Evidences, Projections and Potential Impacts of Climate Change on Food Production in Northeast India

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Abstract

Over the past two decades, climate change has evolved from a subject of future speculation to an inconvenient reality of the present. Given the inextricable link of agriculture with climatic variables, impact of climate change on agriculture and food security has been at the forefront of the research and policy agenda in recent times. However, despite being viewed as a region with the most climate-sensitive agriculture, climate change and its impact on food production in northeast India remains scarcely studied. Nevertheless, climatic changes in northeast India are becoming fairly perceptible, and the changes are far more evident than in other parts of the country. These climatic changes will have definite impacts on food production in northeast India. In this context, the present paper provides a synthesis of the recent evidences, future projections and the potential impacts of climate change on agriculture in northeast India and offers some scientifically-rationalized hypotheses which warrant elaborate experimentations to have a precise estimate of climate change impacts on agriculture.

Keywords: Climate change, Northeast India, Food security

Climate change – a general outlook

Climate change is arguably the most important global change phenomenon which has attracted the attention of scientific community across the globe. With the signs of climate change becoming increasingly tangible with each passing year, concern about its possible implications for various sectors of life on the Earth is also intensifying. On account of its close association with climatic variables such as temperature and precipitation, agriculture is indisputably the most climate-sensitive sector, and thus, the possible impact of climate change on this sector of utmost importance to human welfare has been the most intensively debated and researched topic in recent times.

Rising concentration of atmospheric CO_2, accompanying increase in Earth's surface air temperature and the changes in precipitation pattern have been the three most striking phenomena associated with global climate change. Atmospheric CO_2 concentration has increased by around 40% since the dawn of industrial revolution in the middle of eighteenth century. Its concentration which was around 280 ppm in 1750 AD (pre-industrial era) has now reached up to 390 ppm, and most of this increase has occurred in recent few decades of accelerated anthropogenic activities (Table 1). Keeping in view the recurrent failure of global community in generating a consensus on curbing CO_2 emission, coupled with the continuing high-carbon life style of developed countries, ambitious growth plans of developing countries and the future developmental needs of under-developed countries, the prospect of bringing down CO_2 emission rate in near future seems disappointingly bleak. These are some factors that suggest that the future trajectory of CO_2 emission may become even steeper than the current projections of IPCC (Inter-Governmental Panel on Climate Change), according to which CO_2 concentrations will be at least 550 ppm by 2050, 605-755 ppm by 2070 and is likely to be doubled by the end of this century (IPCC, 2007).

Consequent to heat-trapping effect of rapidly rising atmospheric CO_2, Earth's surface air temperature has also risen considerably over the past hundred years, with the rate of rise becoming increasingly steeper over the decades. Acceleration in atmospheric warming on global scale and in India is illustrated by table 2 and 3, respectively. Temperature is further projected to rise by another 2 to 4.5°C in the later half of this century, with apparently the most plausible estimate of around 3°C with some regional variations around the world. Given that the pattern of precipitation in any area is significantly influenced by the interactions of oceanic surface- and Earth's surface temperature (besides many other factors), the ongoing rise in atmospheric temperature is anticipated to influence the amount and intensity of rainfall too, with their regional variations expected to be far more pronounced than the other climatic variables.

Since atmospheric CO_2 is the sole source of carbon for plants, variations in its concentration

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have obvious implications for plant growth (Kimball et al., 2002). The best growth and yield performances of C_3 crops, such as rice and wheat, are observed at around 1000-1200 ppm CO_2 concentrations (Grotenhuis and Bugbee, 1997; Mackowiak and Wheeler, 1996). As the current atmospheric concentration of CO_2 (385 ppm) is far below than optimum to saturate the growth and yield responses of C_3 crops, any further increase in CO_2 concentration is expected to increase the productivity of these crops (Long et al., 2004; Manoj-Kumar, 2006 & 2010b; Manoj-Kumar et al., 2011c). Crop plants with C_4 photosynthetic pathway (e.g. maize, sorghum, sugarcane etc) will also benefit from rising CO_2 concentration, but unlike C_3 crops which is benefited by both increased photosynthesis as well as improved water use efficiency under elevated CO_2, C_4 crops will be benefited mainly by the later mechanism. In fact, the yield boosting effect of elevated CO_2 (carbon fertilization effect) is now a well established phenomenon which has been experimentally proved across the various agro-ecosystems of the world.

However, unlike the universality of the positive effects of elevated CO_2, impact of rising temperature on crop productivity is expected to vary in different regions of the world depending on the favourability of the existing– and projected levels of atmospheric temperature for the crop growth. Rising temperature in temperate and Polar Regions located at higher latitudes, where crop growth is currently limited by unfavorably low temperature regimes, is expected to reinforce the beneficial effect of elevated CO_2 on crop yield. In contrast, the temperature rise in tropical and subtropical regions located at lower to middle latitudes, where most of the food crops are already growing at the upper limits of their thermal tolerance, may act in opposite direction to that of rising CO_2, with an overall negative impact on crop yield (Manoj-Kumar et al. 2011c, 2012a&b). Furthermore, the potential impact of changes in precipitation pattern is expected to be even more localized than the effects of rising temperature. The regions with higher percentage of agricultural area under assured irrigation will have better adaptive capacity, whereas those with higher percentage of rainfed areas will be more vulnerable to precipitation changes under a changing climate.

Notwithstanding the differential responses of agricultural productivity to changes in different climatic components, such as increasing CO_2 concentration, rising temperature and changing precipitation patterns, it is the interactive effects of all these factors which will dictate the overall impact of climate change on agricultural productivity of a region/country. Fourth assessment report of the IPCC and some other global studies indicate a probability of up to 40% loss in crop production in India with increase in temperature during the last quarter of this century (Parry et al., 2004; Fischer et al., 2002). Some Indian studies on this subject also confirm similar trend of agricultural decline with climate change (Aggarwal, 2003 & 2007; Lal et al., 1998; Rao and Sinha, 1994). Recent studies at the Indian Agricultural Research Institute (IARI) indicate the possibility of loss of 4-5 million tonnes in wheat production with every 1°C rise in temperature even after considering the benefits of carbon fertilization and assuming the constant availability of irrigation water (Aggarwal, 2007). Simulation based studies and some empirical observations also suggest the risk of considerable reduction in rice yield under the projected climate change scenarios in India (Amgain et al., 2006; Mathauda et al., 2000; Saseendran et al., 2000). Nutritional qualities of food grains (in terms of protein, Zn and Fe concentrations, and the bioavailability of the later two) are also expected to decline under the influence of rising atmospheric CO_2 (Manoj-Kumar and Patra, 2010; Manoj-Kumar, 2011c; Manoj-Kumar et al., 2011a). As rice and wheat constitute the main staple food for majority of India's population, the anticipated decline in their yields and nutritional qualities under climate change puts the future prospects of India's food and nutrition security in jeopardy.

Although the impact of climate change on productivity in various sectors of Indian agriculture is now fairly well-studied, the projections made on all India basis do not reflect the extent and direction of effects on regional scale which would be of more practical relevance for undertaking research and policy initiatives for mitigation of- and adaptation to the impacts of climate change. Moreover, the regional specificity of agricultural response to changes in temperature and rainfall pattern makes it imperative to study the impact of climate change on regional scale for the precise assessment of potential impacts and subsequent actions for its mitigation and adaptation. In this context, it is deplorable that the potential impacts of climate change on agriculture in northeast India, which is among the most climate-sensitive regions of the country, has not been adequately studied thus far. The following sections of this paper, therefore, attempts to offer an insightful analysis of the future possibilities of climate change impacts on agriculture in northeast India.

Climate change and agriculture in northeast India: a regional perspective

Considering the fact that more than 86% of the population in northeast India depends on agriculture for their food and livelihood, there exists an inextricable link between agricultural productivity and the food and livelihood security of the people in this region. Unfortunately, agricultural productivity in the region is constrained by a range of factors due to which, despite having ~ 8% of the total geographical area and ~13% of the total rainfall of the country, the region contributes only 1.5% to the total food grain production in the country. While the population growth rate and thus the food demand in this region has been growing at much faster rate than the all India average, average productivity of food crops has been lagging far behind the national average. This has already led to a perpetual deficit of food supply in the region. Given the strong dependence of north-eastern population on agriculture which in turn depends strongly on climatic suitability, even a slight unfavourable shift in its climate (rainfall and temperature in particular) can potentially endanger the food and livelihood security of the people in northeast India (Manoj-Kumar, 2011b).

Although empirical observations on climate change and its effect on agricultural productivity in northeast India is scarce, there are a few sporadic reports about current observations and future projections of climate change in the region; a short and snappy synthesis of these informations are presented hereunder. The implications of the projected changes in climatic variables for agricultural productivity will be elaborated thereafter. Certain hypotheses concerning the possible mechanisms of climate change impacts will also be forwarded which merits elaborate experimentations for holistic assessment of climate change impacts on north-eastern agriculture in future.

Climate change observations and projections for northeast India

There have been some conspicuous changes in temperature as well as rainfall pattern in northeast India over the past century which suggests that climate change is fast becoming an inconvenient reality of present rather than remaining a subject of future speculation only. The atmospheric temperature (annual mean temperature and annual mean maximum temperature) has been rising at a rate quite perceptible to even the common people of the region. According to a recently reported study by Deka et al. (2009), the annual maximum and mean temperature in northeast India during 1901-2003 has increased significantly by a rate of 1.02ºC and 0.60ºC/100 years, respectively (Table 4). Atmospheric temperature in the region is further projected to rise by approximately 3ºC to 5ºC during the latter third of this century (Table 6). It is worth noting that projected temperature rise in northeast India is greater than in other regions of the country. More pronounced still is the reduction in the annual as well as the monsoon rainfall over the years in north-eastern India. The most striking evidence of the declining rainfall in the region comes from the drastically reducing amount of annual rainfall in one of the wettest places in the world i.e. Cherrapunjee. According to a report, Cherrapunjee received less rain in the whole of 2001 – only 363 inches – than it got in just one month in 1861 (Terradaily, March 03, 2007). In July 1861 alone, Cherrapunji had 366 inches of rain. Between August 1860 and July 1861, Cherrapunjee got a record 1042 inches of rain – a world record. But now the annual rainfall there has sharply fallen to less than a third of that. The alarming deficits in annual as well as monsoon rainfall observed year after year in recent times which causes severe droughts across the various states further confirms the climate change-induced decline in rainfall in northeast India (Table 5). Future projections of the season-wise precipitation changes in northeast India and the mean annual cycles of precipitation for different states of northeast India are illustrated in Table 6 and Figure 1, respectively.

Implications for agriculture in northeast India

The implications of climate change on agriculture in northeast India is already discernible although the impact assessment studies are quite limited to reach a convincing conclusion. However a recently released report by Ministry of Environment & Forests, Government of India (Climate change and India: A 4x4 assessment - A sectoral and regional analysis for 2030s, November 2010) provides some approximations of the impact of climate change on agriculture in northeast India. Results of Simulation analysis (using InfoCrop model) in the report indicates that climate change may bring changes in the irrigated rice yields by about –10% to 5%, while the impacts on rain-fed rice are likely to be in the range of –35% to 5% in A1B 2030 climate scenarios in north-eastern regions. In the case of wheat, the yields are projected to reduce by up to 20%. Potato yields are likely to be marginally benefited up to 5% in upper parts of north-eastern region due to climate change influence, but in the central part, the yields are projected to reduce by about 4% while in the southern parts of the region, the negative impacts will be much higher. Maize crop yields are projected to reduce by about 40% in northeast India. Maize and mustard are also likely to experience decrease in productivity in the entire region. Climate change-induced thermal stress effects on livestock productivity in terms of Temperature-Humidity Index (THI) have also been projected in the report. This index represents thermal stress due to the combined effects of air temperature and humidity, and used as an index to monitor the heat-stress related losses in animal productivity. The THI has been anticipated to rise beyond 80 (THI > 80) between April-October months, causing severe stress to the health and productivity of livestock in northeast India under a changing climate.

Even though the report provides useful information about the future impact of climate change, there are certain limitations which suggest that much more needs to be done to predict with more certainty the future of north-eastern agriculture in a changing climate. For example, these predictions did not take into account the socio-economic trends and capability to adjust with a changing climate, improvements in farmers' economic status, market demand, and so on, which drive the changes in yields and production to a large extent. Further, the pests and diseases scenarios are not integrated in this assessment due to lack of proper scientific data. On top of all these, in what seems to be hitherto a most comprehensive assessment of climate change impact on north-eastern agriculture, impact projections have been made only up to the climatic scenario of 2030– not too distant a future from now. However, considering the ever-accelerating rise in atmospheric warming, the associated climatic changes will further intensify towards the middle of this century and beyond, with a definite aggravation of their adverse impacts on agriculture. Briefed below are some of the possible repercussions associated with changes in different climatic variables viz. atmospheric CO_2, temperature and rainfall, which can potentially affect the future prospects of food production in northeast India.

Soil acidity is undoubtedly the most important impediment to crop productivity in northeast India. And a simple logic suggests that, under the business-as-usual scenario, soil acidity may be further intensified under the influence of rising atmospheric CO_2 concentration. This possibility stems from a frequent experimental observation of increased CO_2 production in soil due to increased root and soil microbial respiration under elevated CO_2 atmosphere. Since CO_2 produced this way forms carbonic acid (H_2CO_3) in soil waters, which removes base cations from the soil systems after leaching and produces soil acidity, enhanced CO_2 production in soil under elevated CO_2 can increase carbonic acid leaching and therefore intensify the already existing acute problem of soil acidity in northeast India (Manoj-Kumar, 2011b).

Soil organic matter is yet another attribute of soil health which may suffer a decline in its quantity as well as quality under the influence of rising atmospheric temperature. Since rate of soil organic matter decomposition increases with increasing temperature, the projected rise in atmospheric temperature can reduce the amount of soil organic matter in northeast India. As the labile fractions of soil organic carbon can be decomposed faster than its relatively recalcitrant fractions, atmospheric warming can induce gradual reduction in the proportion of labile carbon fractions which implies reduction in quality of soil organic matter. Quantitative and qualitative reduction in soil organic matter under the future scenario of atmospheric warming can reduce the water and nutrient holding capacity of soil, weaken the buffering capacity of soil to changes in pH and other stresses, degrade soil aggregate stability and physical structure rendering it more susceptible to erosion losses, decrease soil biological activity, and can bring many other associated changes which will ultimately lead to gradual decline in soil health and crop productivity in northeast India. Predictions of increased frequency of high intensity rainfall (even flash flood or cloud burst) will also increase the runoff and erosion losses of surface soils and nutrient content therein, robbing the soil off its already impoverished fertility status in the region. Also, there is possibility of elevated temperature-induced increase in transient salinisation (due to capillary rise of salts up to root zone), denitrification and volatilization loss of nutrients, and nutrient loss through more leaching due to high intensity rainfall events under a changing climate (Manoj-Kumar, 2010).

Agriculture in northeast India is predominantly rainfed where water availability is a major constraint for crop intensification and agricultural productivity, particularly in winter months (November-February). Water requirement for agriculture in this region is further anticipated to increase from approximately 20 km^3 in 2001 to

25.2 km^3 in 2021 (Sharma, 2003). Owing to higher evapotranspiration loss of water under the rising atmospheric temperature, water requirement will increase more steeply under the future scenario of climate change. Contrary to the expected increase in crop water requirements, its availability will decline as evident by erratic trend of rainfall and recurrent occurrence of drought events in the region. Clearly, declining availability against rising requirement of water will pose a severe challenge to the agricultural productivity of northeast India in future.

Crop-pest interactions will also change significantly with climate change leading to impact on pest distribution and crop losses. Crop-weed competition will be affected by rising atmospheric CO_2 depending upon their photosynthetic pathway. However, the associated rise in temperature may further alter the competition depending upon the threshold ambient temperatures. Diseases and insect populations are strongly dependent upon the climatic components such as temperature and humidity. Any increase in these parameters, depending upon their base value, can significantly alter their population, which ultimately results in yield loss. For every insect species there is a range of temperatures within which it remains active from egg to adult stage. Within the favourable range, there is an optimum temperature at which most of the individuals of a species complete their development. Exposure to temperatures on either side of the range exerts an adverse impact on the insect by slowing down the speed of development. If ambient temperature becomes favourable for the pest after temperature increases, the pest incidence may be expected to rise due to increased rates of development, which may result in the completion of more pest generations within shorter period of time. There is strong possibility that increasing temperature in northeast India can induce this kind of alteration in crop-pest interaction which may ultimately result into significant yield losses. In fact, there have already been a few sporadic reports to this effect (e.g. Hueiyen Lanpao, February 25th, 2011) which further embolden the future possibility of such changes in crop-pest interaction, with its dreadful consequences for crop productivity in the region. The possibility of appearance of some new insect and pathogens can also not be ruled out under the future scenario of climate change in northeast India. Since protein and mineral contents of plant tissues are generally reduced under elevated CO_2 condition, it is quite possible that insects will eat up and damage more crops to meet its food and nutritional requirements which will ultimately lead to increased crop loss and reduced productivity in future.

In addition to all these alarming possibilities, there could be many more ways through which climate change can affect the future prospects of food production in northeast India. For instance, the possibility of soil biodiversity loss will reduce the soil resilience to climate change-induced stresses, or the loss of biodiversity at the level of whole agro-ecosystem can reduce the potential capacity of north-eastern agriculture to adapt to a changing climate. In general, the benefits of carbon fertilization effect on crop growth under the rising atmospheric CO_2 is considered the only silver lining in the otherwise dark and dreaded cloud of climate change. However, this effect is practically realized only when there is no limitation of water and nutrients for the growing plants (Campbell and Sage, 2006; Manoj-Kumar and Bhadraray, 2009; Manoj-Kumar et al., 2009a&b; Manoj-Kumar et al. 2011b). Keeping in view the lower availability of nutrients in soil (such as phosphorus), inadequate external input of nutrients from fertilizers, and the reducing availability of water for agriculture, the possible benefits of carbon fertilization can also not be expected in agriculture of northeast India. This implies that climate change will unfurl itself with its full potential to cause the possible decline in agricultural productivity and food security in northeast India.

Conclusion

The signs of climate change are becoming increasingly perceptible with every passing year, and the changes in northeast India appear to be far more evident than in other parts of the country. Also discernible is the impact of these climatic changes on agricultural production in northeast India. Some recent projections for near future indicate that climate change can potentially reduce the productivity of some major crops and livestock in the region. A suite of the logics and explanations forwarded in this paper clearly indicate that in long-term (towards the middle of this century and beyond), actual impacts of climate change on north-eastern agriculture might range beyond the levels being anticipated now, making it further difficult to produce enough food for ensuring food sovereignty of the region. This necessitates the development and promotion of effective mitigation and adaptation strategies for a climate-resilient agriculture production system in northeast India.

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Table 1: Acceleration in rate of atmospheric CO_2 increase over the past 250 years

Year	Approx. CO_2 conc. (ppm)	*Total increase in CO_2 conc. (ppm) during:	*Rate of increase in CO_2 conc. (ppm/yr) during:	*Rate of increase in CO_2 conc. (ppm/yr) over the past:
1750	280	-	-	-
1960	315	1750-1960 (35)	1750-1960 (0.17)	250 years (0.4)
1994	360	1960-1994 (45)	1960-1994 (1.3)	50 years (1.5)
2007	387	1994-2007 (27)	1994-2007 (2.0)	15 years (2.0)

*Approximate values are given in parenthesis following the time period. Computation of rate of CO_2 increase is based on the values of CO_2 reported in multiple sources.

Table 2: Acceleration in rate of atmospheric warming on global scale

Time period under consideration	Rate of increase in atmospheric temperature (ºC/decade)
Last 100 years	0.074
Last 50 years	0.128
Last 25 years	0.177

(IPCC, 2007)

Table 3: Acceleration in rate of atmospheric warming in India

Time period under consideration	Rate of increase in atmospheric temperature (ºC/decade)
1901-2003	0.05
1971-2003	0.22

(Kothawale and Kumar, 2005)

Table 4: Trend rate of temperature in northeast India during 1901-2003

Seasons	Trend rate of temperature (ºC/100 yr)		
	Maximum	Minimum	Mean
Pre-monsoon (March-May)	+0.78	+0.09	+0.44
Monsoon (June-September)	+0.75	-0.32	+0.21
Post-monsoon (October-November)	+1.54	+0.64	+1.09
Winter (December-February)	+1.22	+0.61	+0.92
Annual	+1.02	+0.18	+0.60

(Deka et al. (2009)

Table 5: Trend of deficit rainfall (%) over north-eastern India in recent times*

	2005	2006	2009**	2010**
Assam	-23	-32	-34	-6
Arunachal Pradesh	0	-25	-29	-30
Nagaland	-22	-25	-63	-27
Manipur	-22	-25	-67	-46
Mizoram	-22	-25	-32	-28
Meghalaya	-23	-32	-56	-49
Tripura	-22	-25	-31	-16

*****The rainfall data belongs to IMD's Regional Meteorological Centre, Guwahati, as reported in multiple sources. **report based on rainfall received till July 20th in respective years.

Table 6: Region-wise and season-wise projections of temperature and rainfall changes in India for the period 2070-2099 with reference to the base period 1960-1990*

Region	Jan.-March	April-June	July-Sep.	Oct.-Dec.
Temperature Change (ºC)				
Northeast	4.95	4.11	2.88	4.05
Northwest	4.53	4.25	2.96	4.16
Southeast	4.16	3.21	2.53	3.29
Southwest	3.74	3.07	2.52	3.04
Precipitation Change (%)				
Northeast	-9.3	20.3	21.0	7.5
Northwest	7.2	7.1	27.2	57.0
Southeast	-32.9	29.7	10.9	0.7
Southwest	22.3	32.3	8.8	8.5

(Cline, 2007)

*****Projections are average of predictions of six general circulation models including HadCM3, CSIROMk2, CGCM2, GFDL-R30, CCSR/NIES, and ECHAM4/OPYC3.

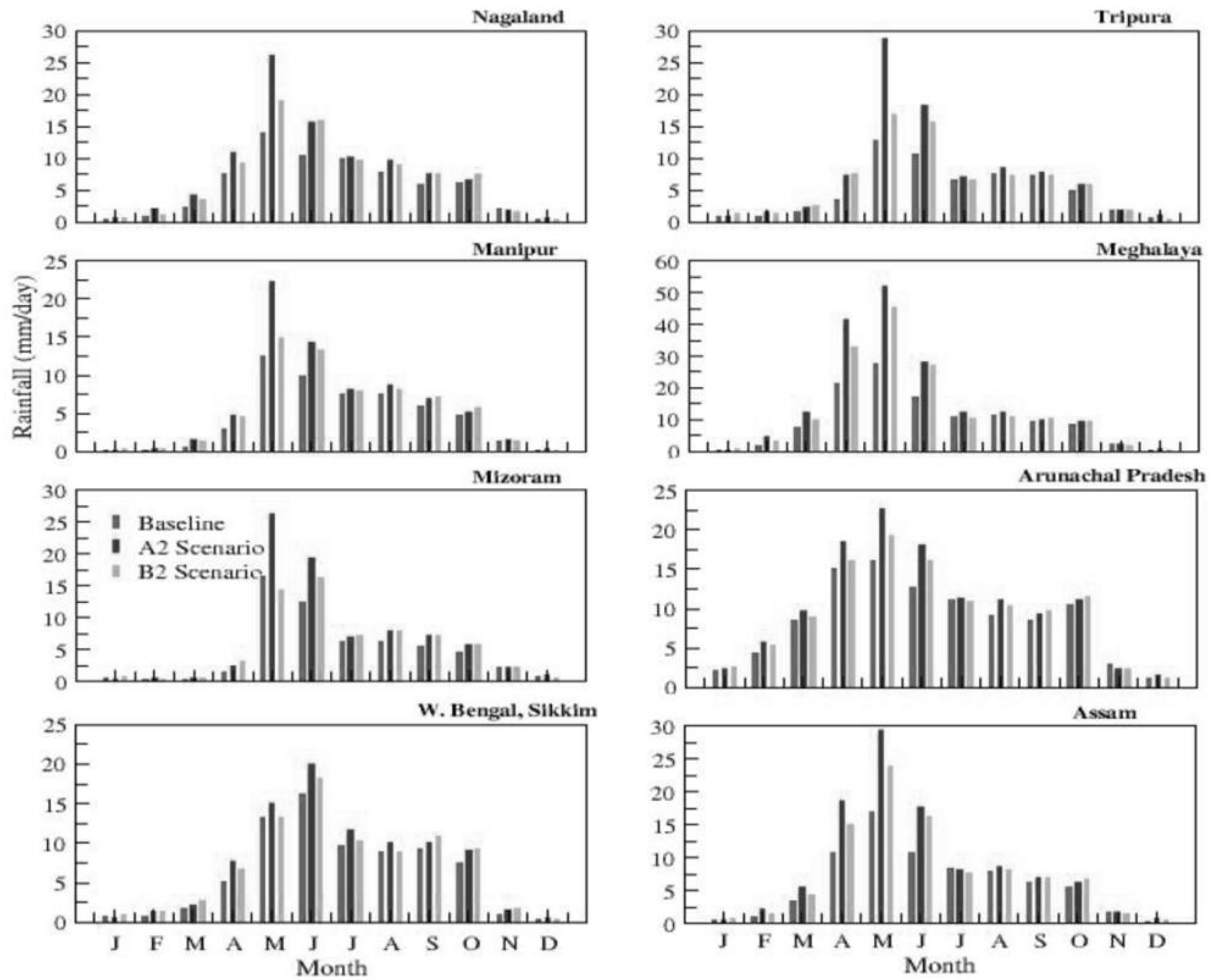

Figure 1. Baseline and future projections (2071-2100) of mean annual cycles of precipitation for north eastern states of India, as simulated by PRECIS (Rupa Kumar et al., 2006)