over Sylhet Plains, south of Meghalaya and are faced with the steep slope of the Meghalaya Plateau. There are many deep steep gorges on this slope. The moisture-laden air masses enter into these narrow gorges and get compressed. But as soon as they rise up the valley slopes, they expand and get cooled and condensed leading to the formation of clouds and occurrence of rainfall. Mowsynram (25^0 19'N and 91^0 36 E receives an average annual rainfall of 1240 cm and Cherrapunji (25^0 17'N and $91^0$44'E) 1080 cm. After having ascended over the Meghalaya, the air masses move further north and east. The east flowing air masses causes rainfall in Barak Valley, Manipur and Nagaland. The north flowing masses descend along the northern slope of Maghalaya, spread over the Brahmaputra valley and strikes against the foothills of Arunachal. The descendence on the northern slopes creates a rain shadow zone in the leeward side of Meghalaya over the Lanka-Lumding region, where average annual rainfall is only 106cm. This is the driest part in Northeast India. In this connection it may be noted that even Shillong, which lies 45 km north of Mawsynram receives only 215cm of average annual rainfall.

The second current of air mass from the Arabian Sea enters Northeast India over the relatively low Garo Hills and North Bengal Plain and moves up the Brahmaputra valley. It also strikes against the Arunachal foothills and causes heavy rainfall. A local low pressure system developed over the upper Brahmaputra valley also attracts it resulting in the occurrence of a higher amount of rainfall there and in its surrounding foothills. This part, therefore, has an average annual rainfall of above 300cm.

The season of southeast monsoon is thus, characterized by heavy rainfall, high relative humidity and light surface wind. Although the temperature varies between 20 ^{0} C in the plains and between 18^0 C and 30 ^{0} C over the hills the weather becomes uncomfortable because of high humidity. As the relative humidity goes on increasing with the increasing rainfall, the month of August becomes most sultry and uncomfortable. The number of rainy days is about 18 in each of June, July and August and about 14 in September. About 80 percent of the total average annual rainfall in the region comes during this season. The amount of rainfall received in this season is about 180cm in Assam, 185cm in the lower parts of Arunachal, 180 cm in Meghalaya, 170cm in each of Nagaland and Manipur and 130cm in each of Mizoram and Tripura. The occurrence of short, rainless, sunny and hot periods in between the spells of rainfall is also a common feature of the season.

2.5: The Season of Retreating Monsoon

Towards the later part of September the sun crosses the equator. The temperature begins to decrease, the low pressure system developed over northern India loosens its grip and the south west monsoon winds ceases to be attracted. The sky clears out with only the isolated patches of cirrus and cumulus cloud wandering aimlessly high up. As the relative humidity remains very high, even a slight fall of temperature is enough to make haze and mist appear in the distant horizons, especially in the mornings and evenings. The temperature comes down to 20^{0}C-25^{0}C in the plains and to 15^0 C-20^{0C} over the hills. The diurnal range of it varies between 2.4^0 C and 5.6^0 C, the more being over the hills. The rainfall decreases and stands at about 12cm-15 cm in the region, except in the southern margin of Meghalaya, where it is more. A few of the tropical cyclones that develop in the Andaman Sea, Gulf of Thailand and South China Sea sometimes affect Bangladesh and Northeast India during this season. However, the number of rainy days decreases to 6-7 in October and 2-3 in November. The wind direction is from the north and northeast. This is a short season covering only the months of October and November. However, it is bracing.

2.6: Climatic Conditions of Assam

The climate of Assam is characterised by its extreme humidity. Its most distinguishing feature is the copious rainfall between March and May at a time when precipitation in upper India is at its minimum stage. Climatically the year can be divided into the cold season and the rainy. The cold weather lasts from October to February and the rest of the year is rainy. The southwest monsoon begins from middle of June. The neighbourhood of Cherapunji and Mawsynram are known to receive the highest rainfall in the world. It is concentrated in four months, June to September.

Assam essentially, observes temperate climate. Its weather is characterized by heavy downpour and humidity. The hilly areas usually experience sub-alpine climatic condition, while excessive sultriness is observed in the plain lands of Assam. Though summer, winter and monsoons are the three seasons that visit the state, rainy season marks most of the months of a year. Summers prevail for a few months between March and June. However, temperature never goes beyond 35°C - 38°C even in the summer months. Rain showers occur erratically and keep the temperature under control, nevertheless humidity levels shoot up. In the late June, monsoon arrives with the oath to drench the state. Usually the intensity of rainfall crosses the extent and leads to natural catastrophes like floods. During the afternoons, thunder and storms are very common. Such heavy precipitation lasts till the month of September. During these months, rainfall appears at its utmost form in Assam.

From late October to late February winter season exists in the state marked by minimum temperature of 6°C to 8°C. During winter, nights and early mornings are misty. This is the only time when Assam observes scanty rainfall. Spring and autumn seasons continue to carry moderate temperatures and less rainfall, making it most suitable seasons to visit Assam.

2.7: Agricultural Seasons and Required Rainfall and Temperature for the Agricultural Crops in Assam

There are two main agricultural seasons in Assam. These two seasons are kharif season and rabi season.

2.7a: Kharif Season: Kharif season begins with the onset of monsoons (June and July) when crop are sown and it ends with the withdrawal of monsoons (September and October), when the crops are harvested. Main kharif crops in Assam are rice, maize, millets, jute, cotton, Groundnut etc.

2.7b: Rabi Season: Rabi season begins with autumn (October and November) when crops are sown and it ends up in the beginning of summer (March and April) when crops are harvested. Main rabi crops in Assam are rice, wheat, grams, mustard and other oilseeds.

2.8: Major Crops in Assam

Assam is an agricultural state and it produces varieties of crops but dominated by rice production. These crops are in the following categories:

1. Cereals, 2. Pulses and Oilseeds, 3. Fibre Crops, 4. Beverage Crops and 5. Cash or Commercial Crops.

2.8a: Cereals: Cereals are a collective name for all kinds of plants having edible seeds. The most common types of cereals are rice, wheat, maize, oats, barley etc. also the basic diet of the state.

2.8b: Rice: Rice is the staple food for the people of Assam. Rice is widely grown in all the districts of Assam. It is basically a kharif crop but in Assam rice is grown in both kharif and rabi seasons. Rice requires a mean annual temperature of 24^0 C with range of 22^0C to 32^0 C. Rainfall should be 1500mm to 2000mm but if the amount of rainfall is less irrigation facilities are required. Rice is well on silty, deltaic and alluvial soils.

2.8c: Wheat: Wheat is grown in very small portion of area in Assam. Wheat is a rabi crop and it requires an average temperature of 10^o C to 30^0 C but at the harvesting period the temperature should be well over 30^0C and there should be no rainfall. During the growing season, wheat requires 500mm to 1000mm of rainfall. To get good production of wheat irrigation facility is required because in Assam winter rainfall is becoming very less day-by-day and sometimes winters become very dry. Wheat grows well on alluvial soil, sandy loamy or well drained black soil.

2.8d: Maize: Maize is often known as corn. It is a coarse grain and it is used both as food and fodder. Maize grows well under different climatic conditions and on different types of soils. It is a kharif crop. Although, maize can be grown under varying climatic conditions, yet 20^0 to 30^0 temperatures is ideal for it. It requires 500 to 1000 mm of rainfall. If the rainfall is low then irrigation is a must for this crop. Maize grows well on loamy, sandy loamy, alluvial and black soils.

2.8e: Pulses: Pulses are leguminous plants with high nitrate content and help to restore soil fertility. This is why pulses are often grown in the course of crop rotation. Pulses like arhar, urad, mung are grown as kharif crops while masur (lentil), grams and peas are grown as rabi crops. Pulses are basically grown all over the state. Pulses require moderate to warm type of climate and as such temperature should be 10^0C to 25^0C. Rainfall should vary between 500mm to 750mm. These crops required dry and light soil.

2.8f: Oil Seeds: Oil Seeds are also grown in Assam. Important oilseeds are groundnut, sesamum, rapeseed, mustard, linseed, castor etc.

Groundnut: It grows in kharif season and is basically a root crop. Groundnut grows well in tropical and sub-tropical areas and temperature requirement for this crop is 20^0C to 28^0C while it requires low amount of rainfall ranging from 500mm to 750mm. It needs dry, light and sandy or sandy loamy soils. It is a drought resistant crop and it is a part of dry farming practice of cropping.

Rapeseed and Mustard: These are the two most important oil seeds of Assam. They are grown in rabi crops. These crops require a temperature of 10^0 to 20^0C but at the time of harvesting the temperature should be over 25^0C. They need moderate amount of rainfall and i.e. 50mm to 100mm. These crops require alluvial or sandy loamy soils and are also grown in black soil.

Sesamum: It is also a kharif crop which requires hot and wet type of climate i.e. temperature should be 20^0C to 30^0C, while rainfall is 500 to 1000mm. It is difficult for this crop to withstand long droughts or heavy rains. It grows well on alluvial soils but light sandy loamy soils are also good for it. It is also grown in red and black soils.

Linseed: It is a rabi crop and requires temperature from 15^0 to 25^0C and a moderate amount of rainfall from 400mm to 75mm. It requires alluvial or clay loamy soils.

Castor Seed: It is a kharif as well as rabi crop. Castor requires 20^0C to 30^0C temperature and the amount of rainfall should be not heavy. It needs 500 to 750mm of rainfall. Deep loamy soils are suitable for this crop.

Conclusion

From the above discussion it has been found that agriculture sector is also responsible for contribution green house emission which causes long term climate change. Climate change again in turn, causes frequent occurrence of extreme events like flood, storms, cyclone, major fluctuations of rainfall and temperature, crop failure and livestock losses and greater food insecurity among subsistence farmers. Therefore, there is an urgent need for indebt study of the linkage between climate change and agriculture sector.