Climatic Data Collection from Tea Gardens and other Sources of Northeast India and their analysis for Climate Change Study

A Network Project Taken by B.P.Chaliha Chair for Water Resources

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Background of the Project

As per an MoU signed on the twenty Six day of September 2008, between the President of India (Through Senior Joint Commissioner (PP), Ministry of Water Resources, Govt. of India) and The Indian Institute of Technology Guwahati (Through Director, IIT Guwahati), a chair entitled "Bimala Prasad Chaliha Chair for Water Resources" was established in IIT Guwahati.

The main objective of the Chair is to carryout studies on Water Resources with special Emphasis on assessment of effect of Climate Change on it and adaptation strategies in respect of planning, design and management of water resources systems of particularly Brahmaputra Basin. An important activity for the chair was set as transfer of technology to various organization of MPOWR/GOI

Preliminary studies carried out on impact of climate change on water resources of Brahmaputra Basin has revealed that there will be significant changes in the rainfall pattern and temperature of this basin. High intensity rainfall of short duration and longer dry period will have adverse effect on flood and drought scenario of the region.

Such future scenarios are forecasted by downscaling General Circulation Model (GCM) (also stated as Global Climate Model (GCM)) to basin level and possible changes in various climatic parameters with time are estimated. However, reliability of such forecast depends to a great extent on proper calibration and validation of the model. For calibration and validation of climate model, it is necessary to have long data series. Reliable assessment of such future water availability scenario can help a lot in making strategic planning for water management. Though Indian Meteorological Department (IMD) has data for some specific locations of this reason, use of long data series from other sources with better spatiotemporal resolution can always enhance climate change analysis.

Tea gardens of this region have been collecting daily climate data for their purpose. This data set will be of tremendous help for downscaling of GCM to the basin level and hence for forecasting the future climatic scenario. Keeping this in mind concept of a network project on data collection from tea gardens of the region and other agencies was presented in the Management Committee meeting of Chair professor held at IIT Kharagpur and committee appreciated the idea. To take this idea forward, Prof. Sarma (B.P.Chaliha Chair) hold a meeting Tea Consultant Mr. P.K.Sarma at IIT Guwahati and a letter in this regard was communicated to Tea Board of India seeking their support. Accordingly, a meeting was organized at Dibrugarh with senior official of ABITA to have their views on data sharing. Later meeting was also held with TAI, NETA, ATPA, Bharotia Chah Parishad and also with Assam State Electricity Bord. All agreed to share their available data and IIT Guwahati agreed to look into water related problem of tea gardens and to provide general suggestion for improving water management in tea garden. Accordingly this project was taken up.

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1. Introduction

1.1. Objectives of the Project

The objective of this project is to strengthen the climatic database of the north-eastern region of India, so that impact of climate change on water resources of Northeast India can be assessed with higher reliability and management strategy can be taken up accordingly. To increase special resolution of climatic database, it is necessary to collect data from various possible sources apart from the IMD data. Therefore, this project is being taken up in collaboration with Tea Board of India, other tea associations and State Electricity Board of Assam.

Identification of typical water management problems of Brahmaputra Basin is another objective of this project. Emphasis has been given in identifying problems in agricultural sector, including tea garden. Reduction in crop yield due to draught /water logging, loss of crop land due to erosion are some of the problems that can be solved by proper management of available water.

1.2. River System and Climate

Brahmaputra River is one of the most sedimentation charged river in the world and also has the highest flood potential in the valley. The Valley of Brahmaputra River covers 60% of the state of Assam in North Eastern region of India. The total distance covered by Brahmaputra River is 2900 Km from the source of Eastern Himalaya to the Bay of Bengal. The river is running through China, India and Bangladesh. While 58% of its basin is in India, the catchment area of Nepal, Bhutan and Myanmar (Burma) also based on this river.

The river is fed by the south west summer monsoon, when 80% of the India’s total precipitation occurs. Historical records reveal that 24 hours continuous precipitation can also occur in this river valley. The monsoon sets in the last part of May or first week of June and withdraws in the last week of September. The Annual rainfall of Assam varies in a range of 1000mm to 2500 mm; however, the average annual precipitation is generally stated as 2000mm. About 60 to 70% rain occurs during rainy season i.e. during monsoon period from June to September, 15 to 20% during pre monsoon period and 7 to 10% during post monsoon period. A light rain also occurs during winter. About 74% of the people of this valley are engaged in Agriculture and allied activities. Monsoon based rice production is the principal crop covering about 67% of the total cropping area.

1.3. Agriculture

Out of the total geographical area of 78.44 lakh hectares, gross cropping area is 39.99 lakh hectares. Out of this gross potential, area for irrigation has been estimated at about 27 lakhs hectares. Necessary plan has been taken to irrigate 10 lakh hectares through major and medium irrigation scheme and 17 lakh hectares through minor irrigation scheme. Till 2009-2010, the irrigation Department has created potential of 7.76 lakh hectares irrigation through major/medium and minor irrigation scheme (Source-Irrigation department, Assam).

About 55% of the Indian Tea is produced in this valley and contribute about 16% of world tea production. Large number of tea estates of this region is facing water related problems of different nature.

1.4. CLIMATE CHANGE ISSUES

The Inter Government panel on Climate Change (IPCC 2007) identified five key areas that will be affected by Climate Change and these are:

a) Water
b) Agriculture
c) Ecosystem
d) Health
e) Coast-line

Preliminary studies carried out at IIT Guwahati (Kumar 2010, Deka and Sarma 2011, Vinnarasi and Sarma 2011) on impact of climate change on water resources of Brahmaputra Basin has revealed that there will be significant changes in rainfall pattern and temperature of this Basin. High intensity rainfall of short duration and longer dry period will have adverse effect on flood and drought scenario of this region. Analysis of extreme flood and draught (Sarma 2010) of Brahmaputra Basin showed that it is essential to consider extreme conditions while designing various hydraulic structures.

To study the impact of climate change on water resources requires dependable and long climatic data series for calibration of model parameter. This will help assessing future water availability scenario and making strategic planning for water management.

The following climatic parameters influence water scenario.

a) Rainfall
b) Temperature
c) Humidity
d) Wind velocity
e) Sun shine hours
f) Soil temperature
g) Evaporation Rate

Dependable data of the above climatic factors is the major hindrances to the project. Therefore the project "***Climatic Data Collection from Tea Garden and other sources of***

NE India for Climate Change Study" was formulated to collect available secondary data for these parameters.

1.5. Organization of the Report

Details about source of data, method of data collection, parameters collected are given in chapter-2 along with detail analysis of the collected data. Impacts of rainfall on various agricultural crops are discussed in the chapter-3. Water related problems like flood and erosion that affects human life and agriculture are discussed in the chapter-4. Possible solution strategies for some of these typical problems are presented in chapter-5. Scope of developing small hydroelectric project is presented in the chapter-6. Chapter-7 deals with the generation of future precipitation scenario under the impact of climate change. Strategic planning required to alleviate the impact of climate change is also included in this chapter. Scope of future study and a procedure of collecting information from IIT Guwahati are presented in chapter-8. Chapter-10 contains a conclusion on the entire projects.

2. Data Collection and Analysis

2.1. Introduction

To optimize the effort in data collection a detail planning was made so that all required information can be collected in proper format in one go. Accordingly a programme was made to collect the data in a planned manner. Source of data, method adopted for collection, and necessary analysis of data are presented in this chapter.

2.2. Sources of Data

The following secondary sources were identified for collecting climatic data:

a. The tea gardens of N.E. region,
b. Indian Meteorological Department,
c. Tocklai Experimental Research Station,
d. Assam Agricultural University,
e. Assam state Electricity Board,
f. Meghalaya State Electricity Board,
g. Various Hydro Electrical Power projects of N.E. region, and
h. State Agriculture Departments of N.E. region.

2.3. Method Adopted

Since, in the past, system of preserving the data in soft form through computer system was not available, the data were preserved in books in the form of hard copy. Therefore, it was necessary to collect the data in a planned manner as well as arrange these in a proper format so that the data are meaningful and easy to study.

It was also observed that there is difference in soil profile, soil texture and structure, behaviour of the river as regards to its movement and erosion of the bank, water logging condition, drought condition in various parts of N.E. region. As these information are extremely important for deciding water management strategy, it was decided to collect all relevant information related to soil and water irrespective of their immediate need.

Formats for data collection were forwarded to the above organizations and data were collected directly in this format wherever possible or were arranged in this format by the project team. The formats for data collection are shown in the following Annexures:

Annexure I: Information of the Tea Estate /Organization at a glance
Annexure II: Format for collecting rainfall data
Annexure III: Format for collecting temperature data
Annexure IV: Format for collecting relative humidity data

Annexure V: Format for collecting other elements of climate e.g. sunshine hrs, wind velocity, soil temperature, evaporation rate.

2.4. Procedure of data collection

a) Availability of climatic data in IMD was explored and gap in respect of space, time and climatic parameters were identified.
b) The meeting were organized with Tea Board of India, North Eastern Region, ABITA,TAI, NETA,ATPA, Bharotiya Cha Parisad,Tocklai Experimental Research Station, Jorhat, ASEB, IMD Guwahati at mutually convenient location to explain the following
   - Objective of the work
   - Need of data for climate change analysis
   - Benefit that Tea Estates/ASEB/University and other organization are going to get from this study

   All agreed to provide the data and accordingly data were collected by visiting different organizations and tea gardens. A portable scanner was used for collecting softcopy of the data that were in hard form.

2.5. Analysis of Data

Following climatic data were collected from the following sources:

a) Tea Gardens (Rainfall and Temperature for 210 stations/gardens)
b) Assam State Electricity Board (Rainfall and Temperature from 4 stations)
c) Assam Agriculture University, Jorhat (Rainfall for one station(Jorhat))
d) Department of Agriculture, Government of Assam (rainfall and crop production data for all district)
e) A MoU has been made with Indian Meteorology Department for collecting climatic parameters free of cost and IMD and CWC will remain a party to the work taken up by the Chair professor.
f) Application has also been made to Tocklai Experimental Research Station, Jorhat if it is possible to share their data.

The data collected in the raw form were digitized and transferred to a proper format as per above Annexure. Statistical analysis of rainfall and temperature data was carried out district-wise and river basin-wise.

2.6. Analysis of Rainfall Data

The rainfall data so far collected are presented through the following graphs district wise. Average district rainfall is only shown and the specific locations are not given in this report at present. Maximum daily rainfall recorded in a month is also plotted for those districts for which daily precipitation data are available.

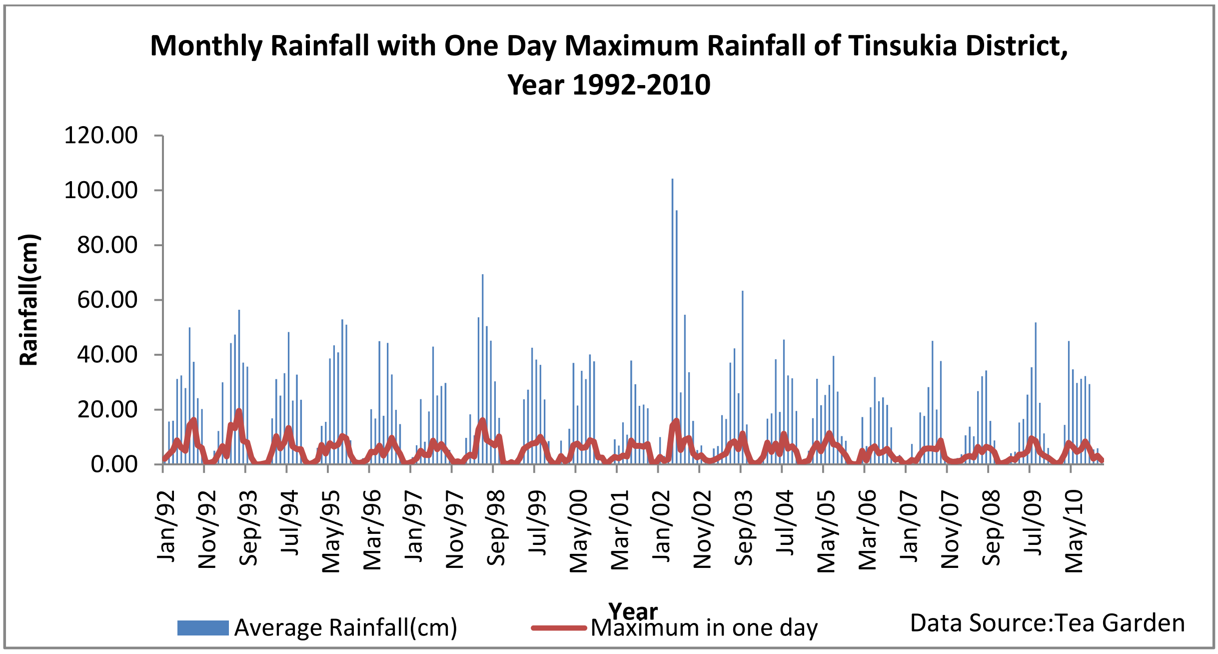

Fig 2.1 **Monthly Rainfall with One Day Maximum Rainfall of Tinsukia District, Year 1992-2010**

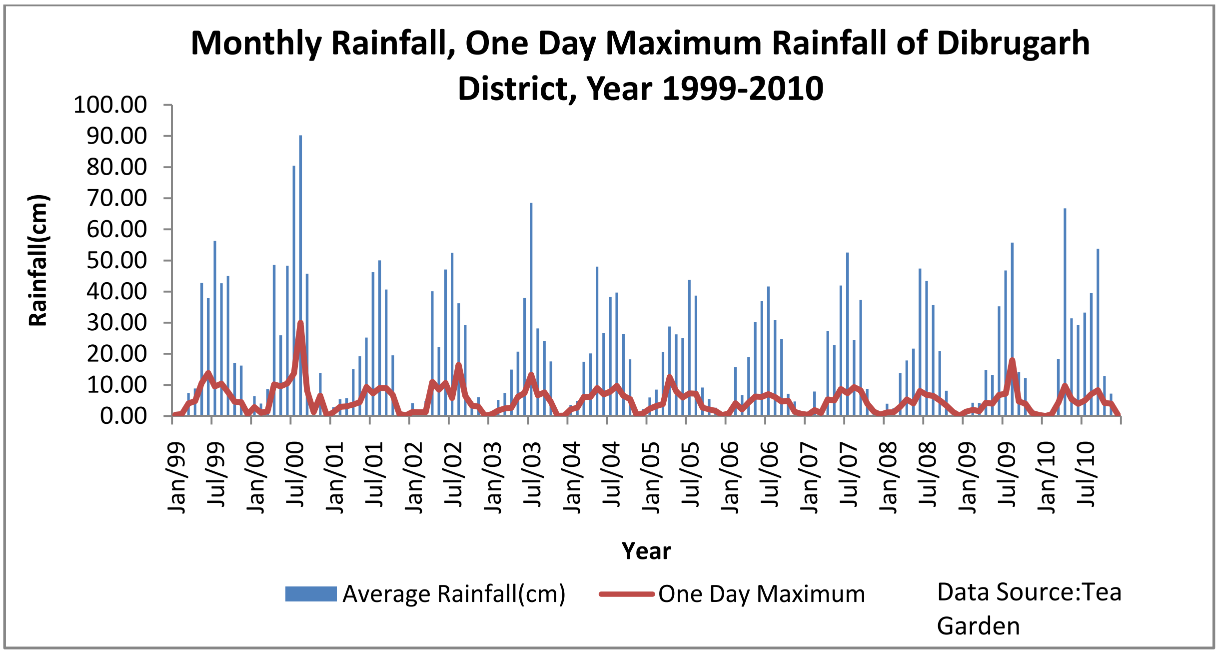

Fig 2.2 Monthly Rainfall, One Day Maximum Rainfall of Dibrugarh District, Year 1999-2010

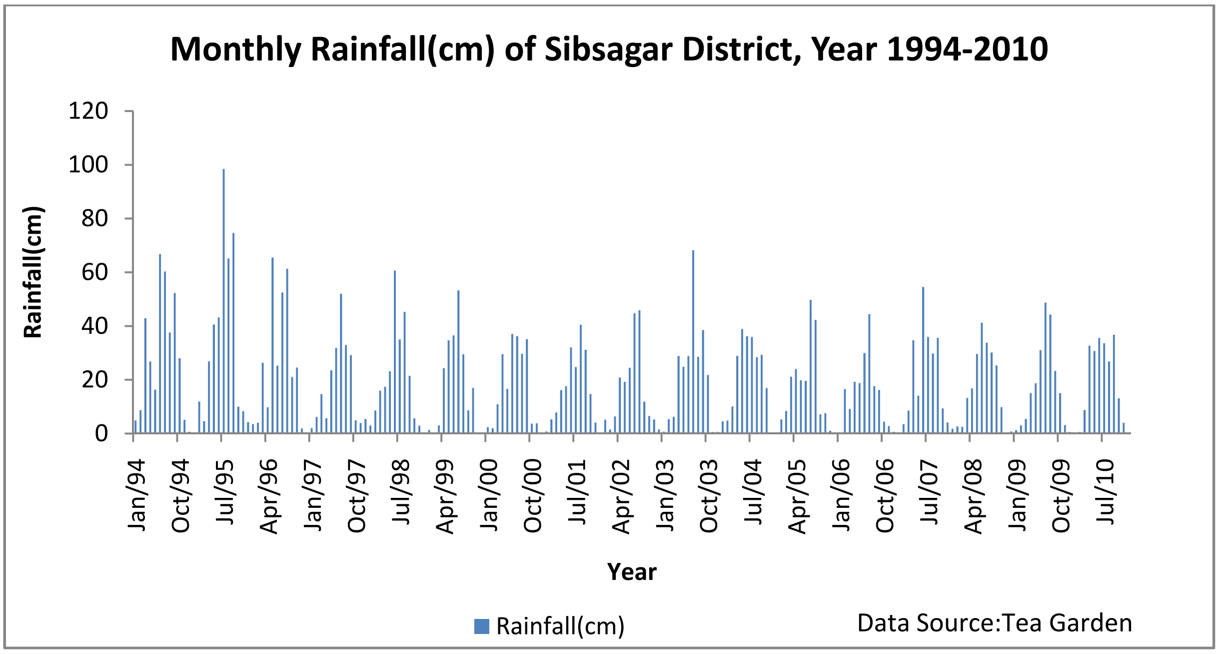

Fig 2.3 Monthly Rainfall(cm) of Sibsagar District, Year 1994-2010

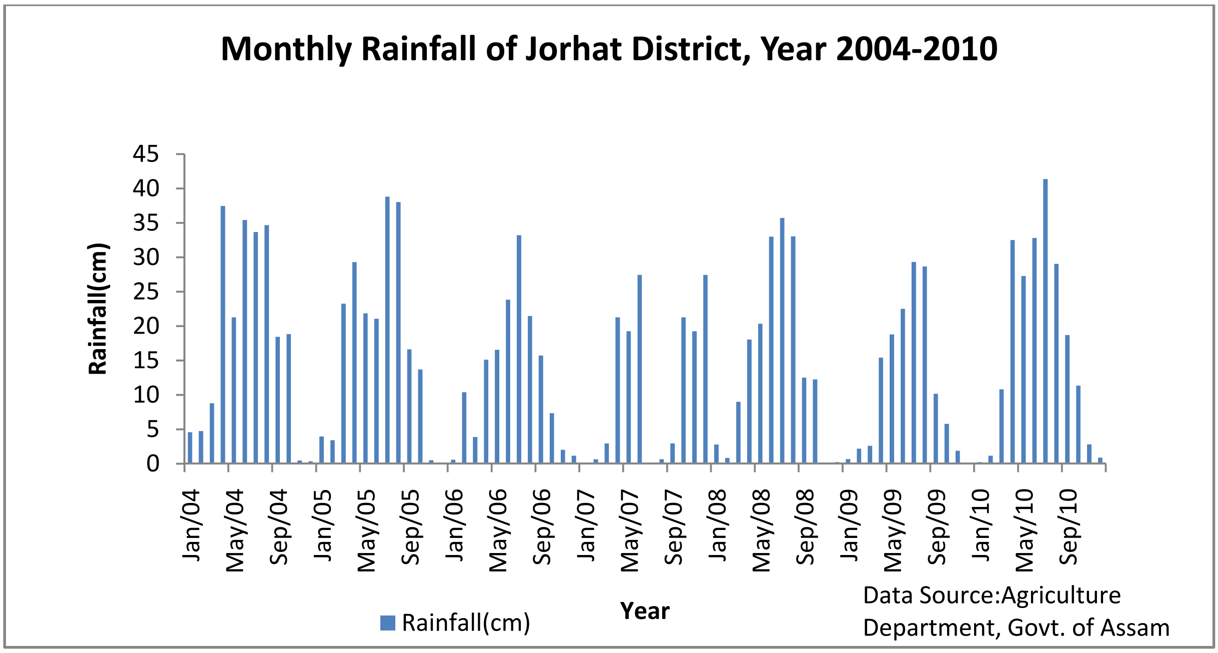

Fig 2.4 Monthly Rainfall of Jorhat District, Year 2004-2010

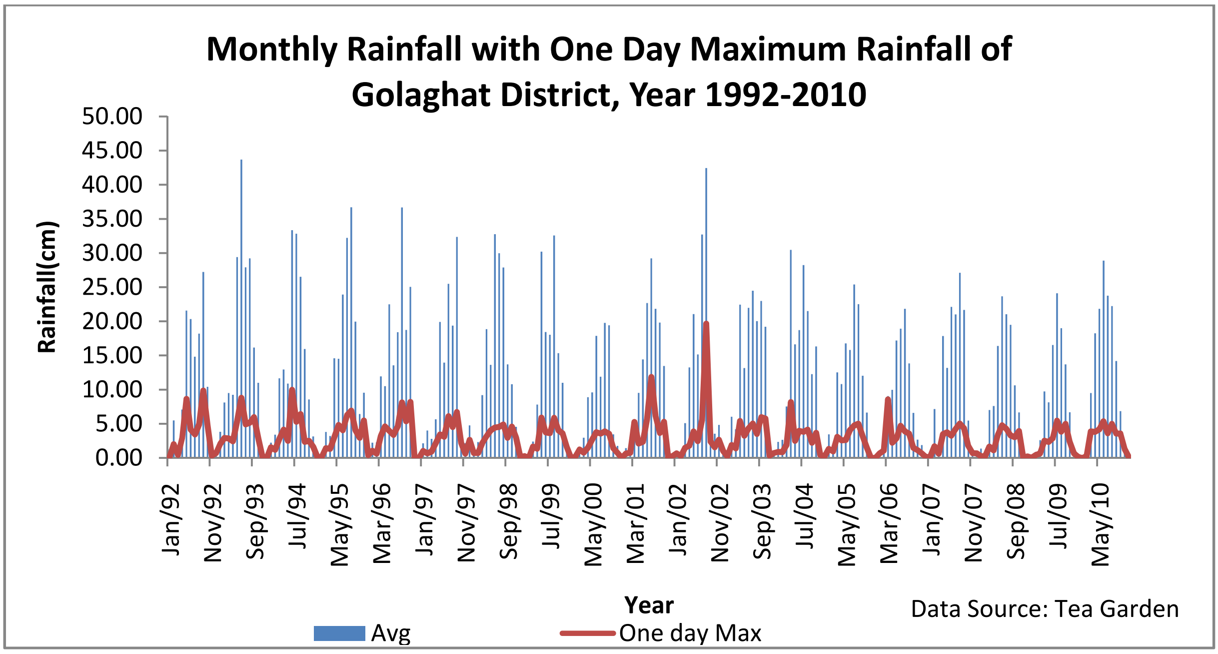

Fig. 2.5 Monthly Rainfall with One Day Maximum Rainfall of Golaghat District, Year 1992-2010

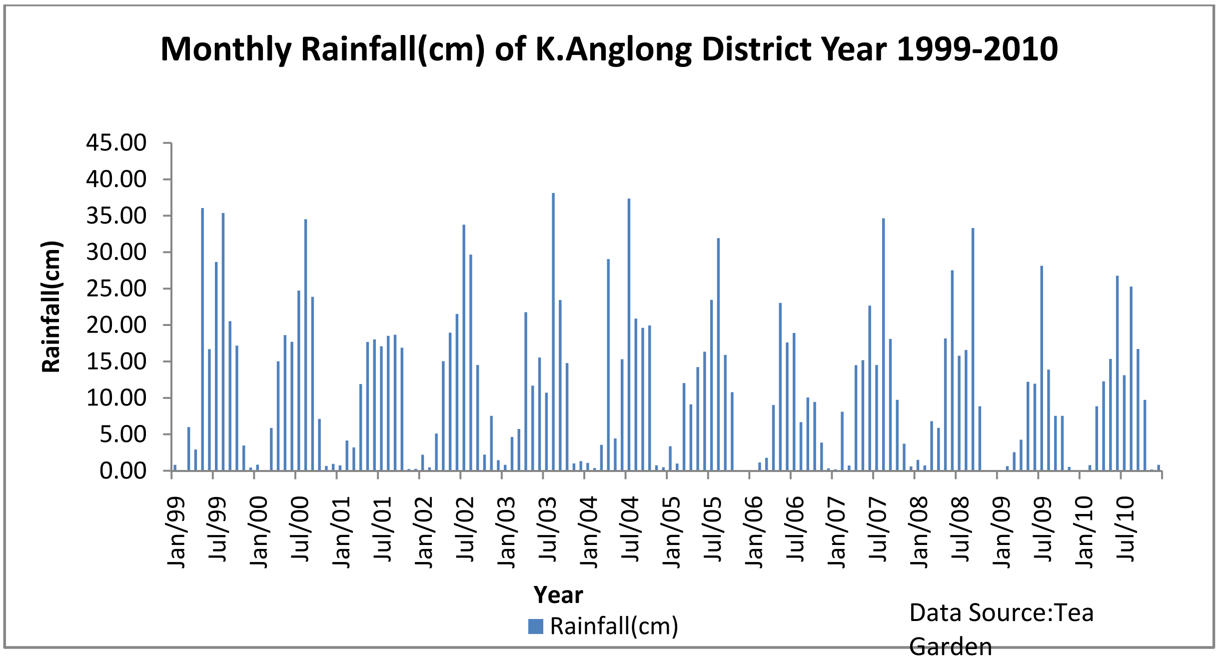

Fig. 2.6 Monthly Rainfall(cm) of K.Anglong District Year 1999-2010

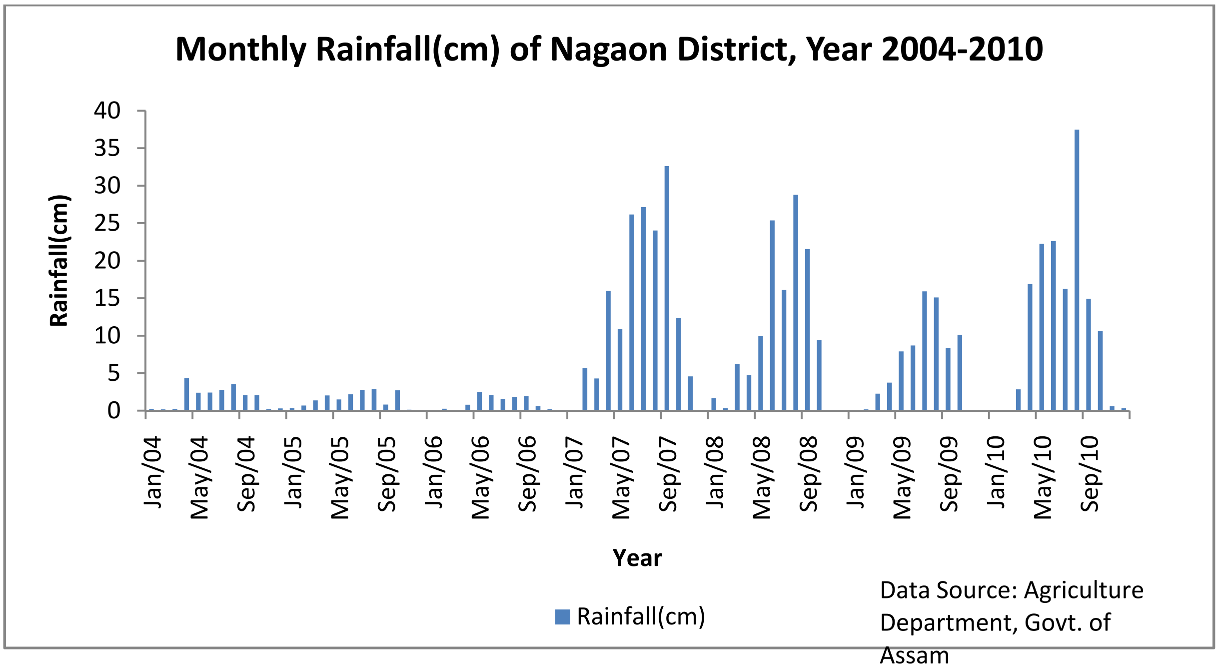

Fig. 2.7 Monthly Rainfall(cm) of Nagaon District, Year 2004-2010

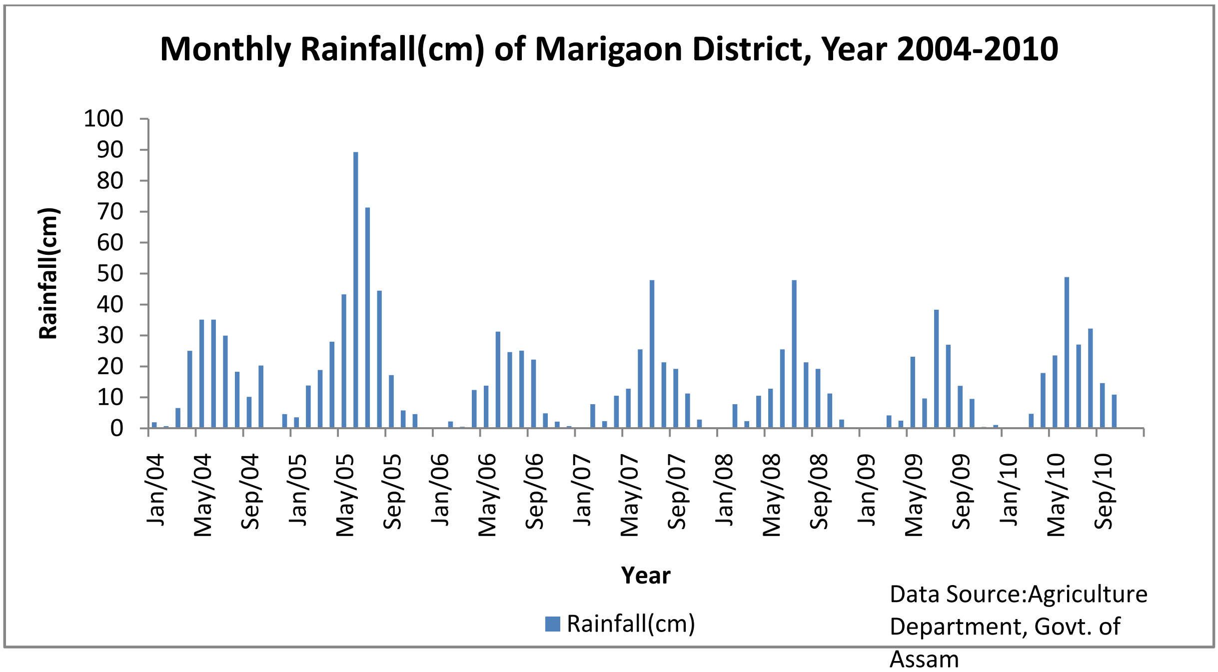

Fig. 2.8 Monthly Rainfall(cm) of Marigaon District, Year 2004-2010

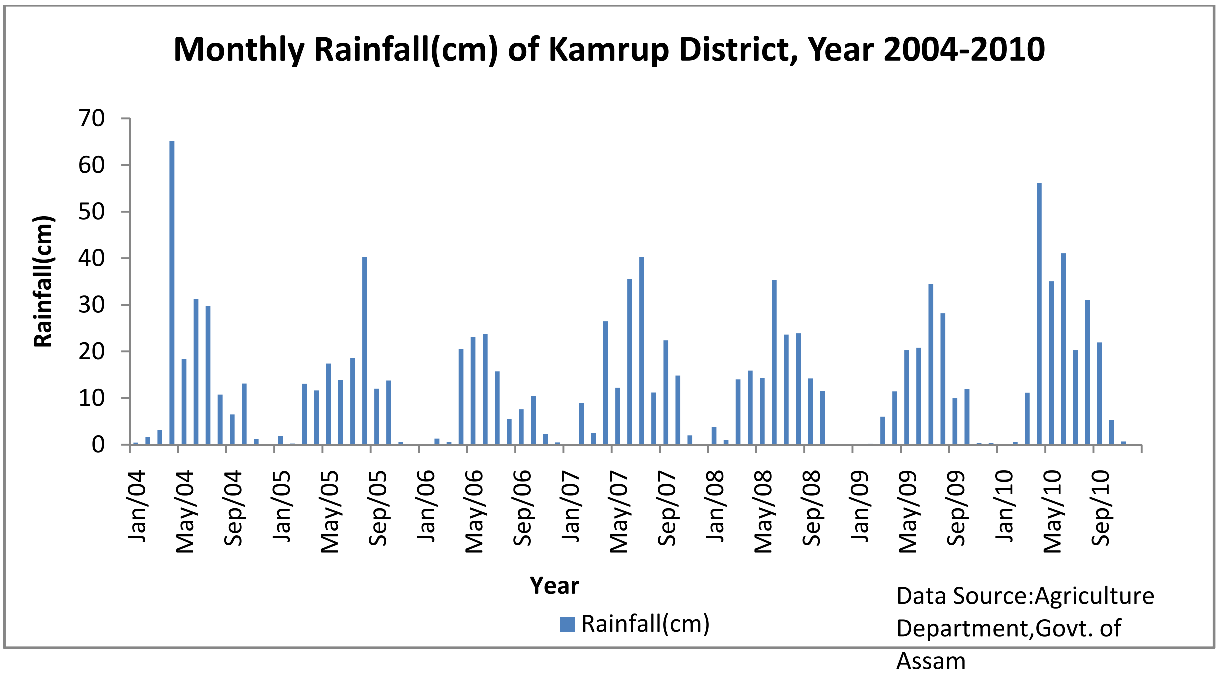

Fig. 2.9 Monthly Rainfall(cm) of Kamrup District, Year 2004-2010

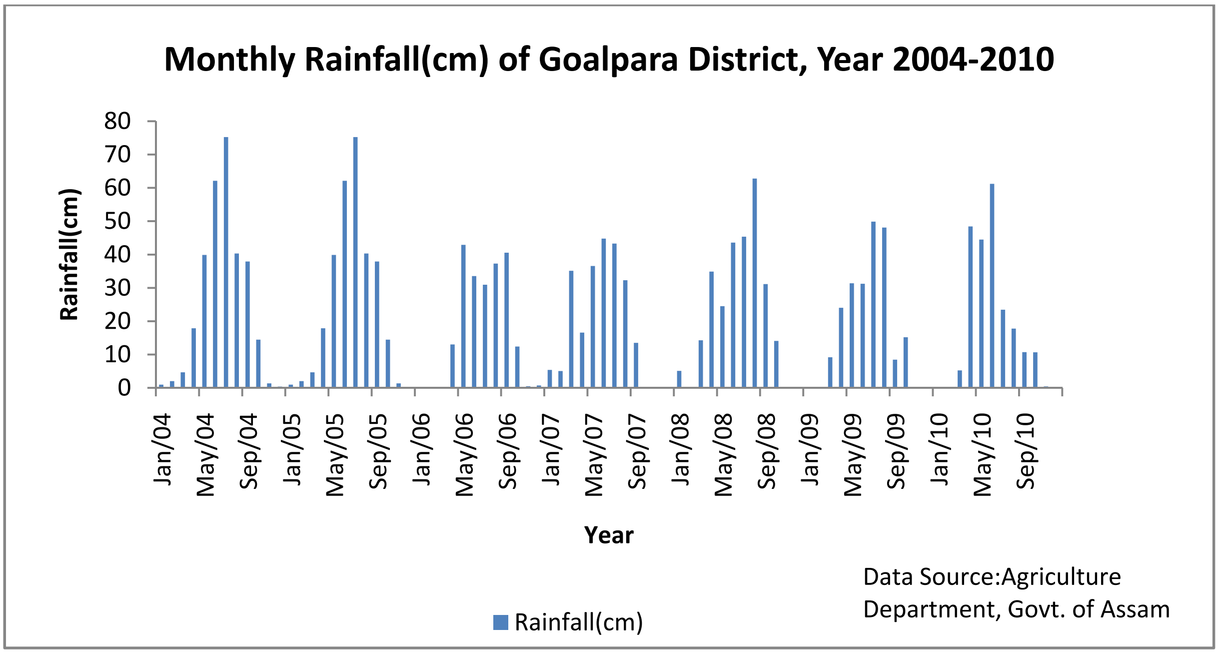

Fig. 2.10 Monthly Rainfall(cm) of Goalpara District, Year 2004-2010

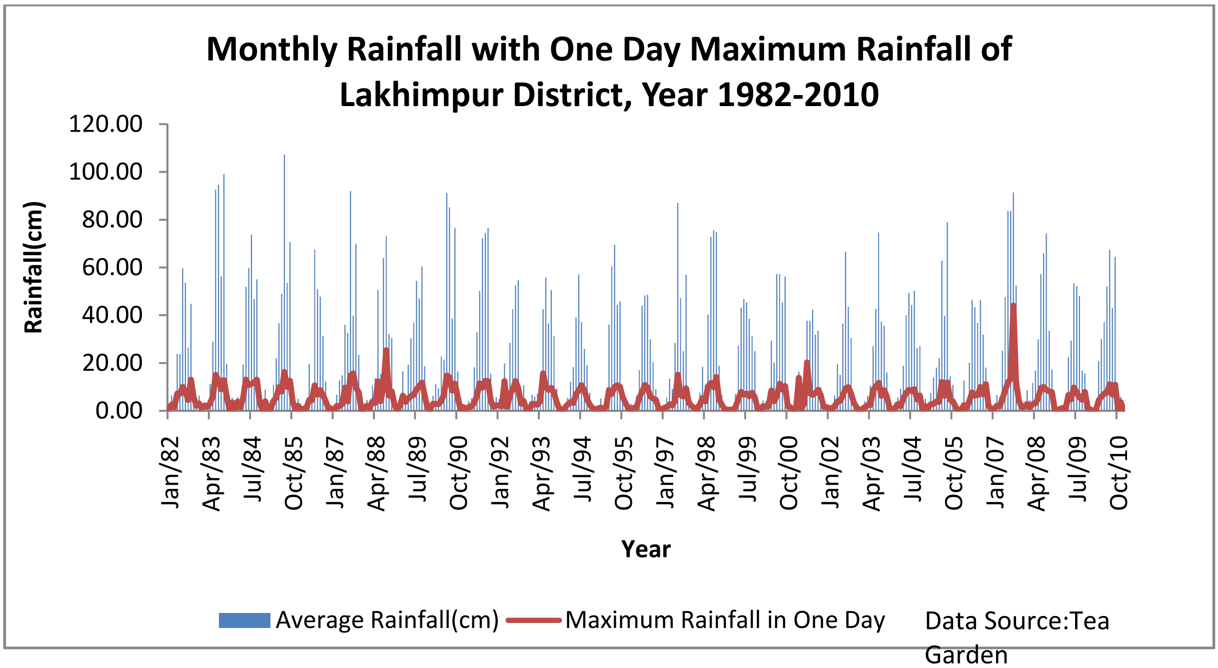

Fig. 2.11 Monthly Rainfall with One Day Maximum Rainfall of Lakhimpur District, Year 1982-2010

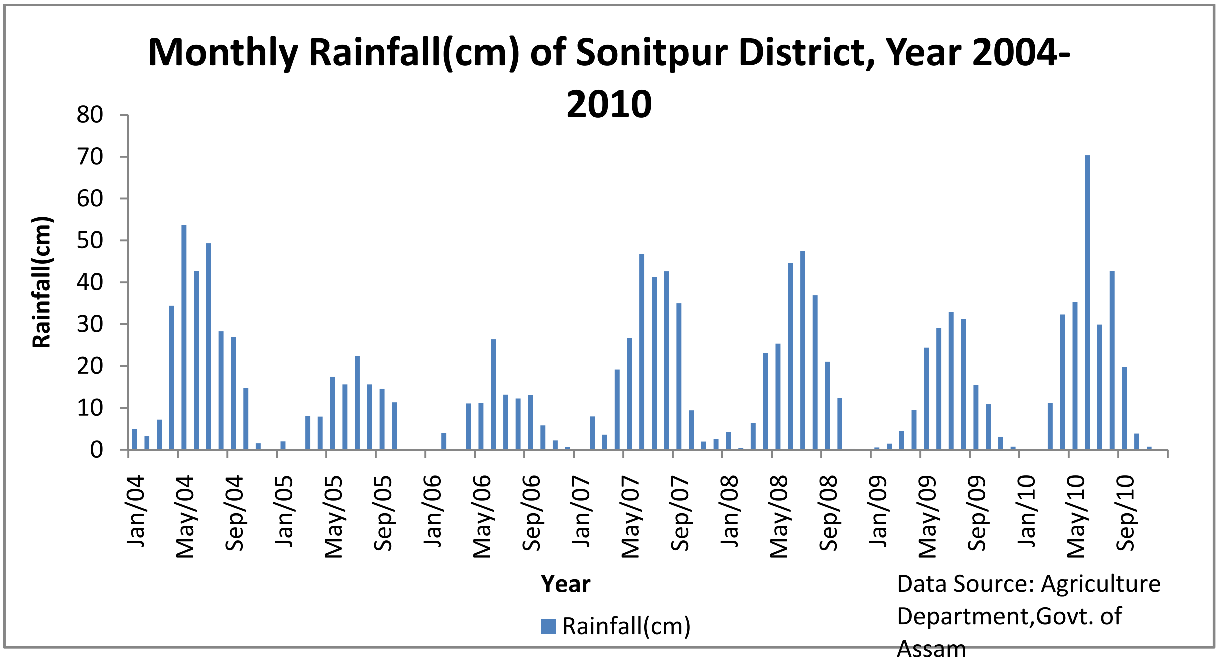

Fig. 2.12 Monthly Rainfall(cm) of Sonitpur District, Year 2004-2010

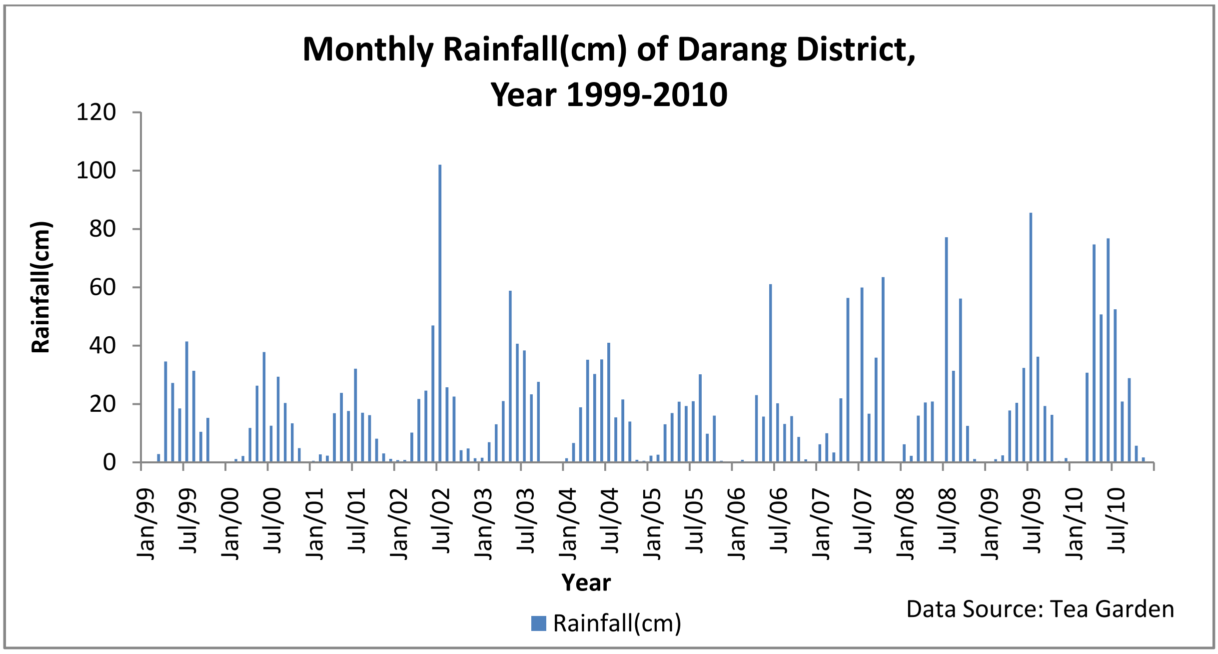

Fig. 2.13 Monthly Rainfall(cm) of Darang District, Year 1999-2010

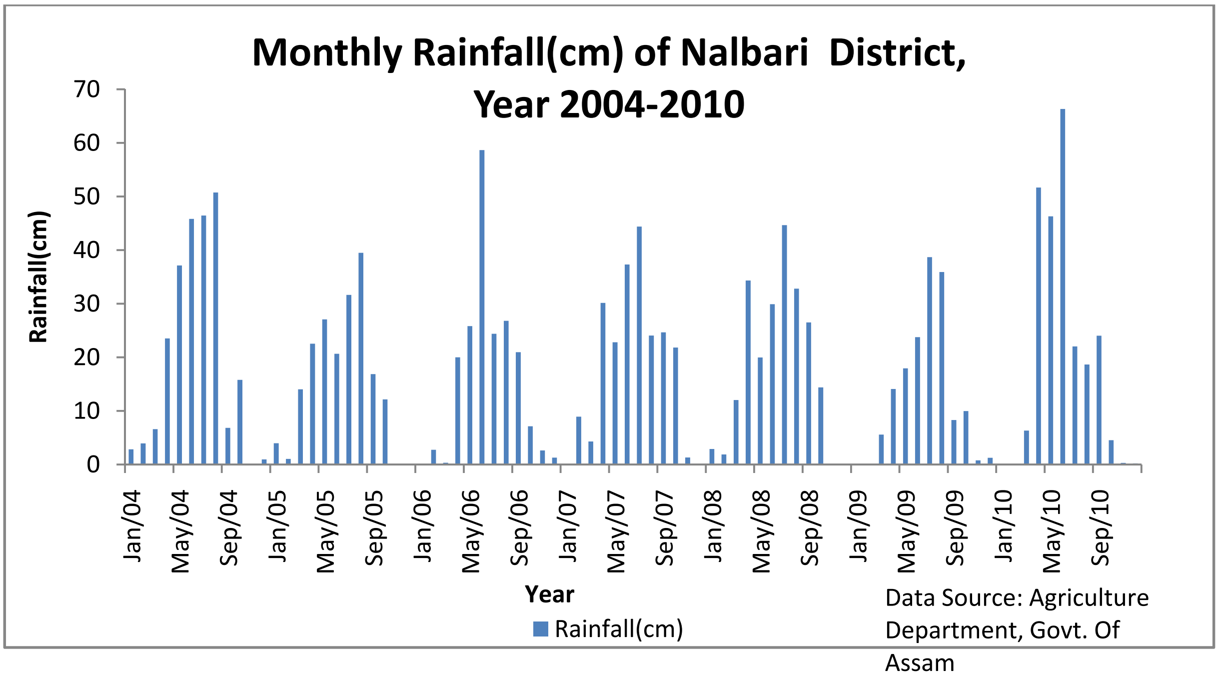

Fig. 2.14 Monthly Rainfall(cm) of Nalbari District, Year 2004-2010

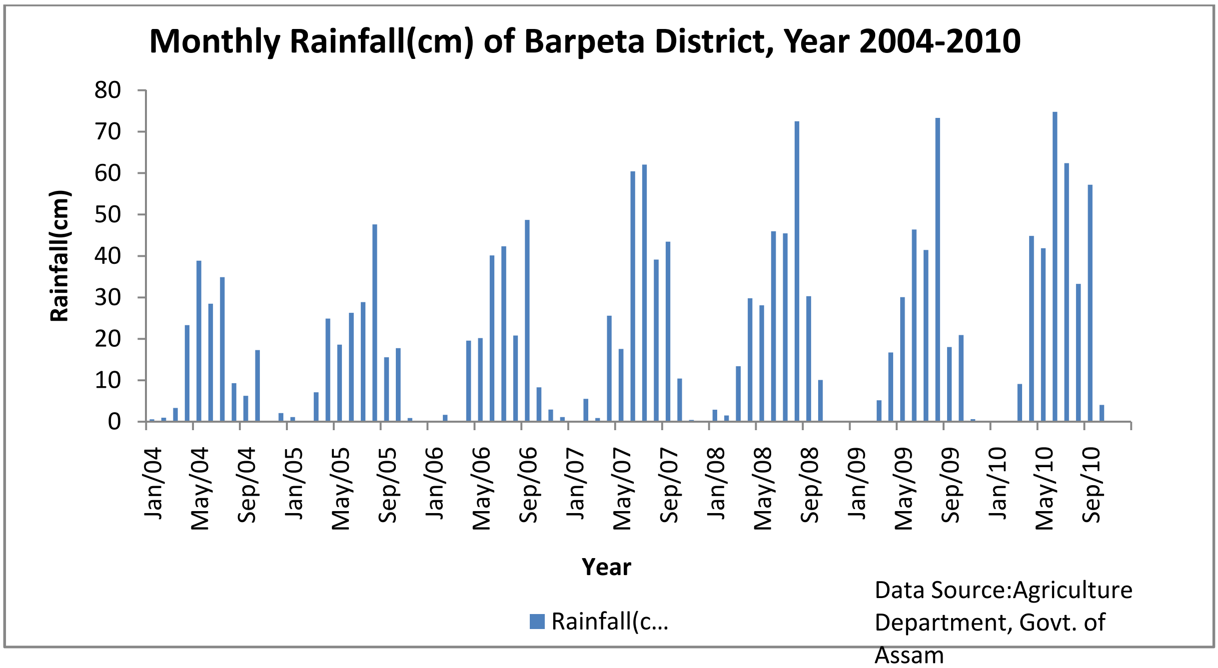

Fig. 2.15 Monthly Rainfall(cm) of Barpeta District, Year 2004-2010

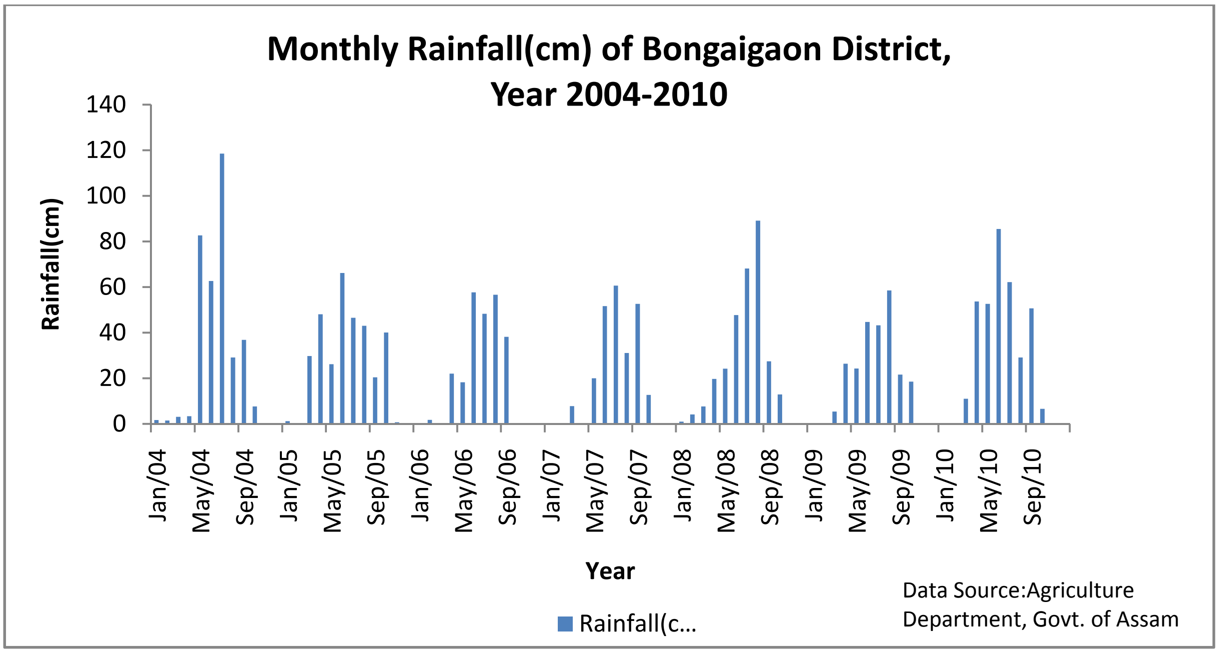

Fig. 2.16 Monthly Rainfall(cm) of Bongaigaon District, Year 2004-2010

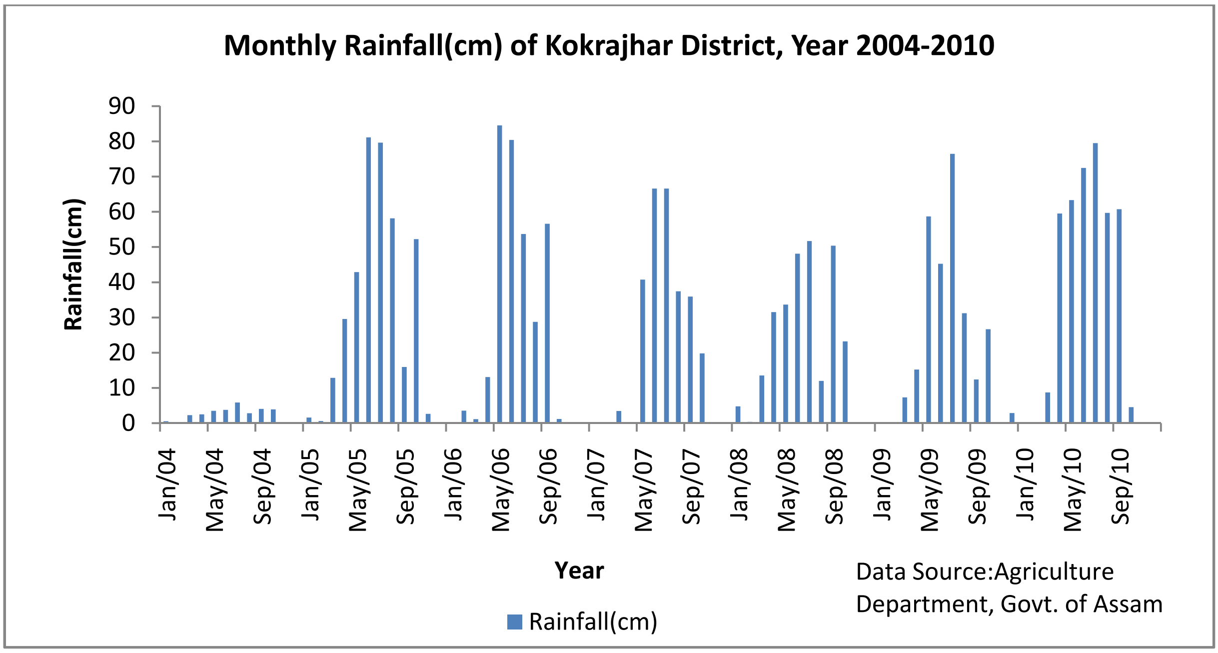

Fig. 2.17 Monthly Rainfall(cm) of Kokrajhar District, Year 2004-2010

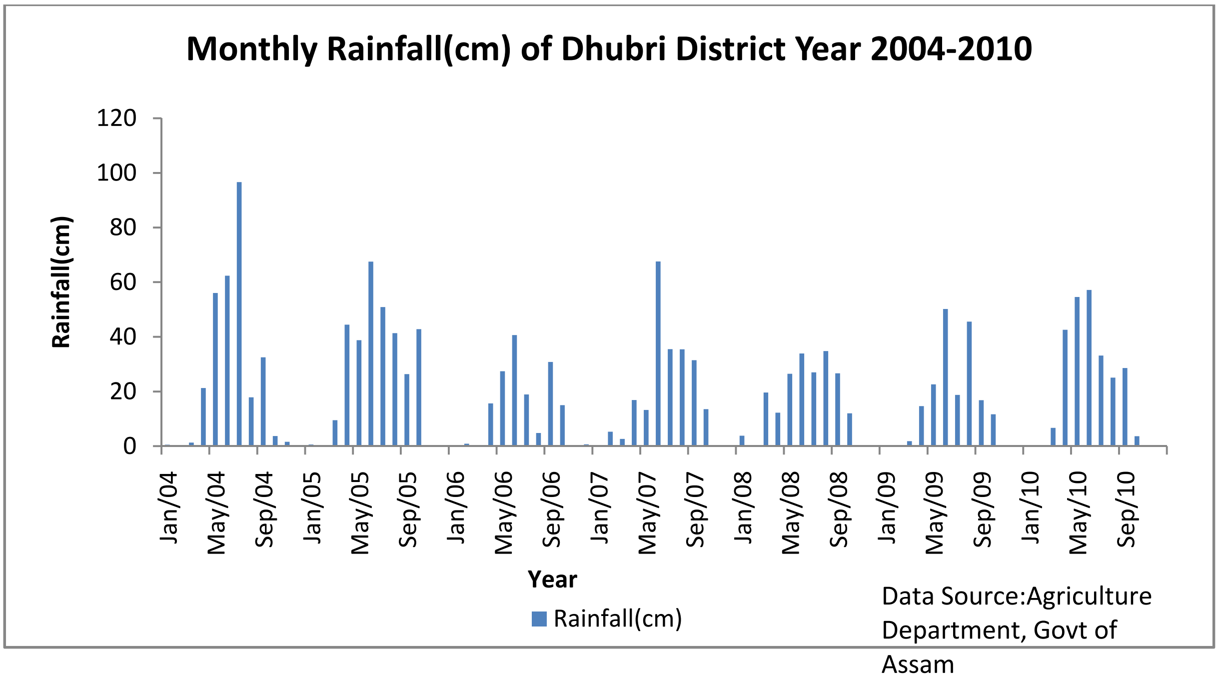

Fig. 2.18 Monthly Rainfall(cm) of Dhubri District Year 2004-2010

2.7. INFERENCE DRAWN FROM RAINFALL DATA

From the rainfall data collected from the different district it can be concluded that

a. A significant variation in total yearly rainfall with time has been seen in almost all districts. However, it cannot be said to follow an increasing or decreasing trend. Many a time a continuous drop in annual rainfall has been observed for 5 to 6 years and then a rising trend has been seen. Therefore, a decision regarding rainfall trend should not be taken based on observation of rainfall series of small length.
b. Monthly distribution of rainfall also varies from time to time. Therefore, in agricultural planning, possibility of having unexpected adverse condition should always be kept in mind.
c. Observation of maximum daily rainfall has revealed that extremely high daily rainfall as compared to it normal value can occur during the monsoon period. Such high rainfall can cause devastating erosion and flood.
d. Such variation in rainfall will definitely have some impact on various sectors of economy and this need to be studied in detail.

2.8. ANALYSIS OF TEMPERATURE DATA

The temperature data were not available for all districts and therefore the data collected for four districts are analysed and presented through the following figures.

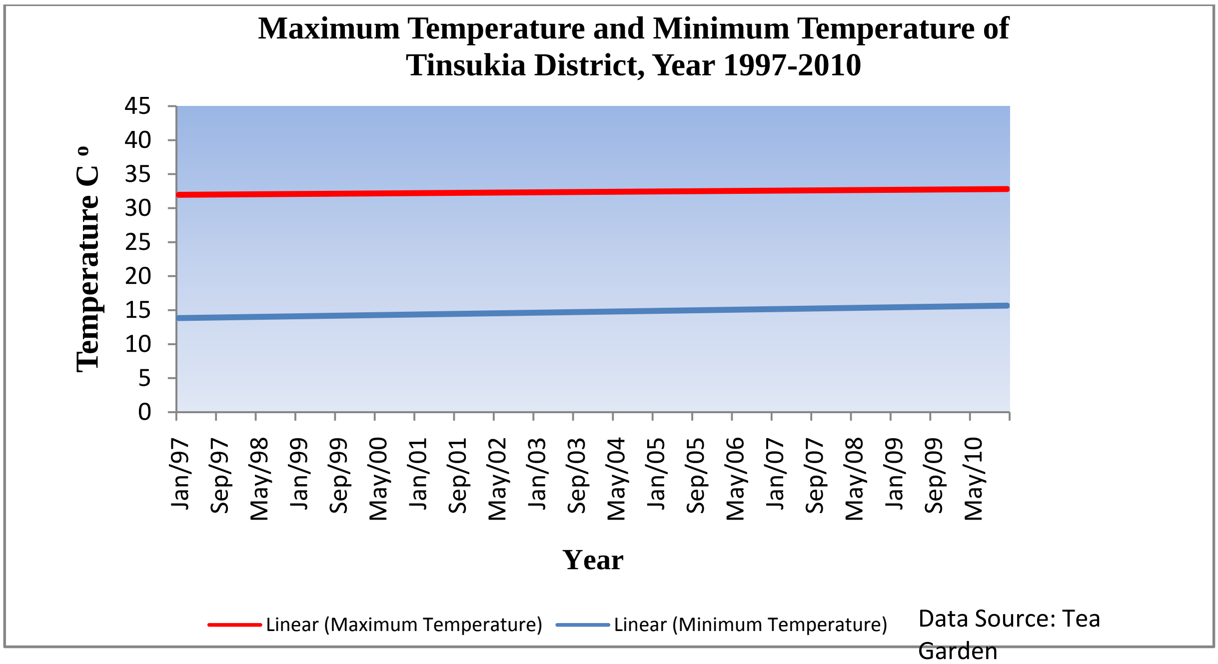

Fig. 2.19 **Maximum Temperature and Minimum Temperature of Tinsukia District, Year 1997-2010**

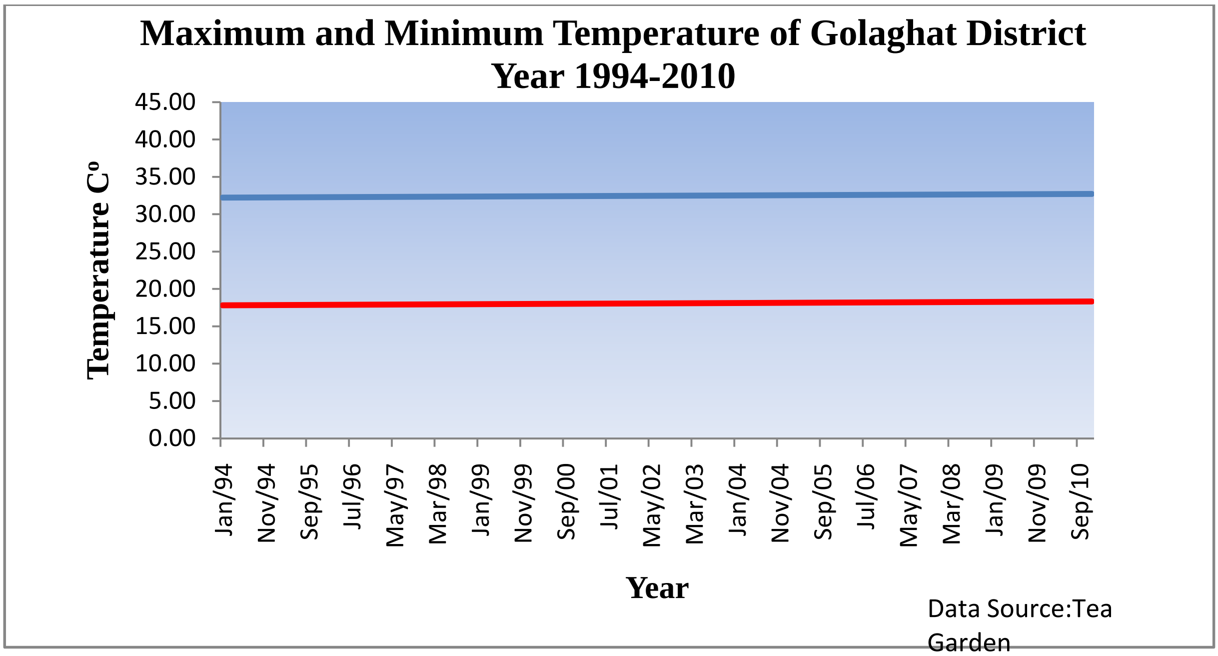

Fig. 2.20 Maximum and Minimum Temperature of Golaghat District Year 1994-2010

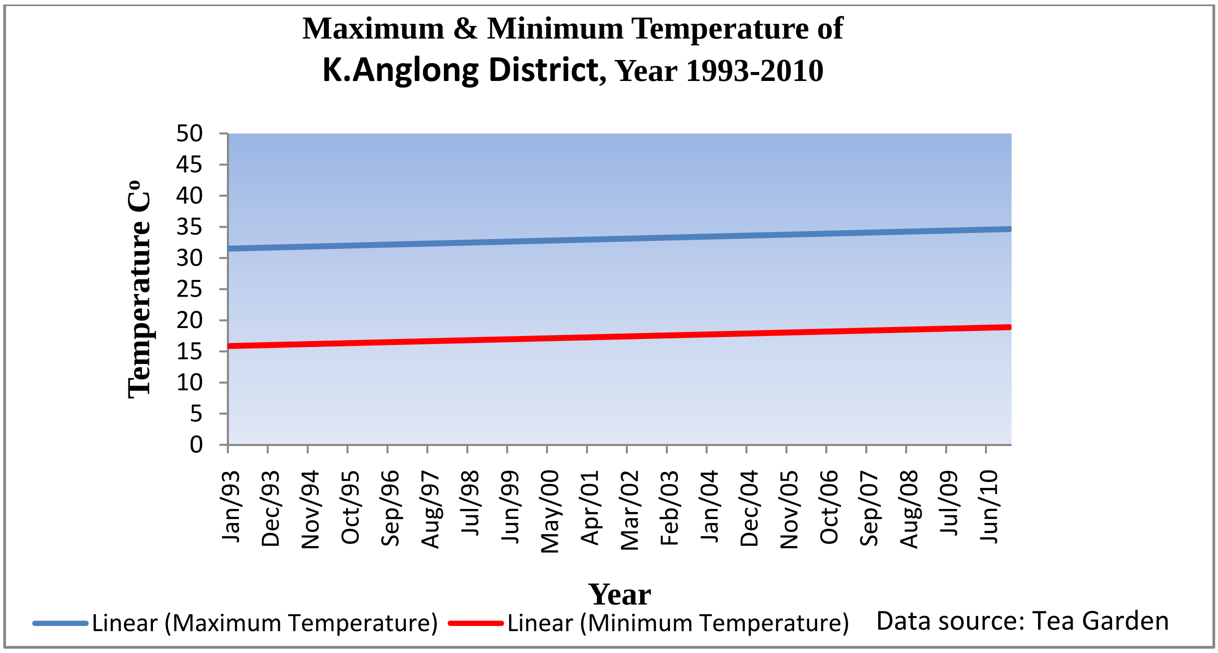

Fig. 2.21 Maximum & Minimum Temperature of K.Anglong District, Year 1993-2010

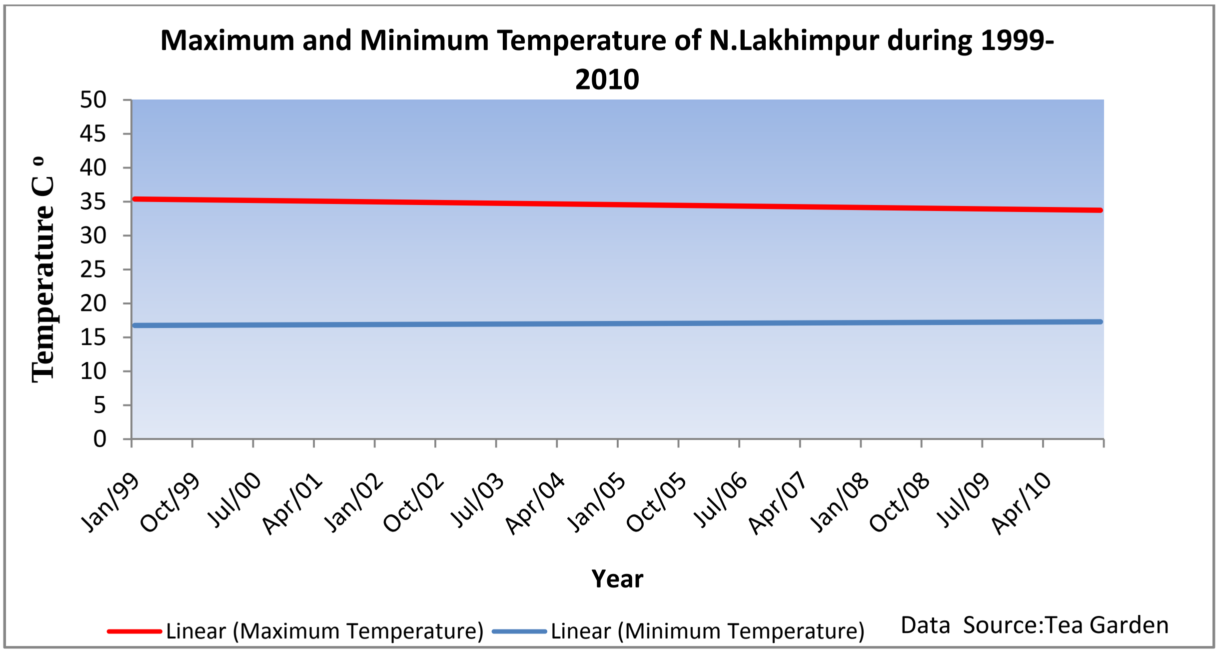

Fig. 2.22 Maximum and Minimum Temperature of N.Lakhimpur during 1999-2010

2.9 INFERENCE DRAWN FROM TEMPERATURE DATA ANALYSIS

Both the maximum and minimum temperature has a increasing tends to in Tinsukia, Golaghat and K.Anglong District but there appears to be no change in maximum temperature and only minimum temperature is in increasing trend in N.Lakhimpur district. The impacts of these changes need to be studied for different sectors of economy.

3 Relationship between precipitation and Agriculture

3.1 Introduction

Rainfall is the primary source of water for Agriculture. The total rainfall and its monthly distribution are first consideration for selecting and growing a crop.Out of all the all the elements controlling the climate, the variability of distribution cf rainfall from one year to the other throughout the season is very important for success of crop production.

3.2 The relation between precipitation and few field crops and tea

3.2.1 Relation between precipitation and rice production

The following graphs (fig 3.1 through 3.18) show the relationship between precipitation and rice production in different district of Assam.

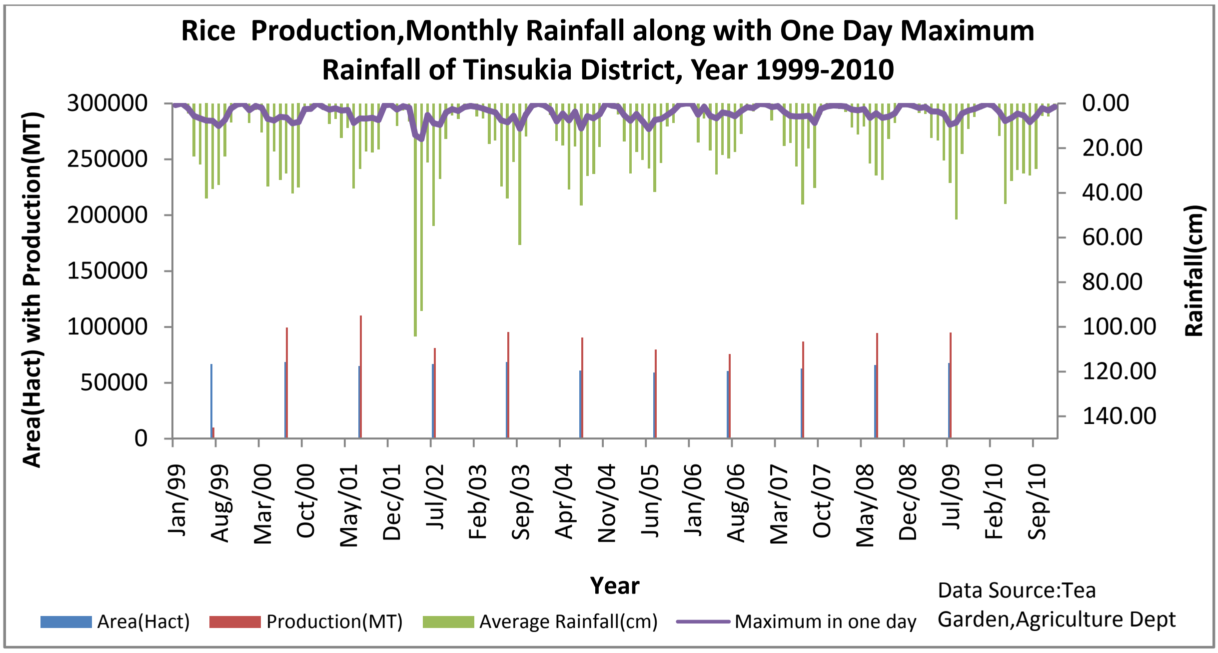

Fig 3.1 **Rice Production, Monthly Rainfall along with One Day Maximum Rainfall of Tinsukia District, Year 1999-2010**

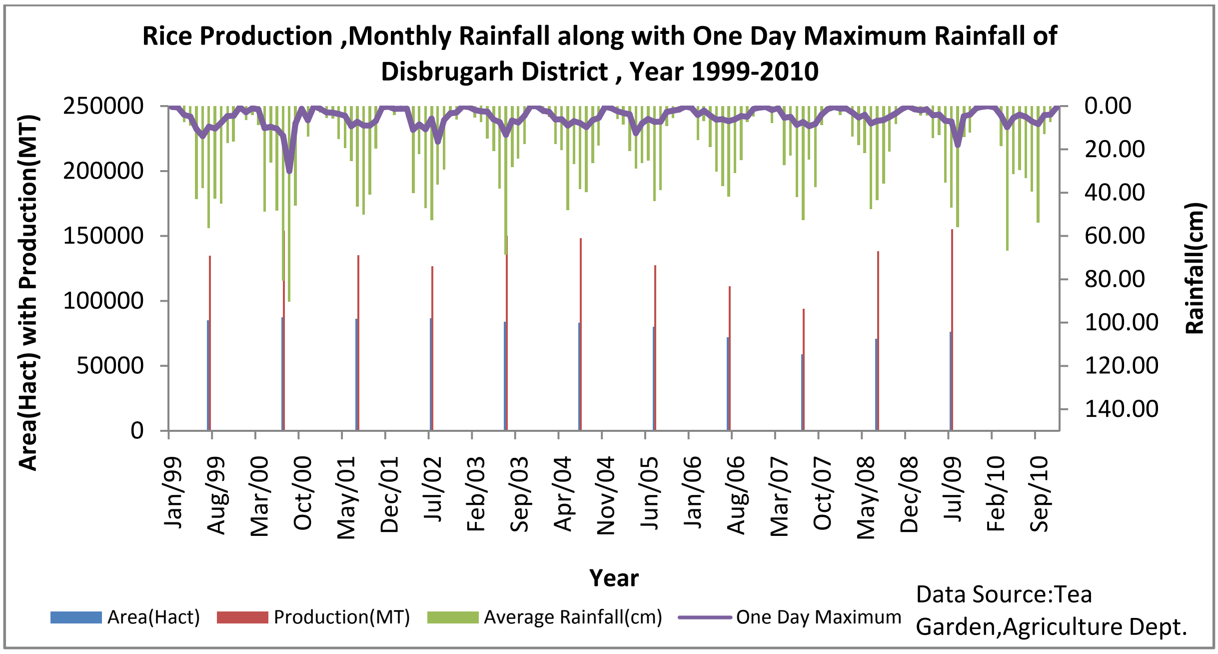

Fig. 3.2 **Rice Production ,Monthly Rainfall along with One Day Maximum Rainfall of Disbrugarh District , Year 1999-2010**

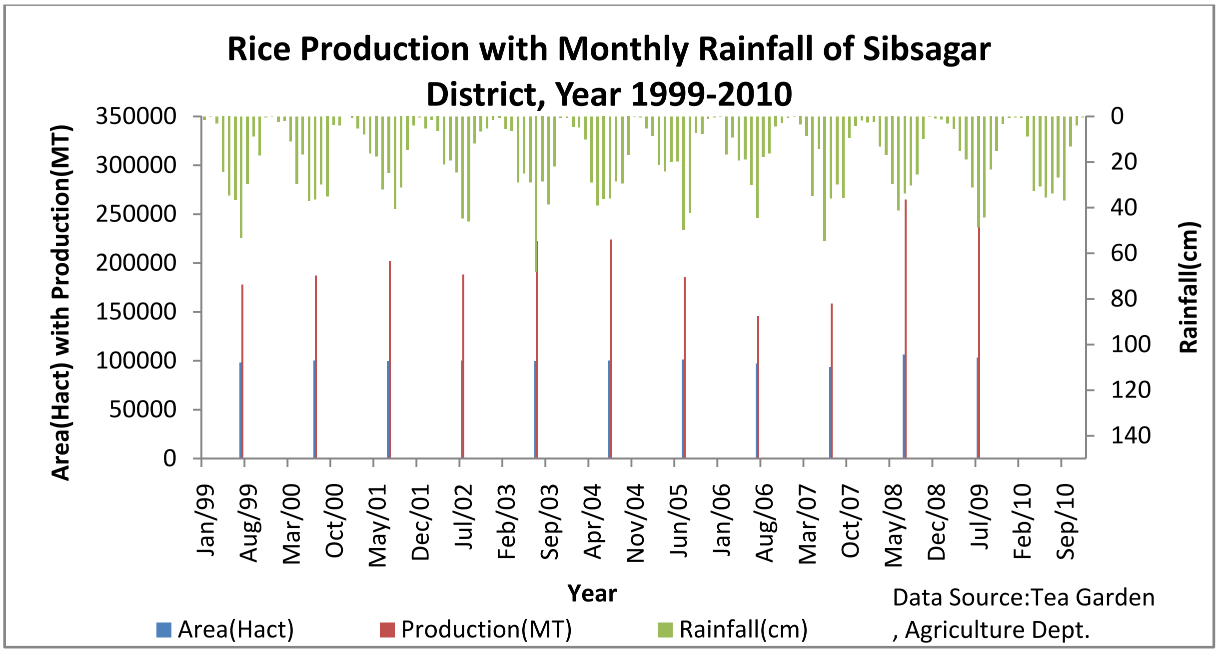

Fig. 3.3 Rice Production with Monthly Rainfall of Sibsagar District, Year 1999-2010

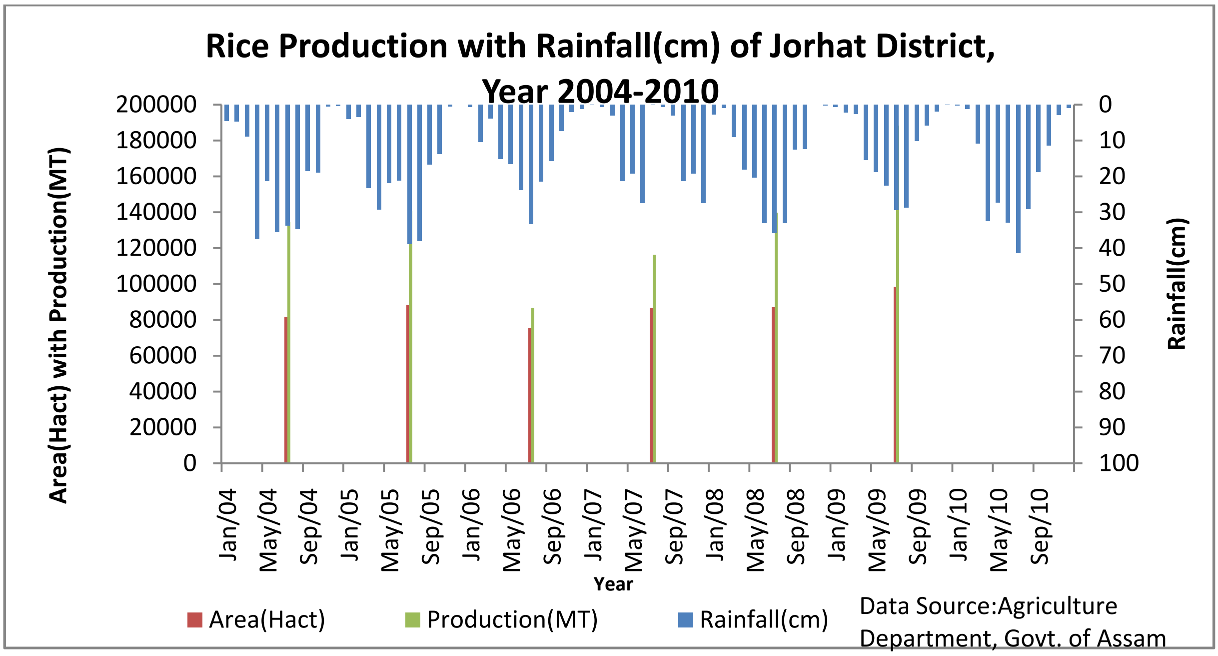

Fig. 3.4 Rice Production with Rainfall(cm) of Jorhat District, Year 2004-2010

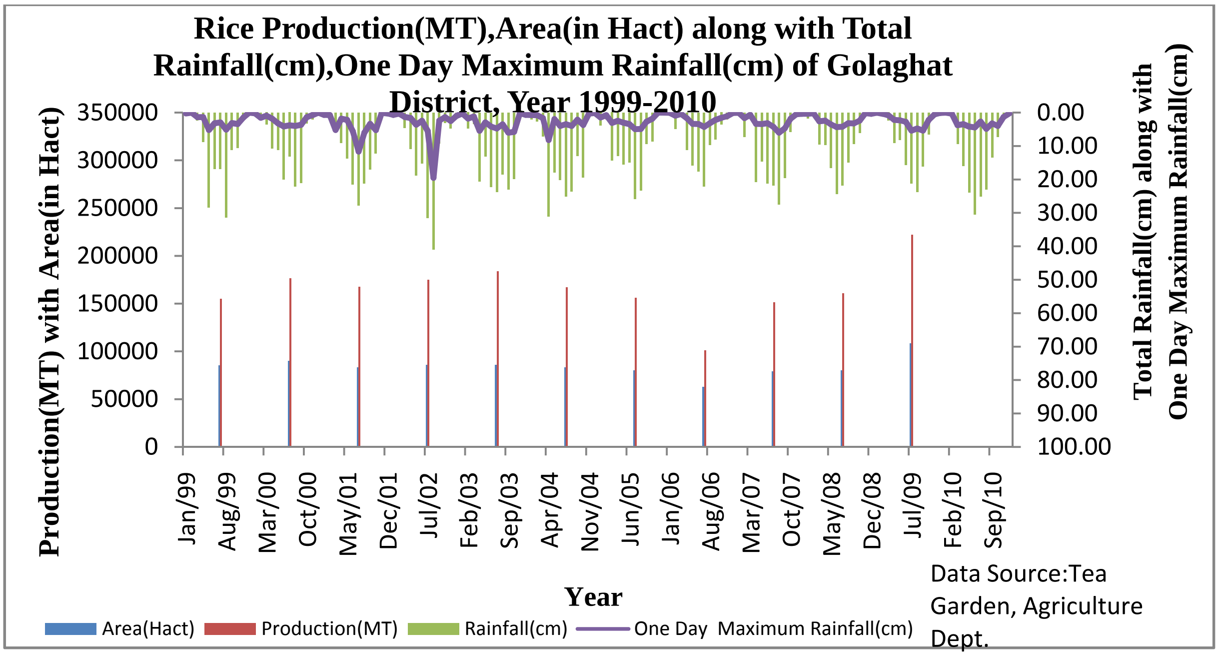

Fig. 3.5 Rice Production(MT),Area(in Hact) along with Total Rainfall(cm),One Day Maximum Rainfall(cm) of Golaghat District, Year 1999-2010

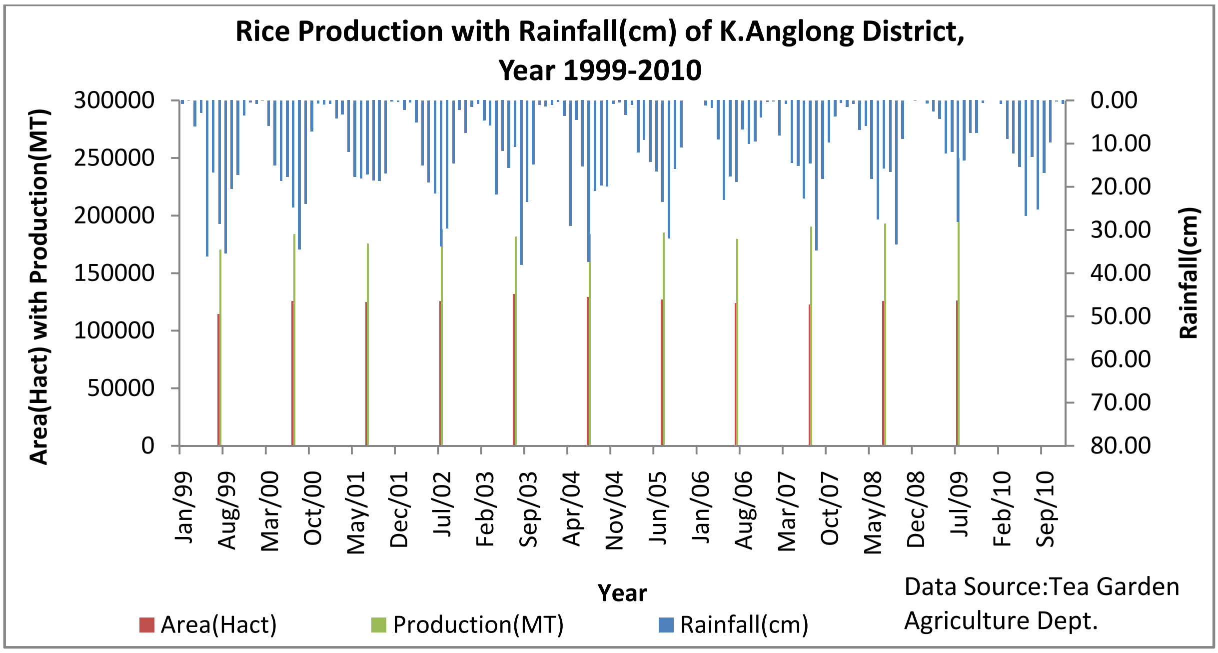

Fig. 3.6 Rice Production with Rainfall(cm) of K.Anglong District, Year 1999-2010

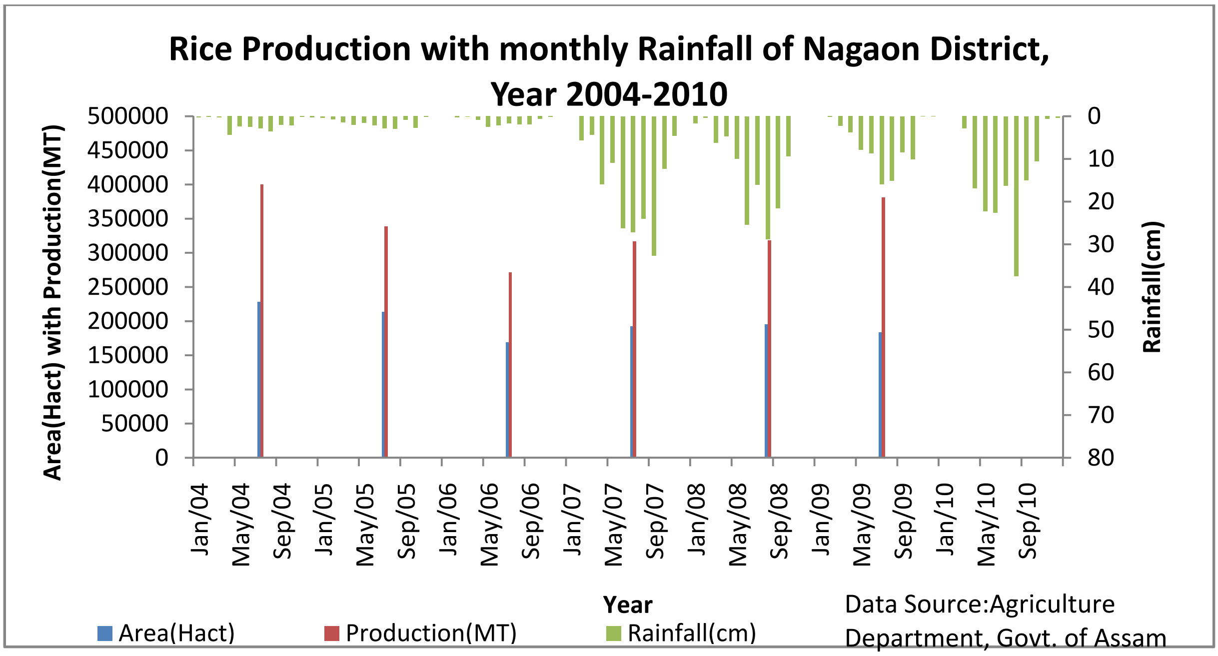

Fig. 3.7 Rice Production with monthly Rainfall of Nagaon District, Year 2004-2010

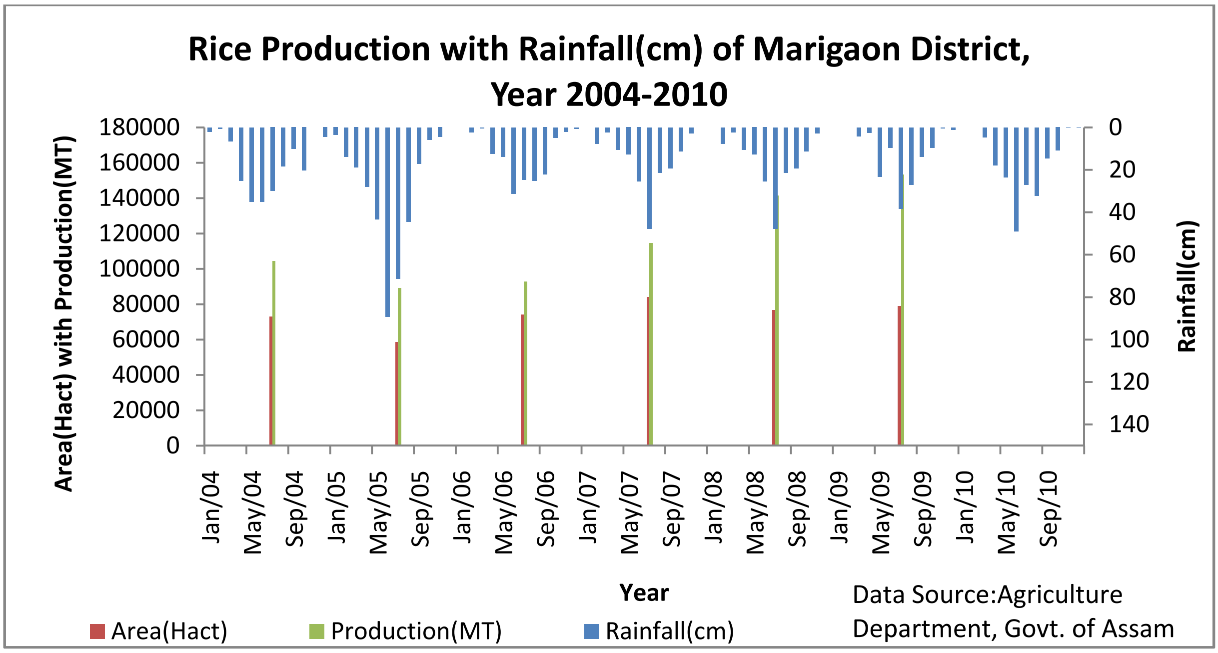

Fig. 3.8 Rice Production with Rainfall(cm) of Marigaon District, Year 2004-2010

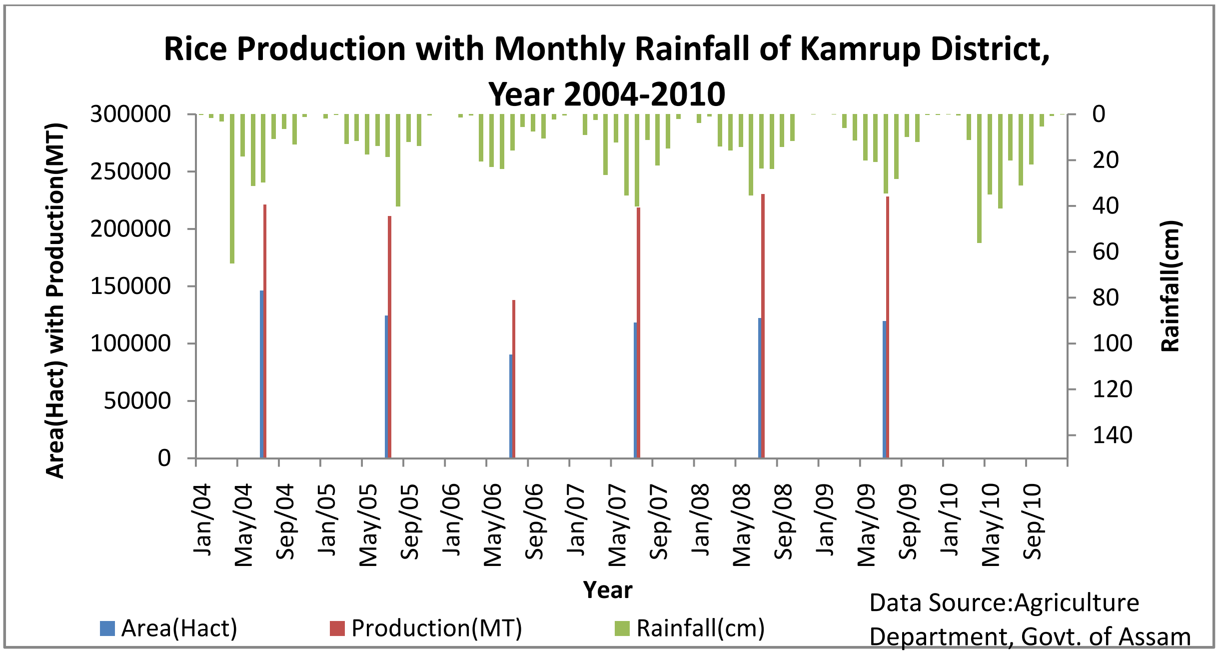

Fig. 3.9 Rice Production with Monthly Rainfall of Kamrup District, Year 2004-2010

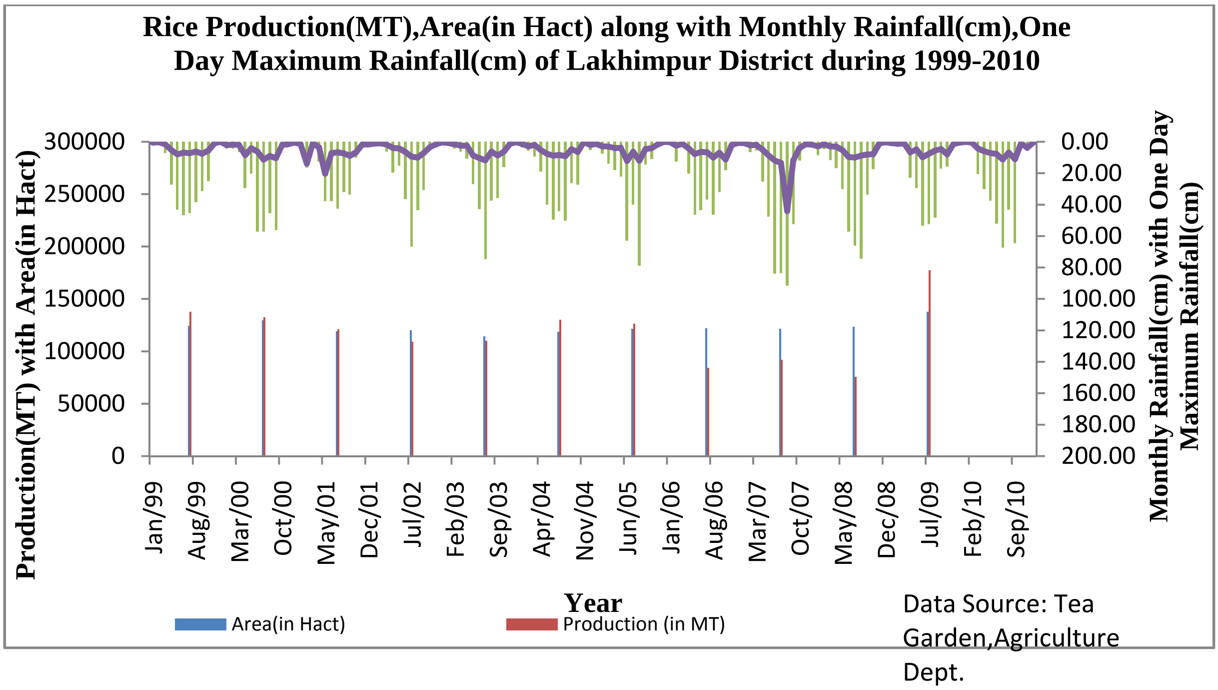

Fig. 3.10. Rice Production(MT),Area(in Hac) along with Monthly Rainfall(cm),One Day Maximum Rainfall(cm) of Lakhimpur District during 1999-2010

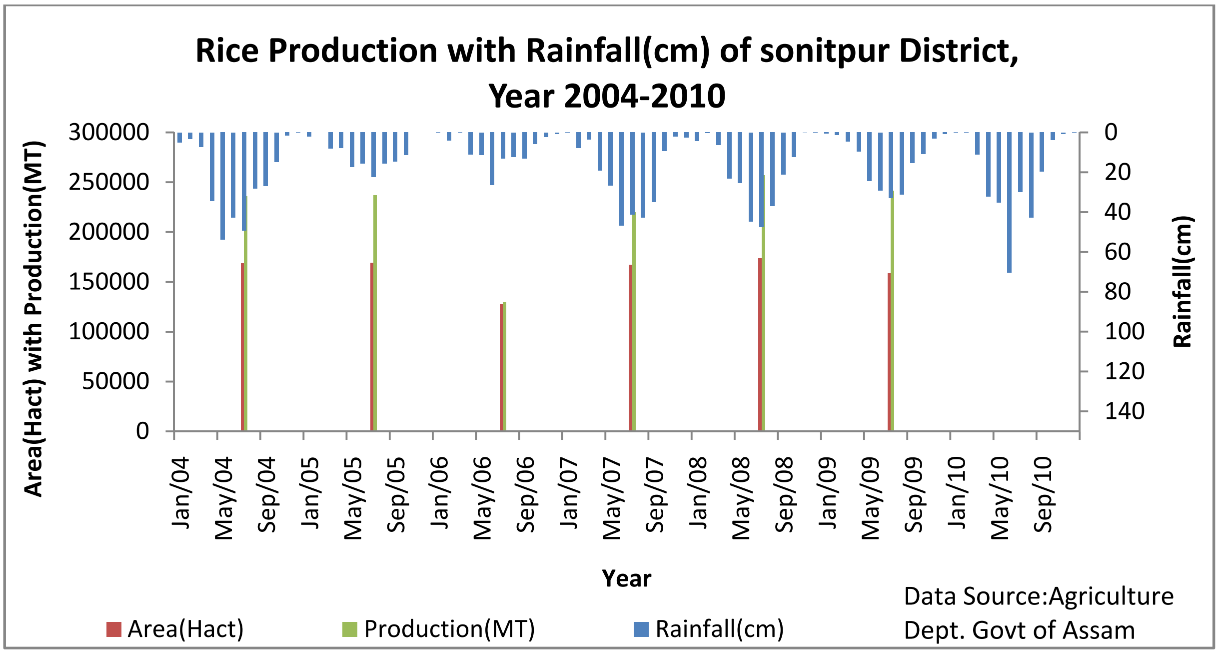

Fig.3.11 Rice Production with Rainfall(cm) of sonitpur District, Year 2004-2010

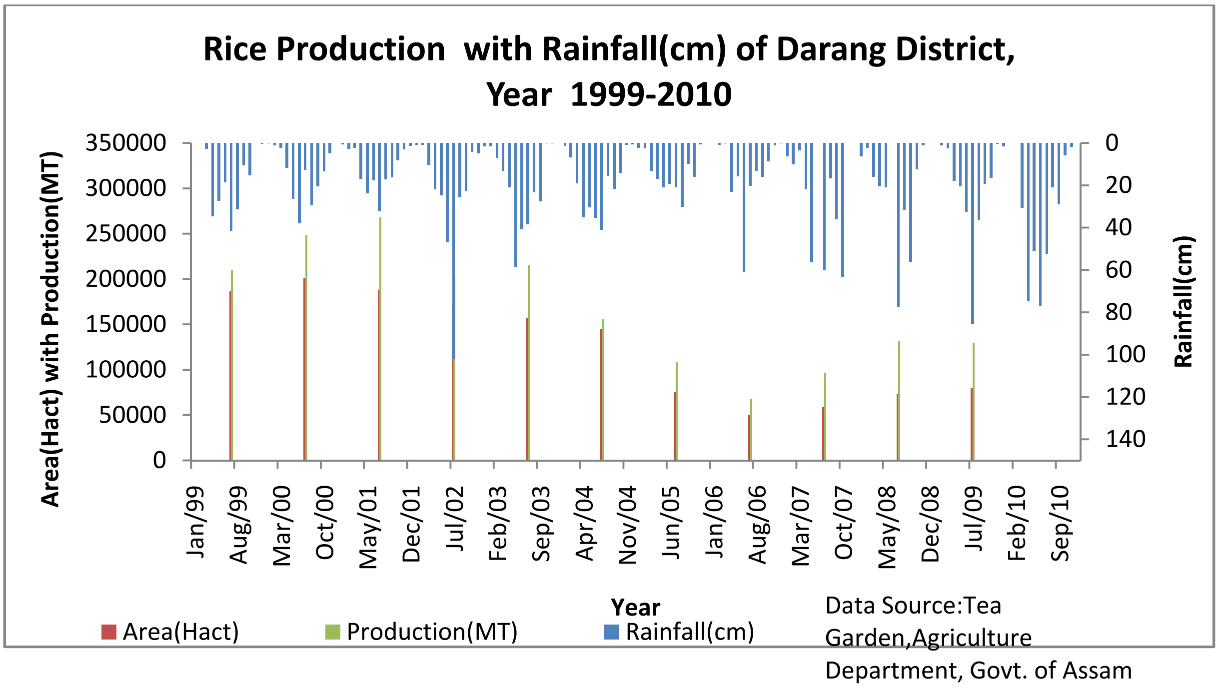

Fig.3.12 Rice Production with Rainfall(cm) of Darang District, Year 1999-2010

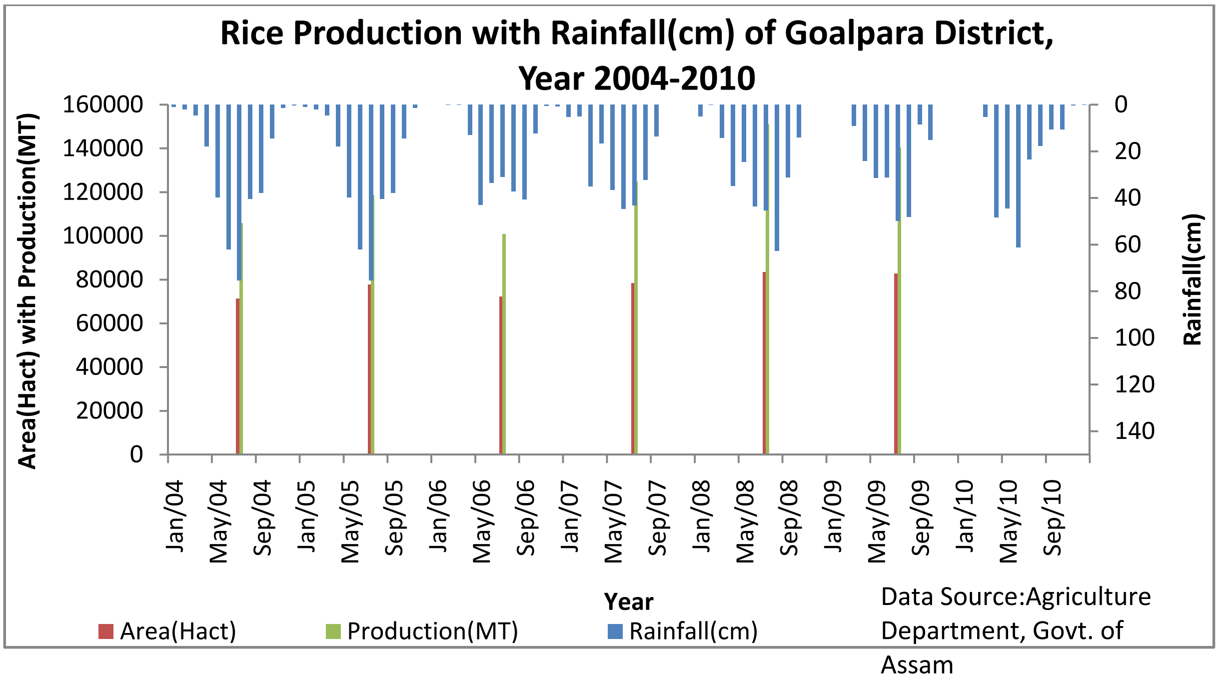

Fig.3.13 Rice Production with Rainfall(cm) of Goalpara District, Year 2004-2010

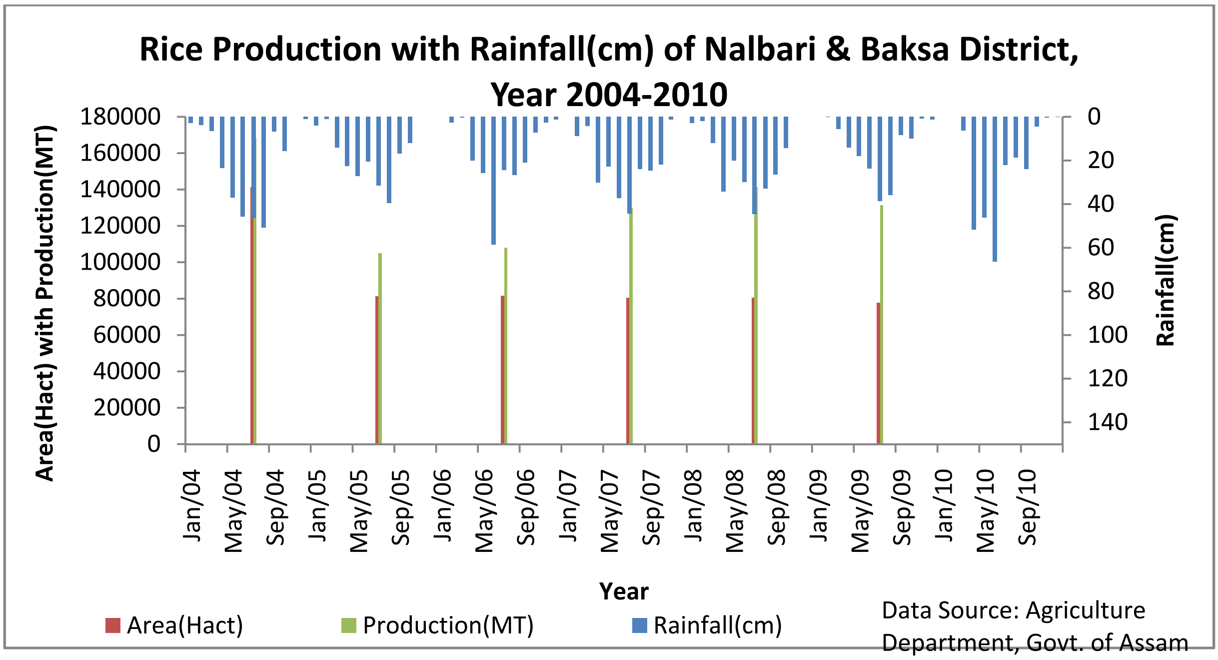

Fig.3.14 Rice Production with Rainfall(cm) of Nalbari & Baksa District, Year 2004-2010

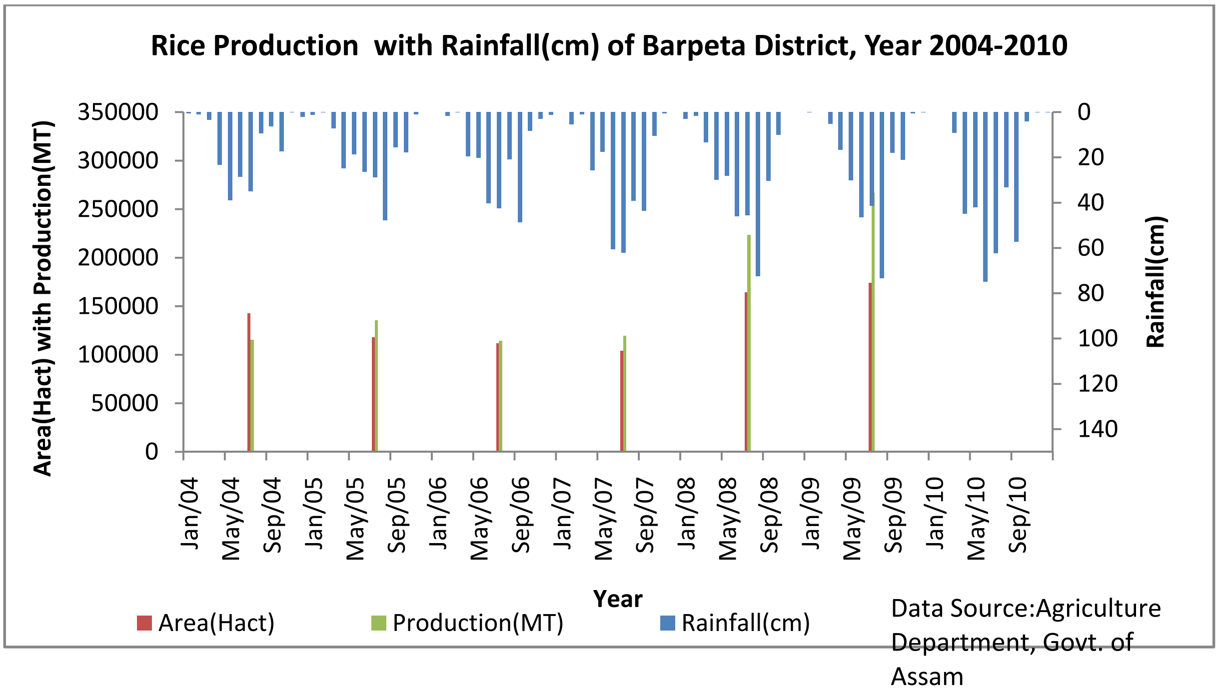

Fig 3.15 Rice Production with Rainfall(cm) of Barpeta District, Year 2004-2010

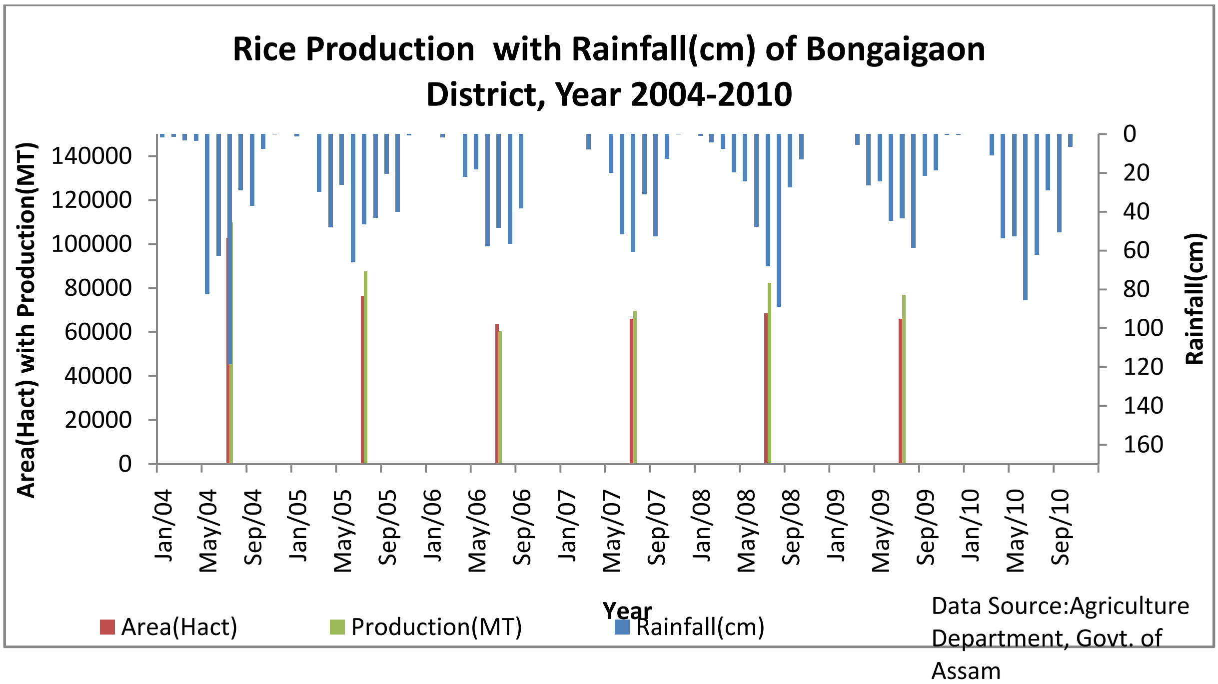

Fig 3.16 Rice Production with Rainfall(cm) of Bongaigaon District, Year 2004-2010

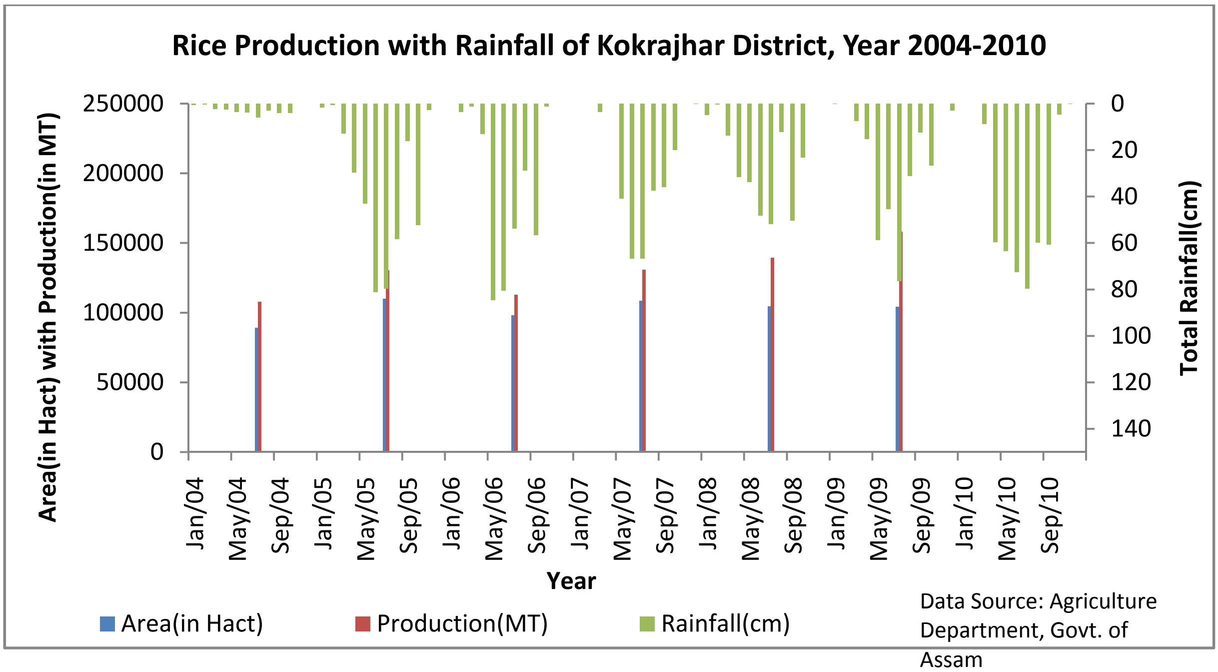

Fig.3.17 Rice Production with Rainfall of Kokrajhar District, Year 2004-2010

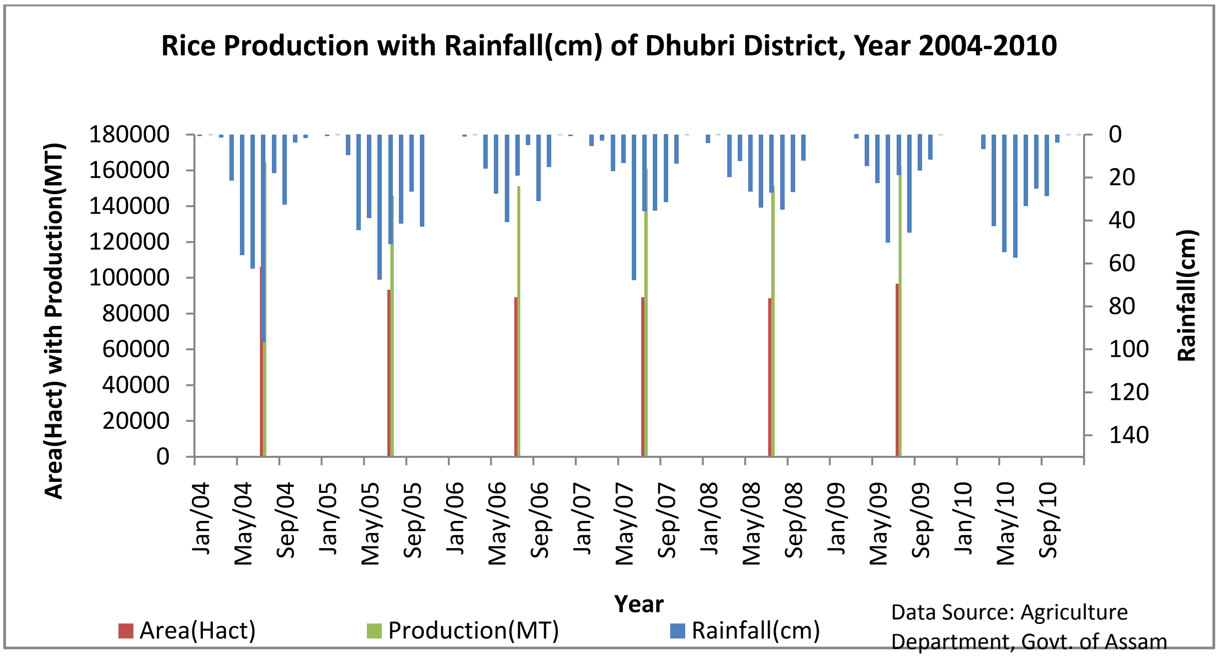

Fig.3.18 Rice Production with Rainfall(cm) of Dhubri District, Year 2004-2010

3.2.2 Relation between precipitation and wheat production

The Following graphs (Fig. 3.19 through Fig. 3.35) show the relationship between precipitation and Wheat cultivation in different district of Assam

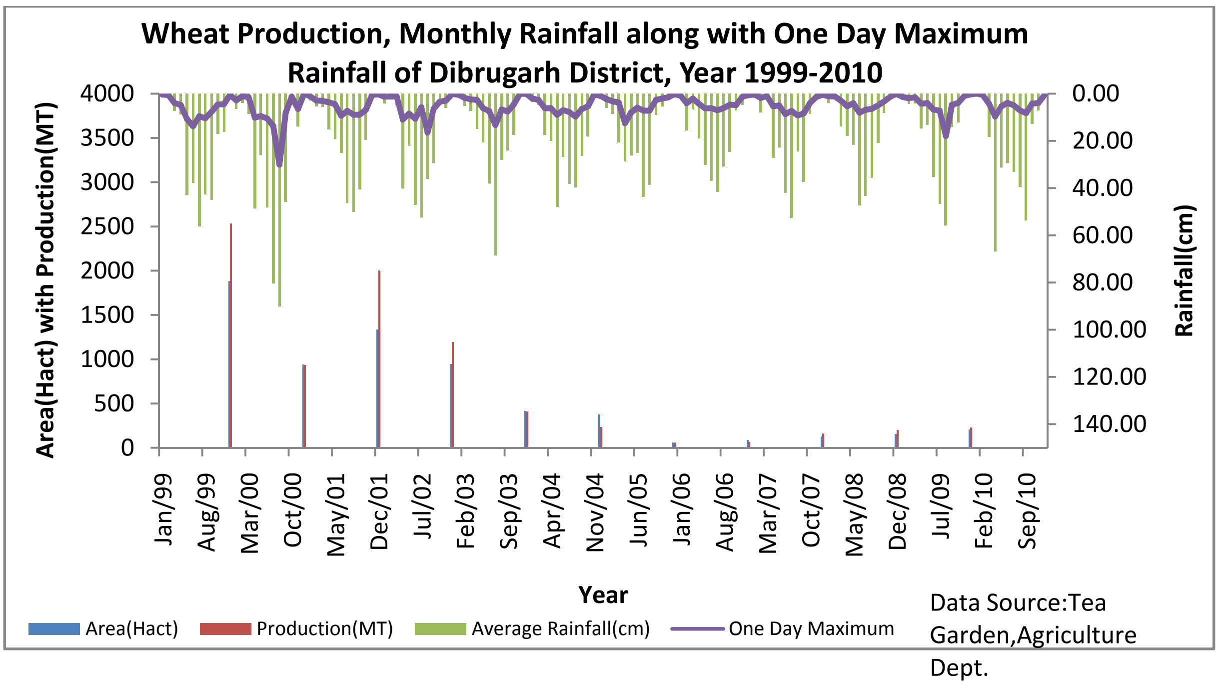

Fig 3.19 Wheat Production, Monthly Rainfall along with One Day Maximum Rainfall of Dibrugarh District, Year 1999-2010

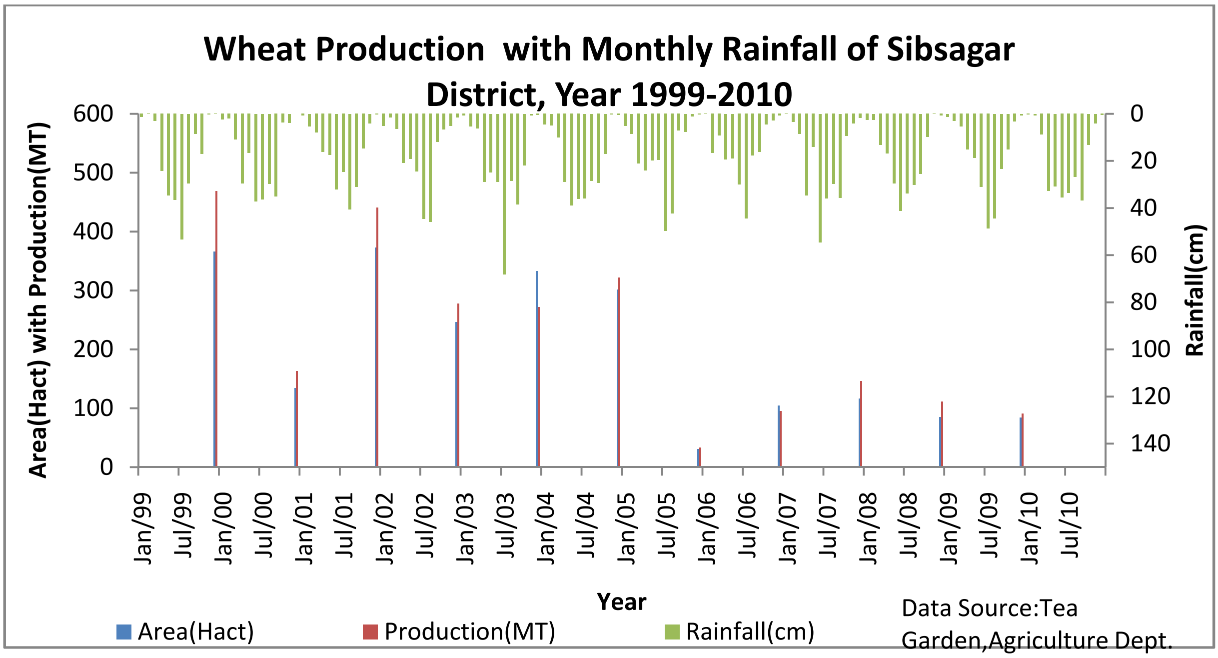

Fig.3.20 Wheat Production with Monthly Rainfall of Sibsagar District, Year 1999-2010

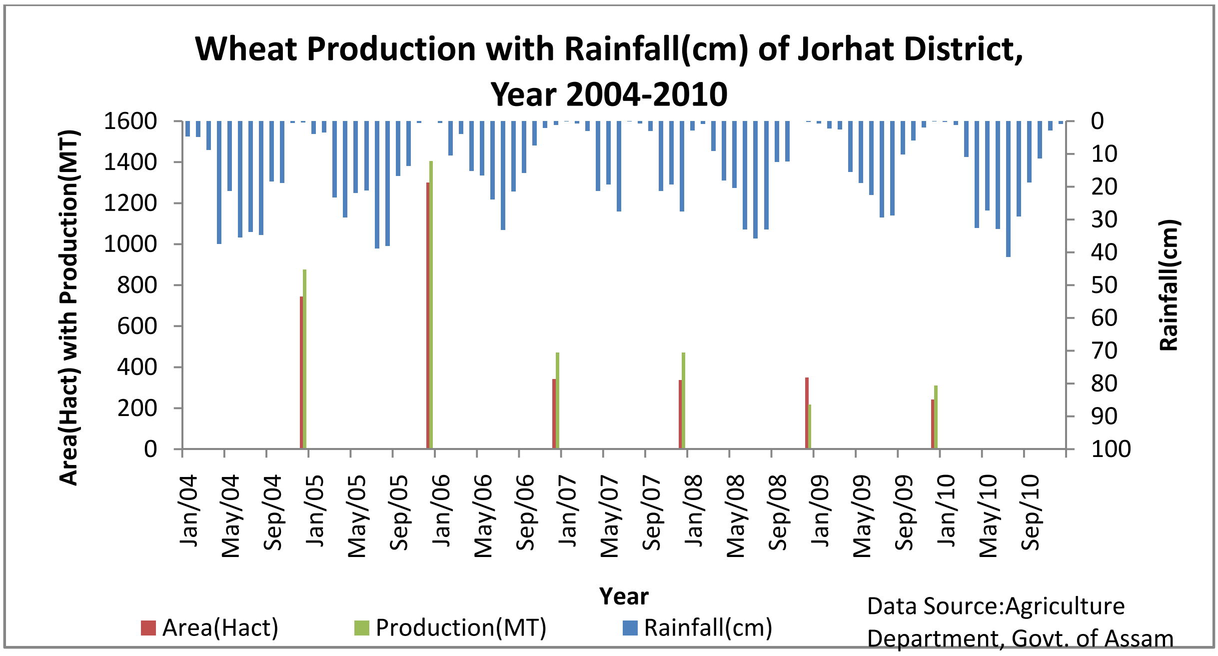

Fig.3.21 Wheat Production with Rainfall(cm) of Jorhat District, Year 2004-2010

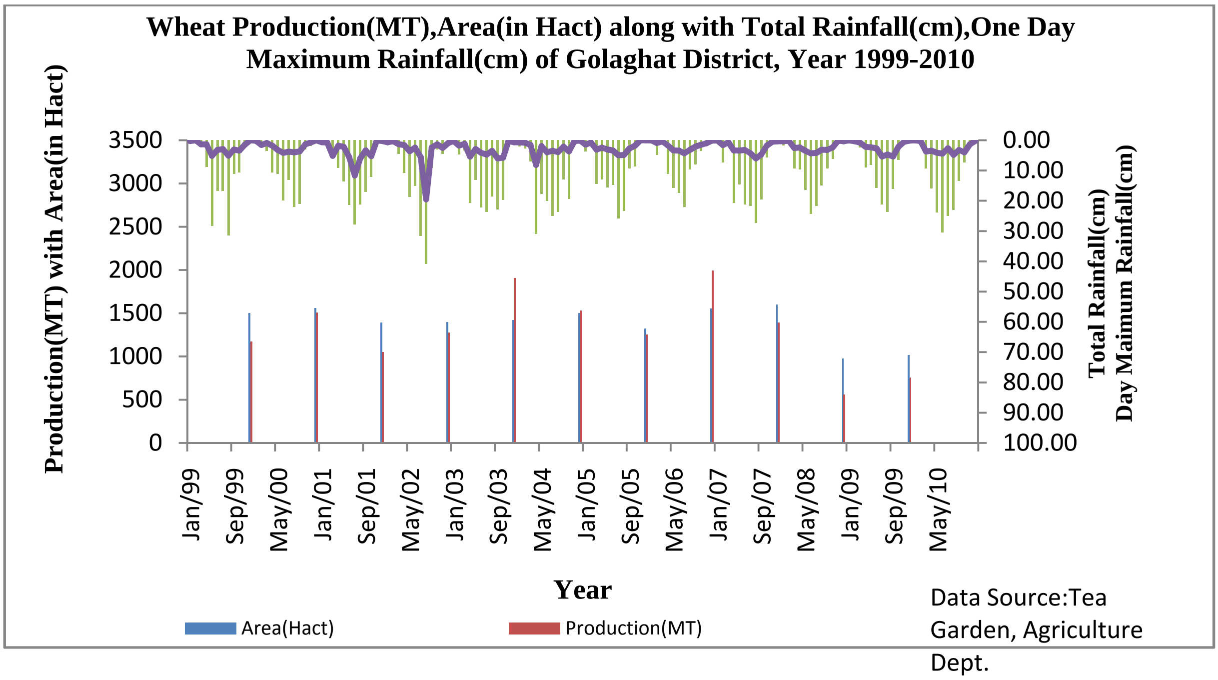

Fig.3.22 Wheat Production(MT),Area(in Hact) along with Total Rainfall(cm),One Day Maximum Rainfall(cm) of Golaghat District, Year 1999-2010

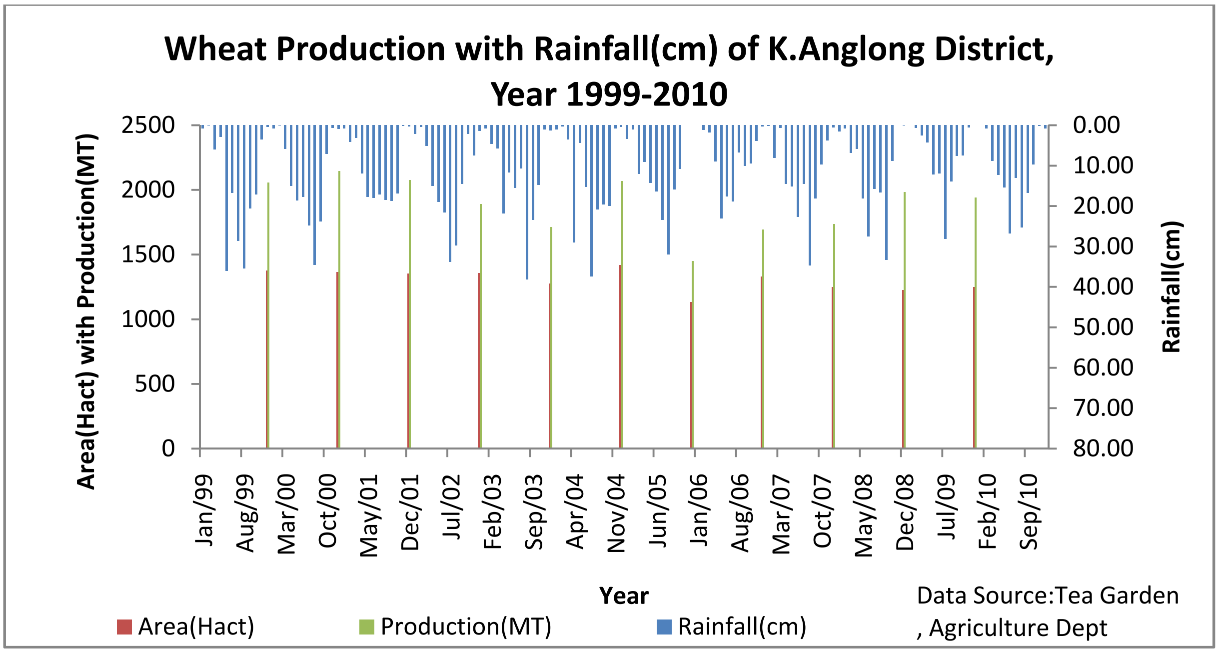

Fig.3.23 Wheat Production with Rainfall (cm) of K.Anglong District, Year 1999-2010

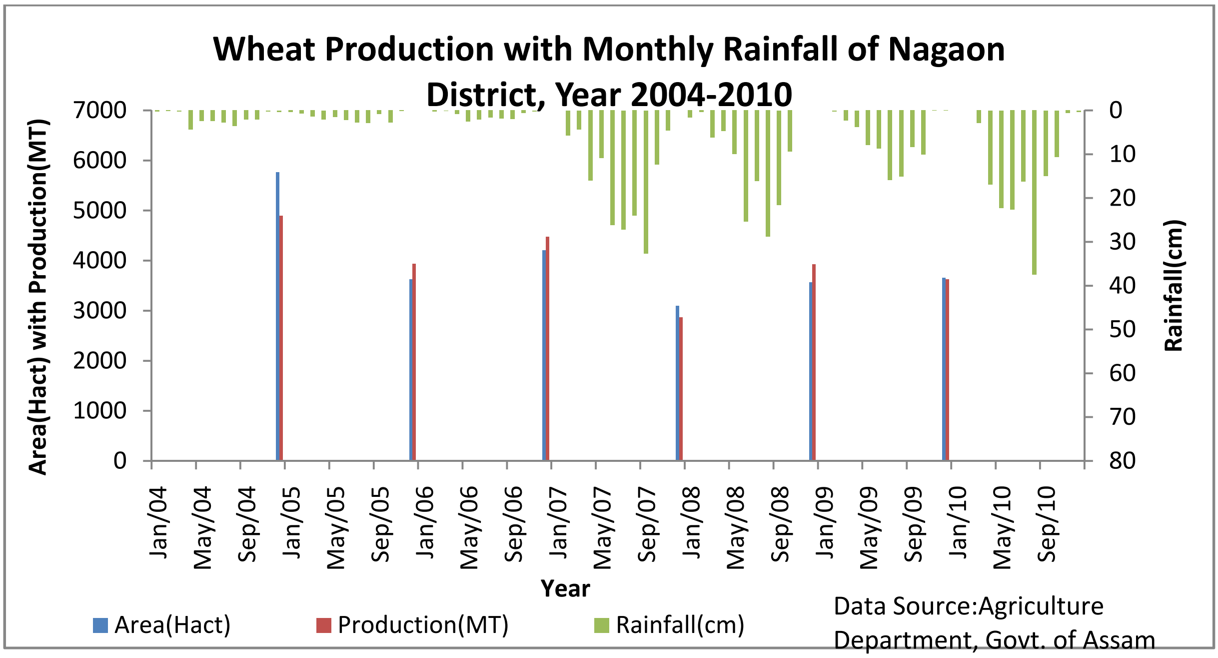

Fig.3.24 Wheat Production with Monthly Rainfall of Nagaon District, Year 2004-2010

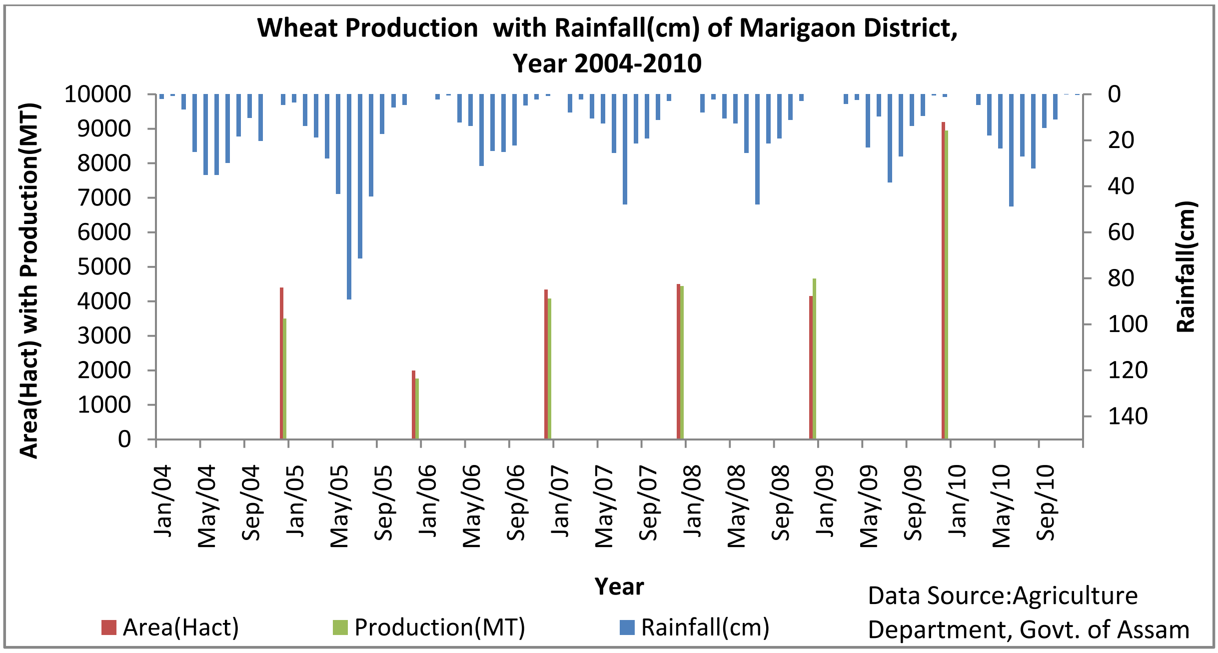

Fig. 3.25 Wheat Production with Rainfall (cm) of Marigaon District, Year 2004-2010

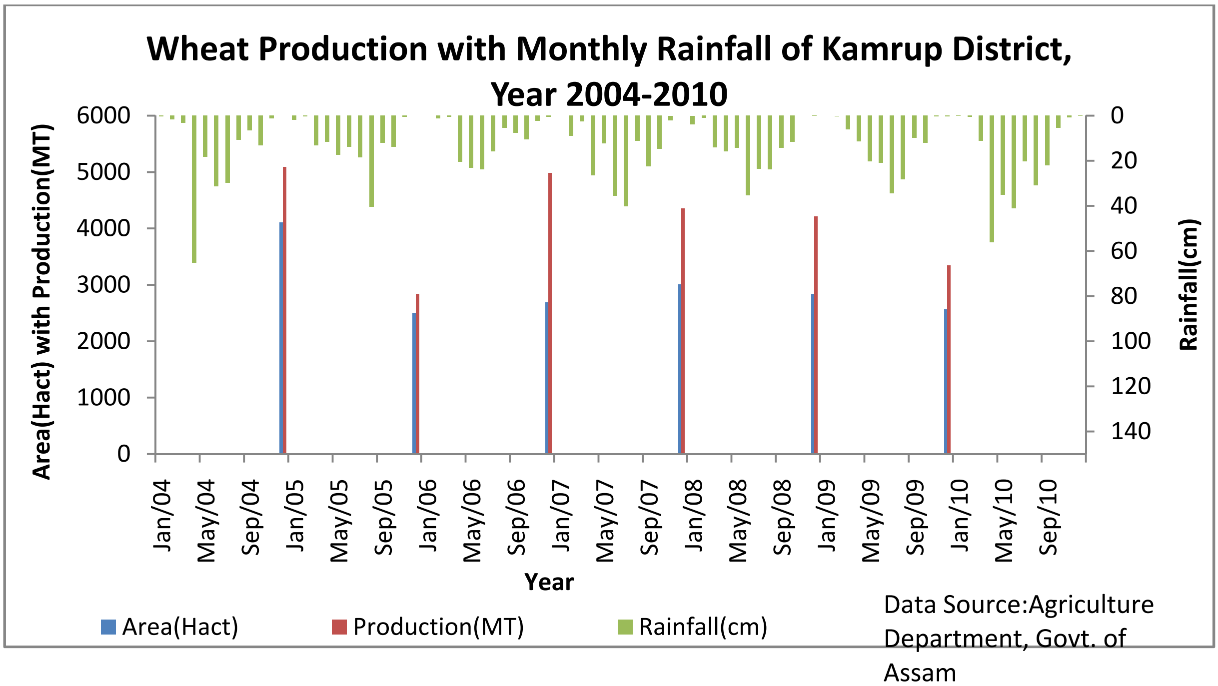

Fig. 3.26 Wheat Production with Monthly Rainfall of Kamrup District, Year 2004-2010

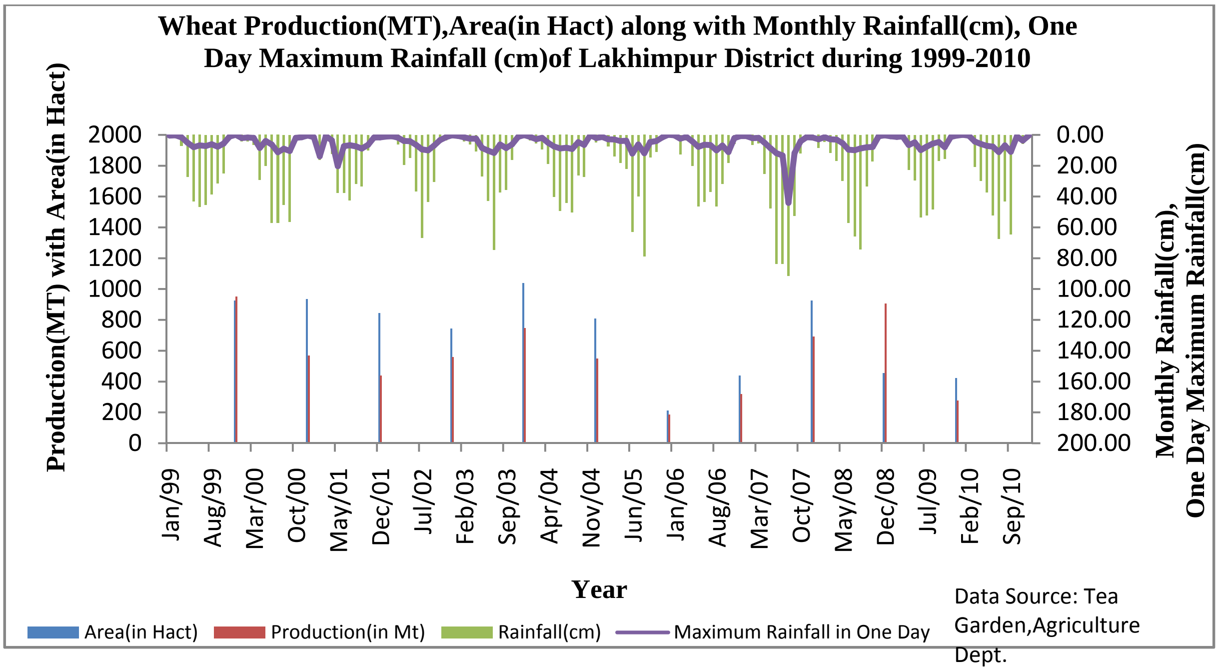

Fig. 3.27 Wheat Production (MT),Area(in Hact) along with Monthly Rainfall(cm), One Day Maximum Rainfall (cm)of Lakhimpur District during 1999-2010

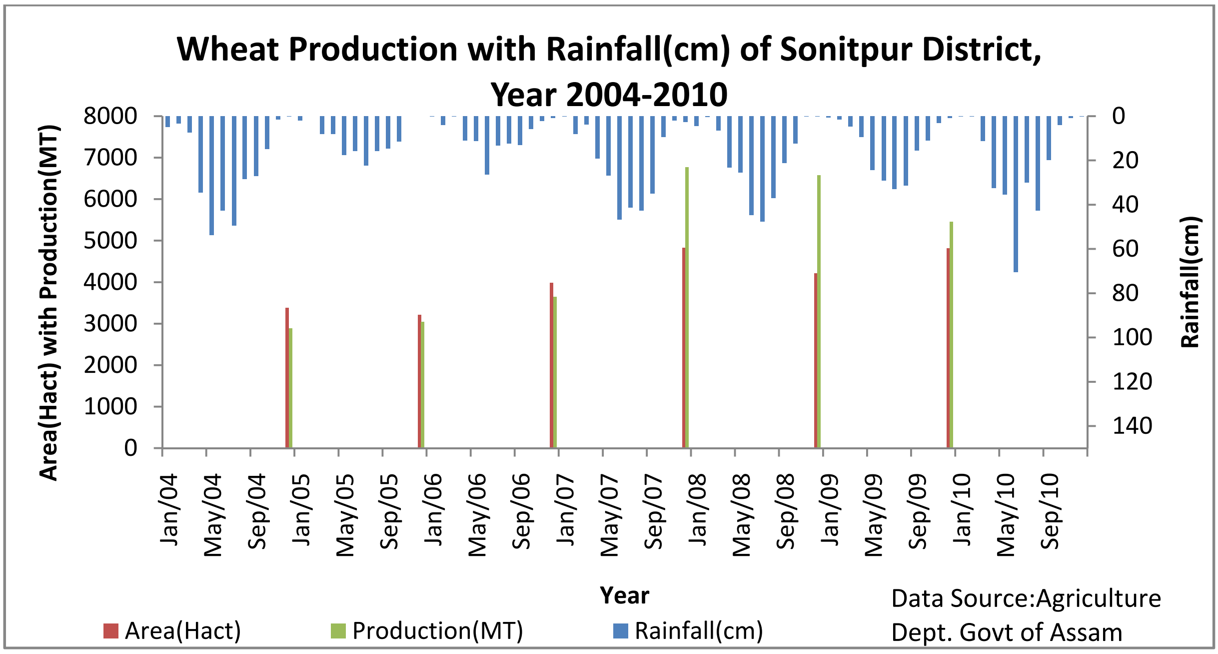

Fig. 3.28 Wheat Production with Rainfall(cm) of Sonitpur District, Year 2004-2010

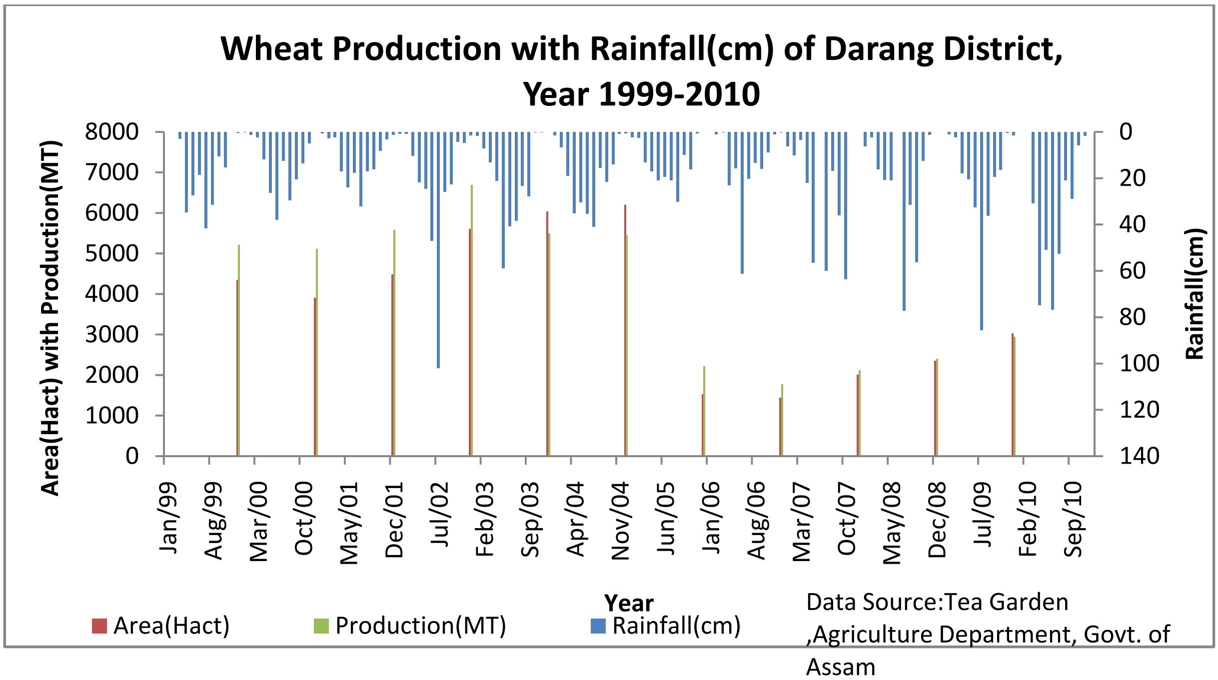

Fig. 3.29 Wheat Production with Rainfall(cm) of Darang District, Year 1999-2010

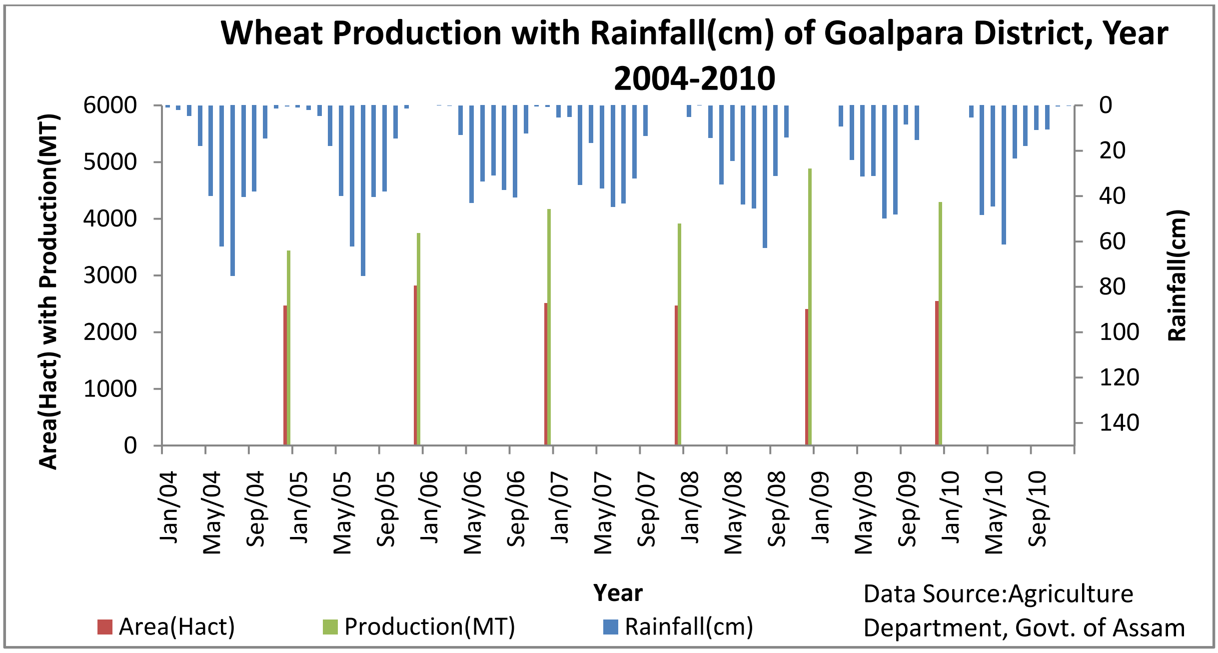

Fig. 3.30 Wheat Production with Rainfall(cm) of Goalpara District, Year 2004-2010

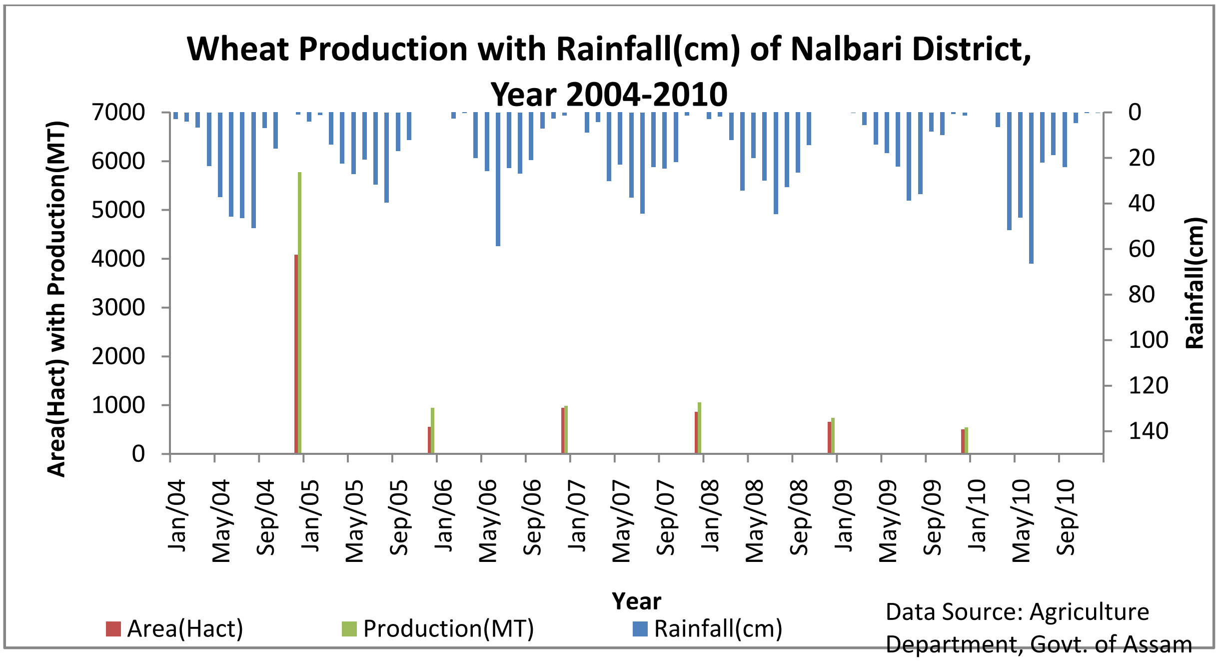

Fig. 3.31 Wheat Production with Rainfall(cm) of Nalbari District, Year 2004-2010

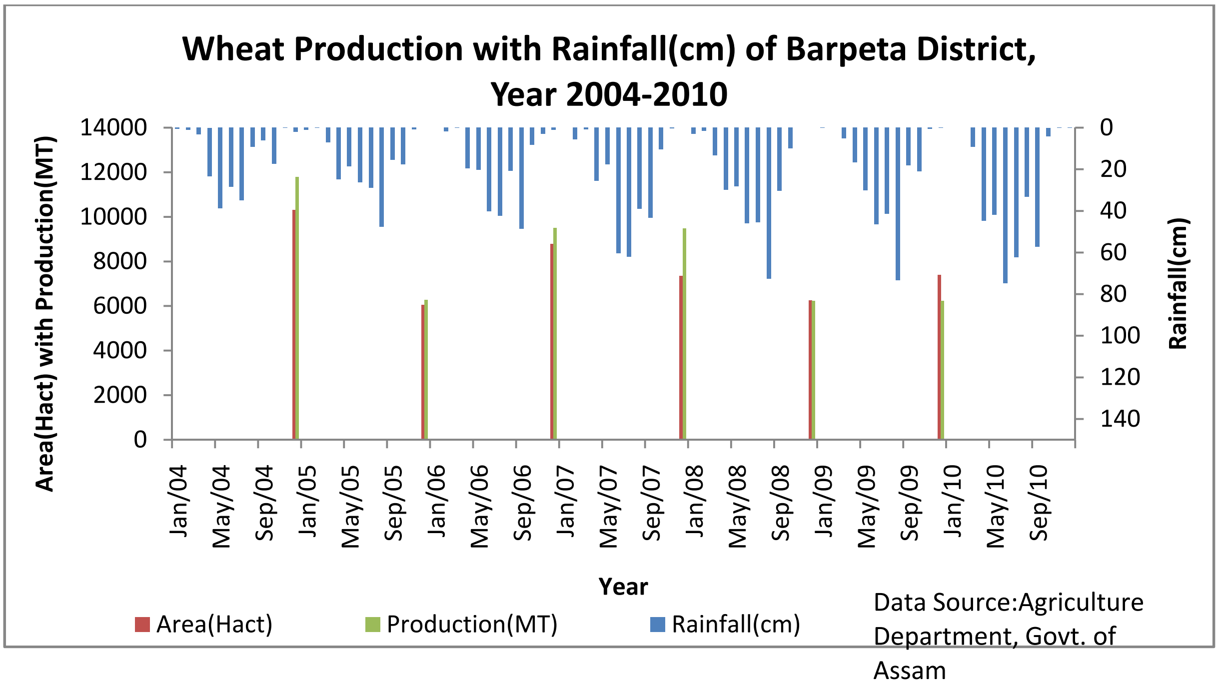

Fig. 3.32 Wheat Production with Rainfall(cm) of Barpeta District, Year 2004-2010

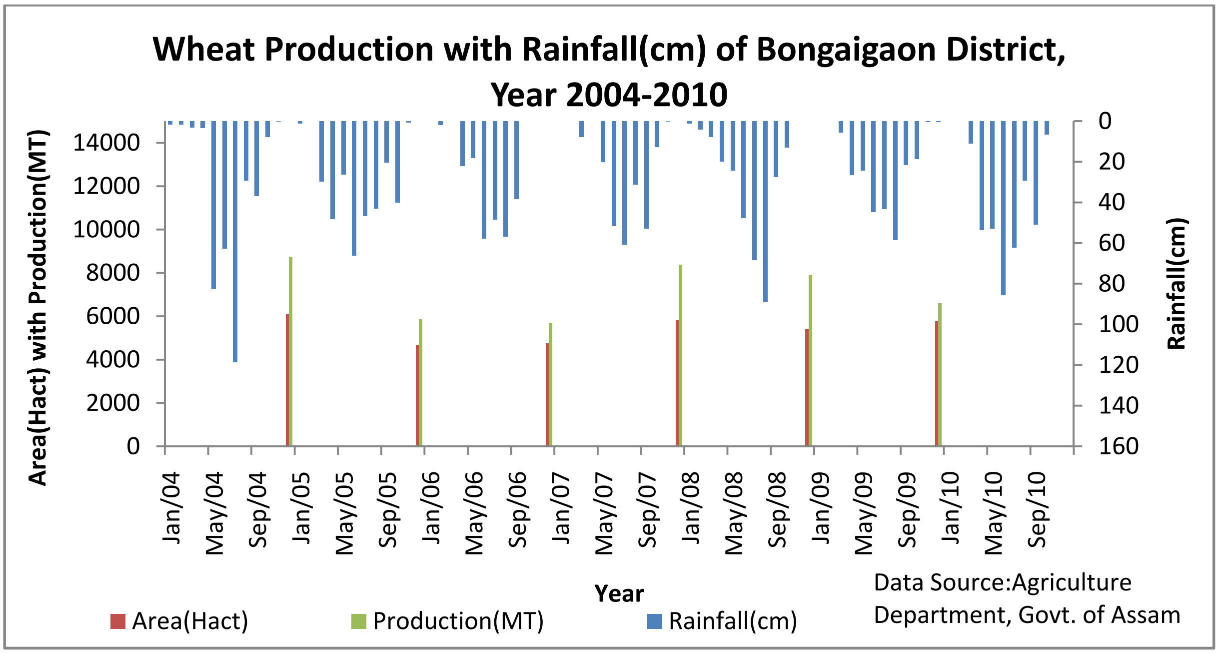

Fig. 3.33 Wheat Production with Rainfall(cm) of Bongaigaon District, Year 2004-2010

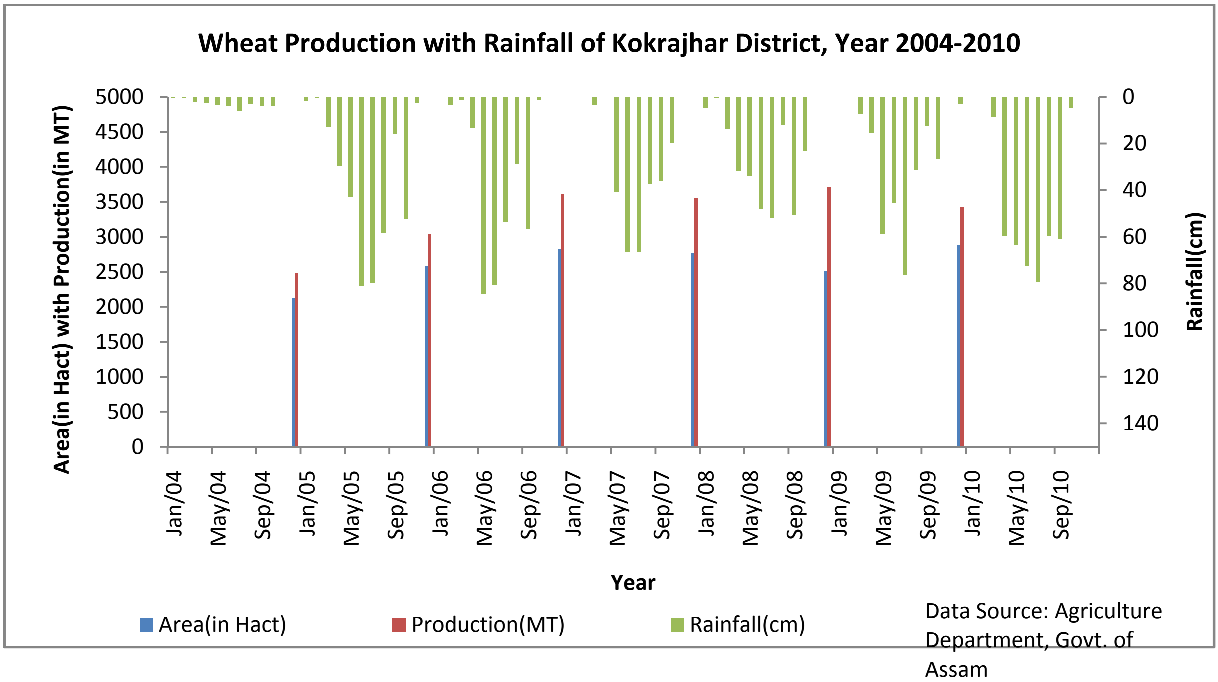

Fig. 3.34 Wheat Production with Rainfall of Kokrajhar District, Year 2004-2010

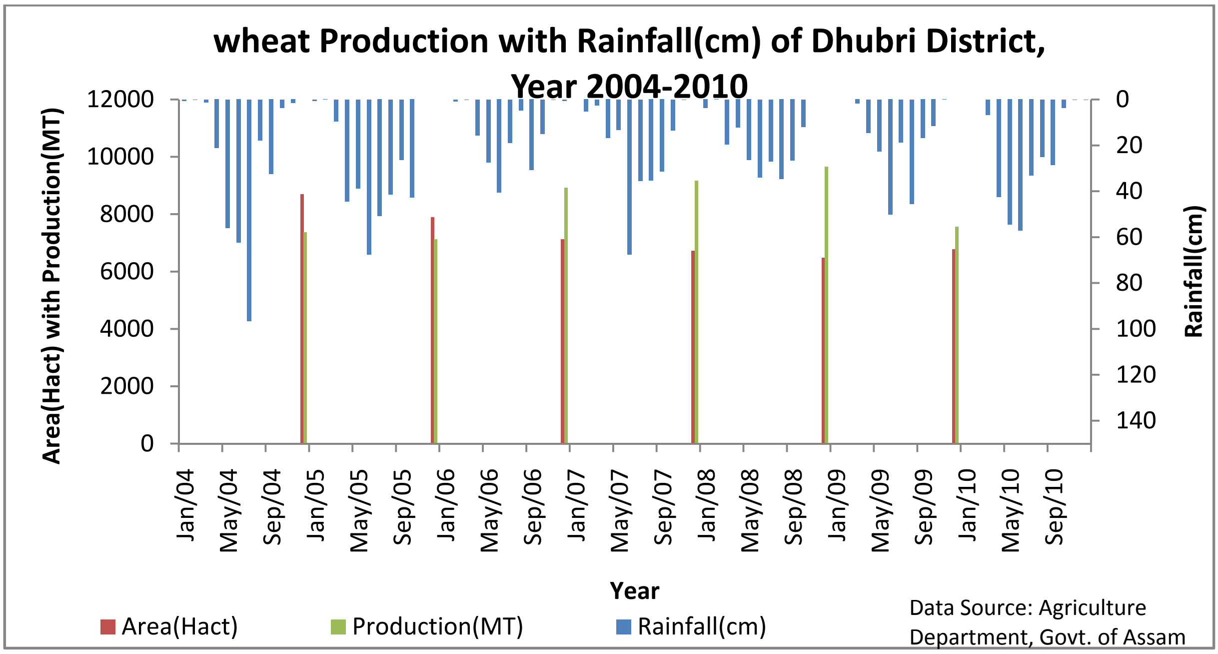

Fig. 3.35 wheat Production with Rainfall(cm) of Dhubri District, Year 2004-2010

3.2.3 Relation between precipitation and Jute production

The following graphs (Fig. 3.36 to fig. 3.53) shows the relation between the precipitation and Jute cultivation in Assam

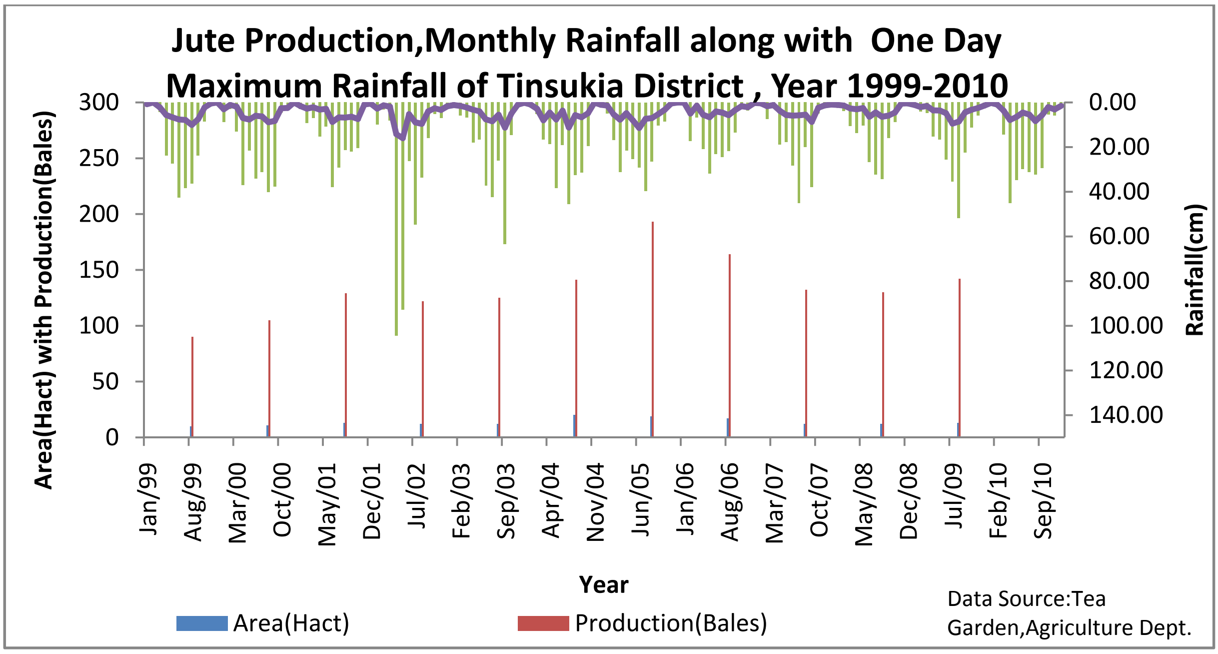

Fig. 3.36 Jute Production,Monthly Rainfall along with One Day Maximum Rainfall of Tinsukia District , Year 1999-2010

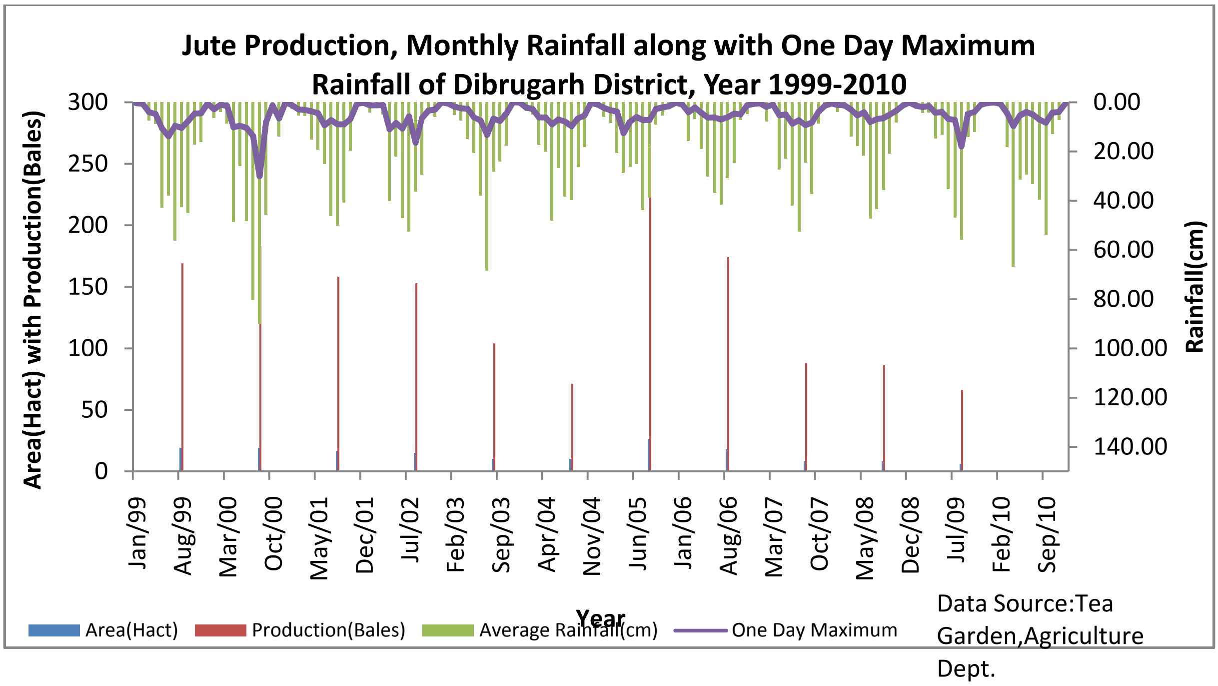

Fig. 3.37 Jute Production, Monthly Rainfall along with One Day Maximum Rainfall of Dibrugarh District, Year 1999-2010

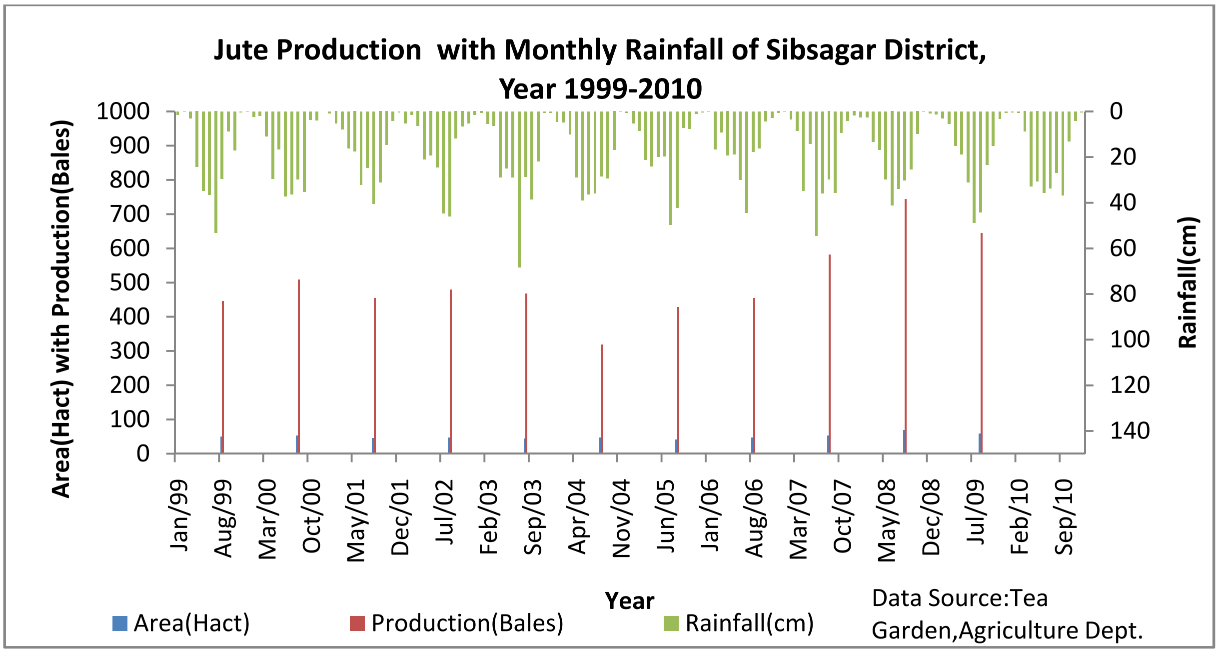

Fig. 3.38 Jute Production with Monthly Rainfall of Sibsagar District, Year 1999-2010

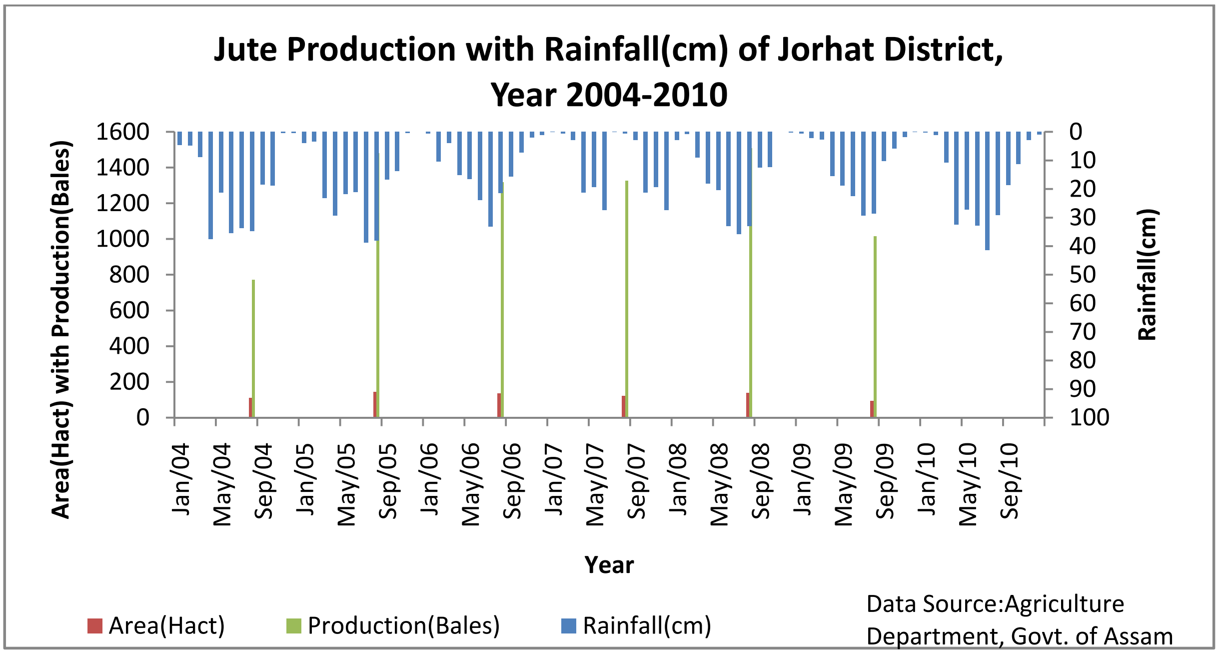

Fig.3.39 Jute Production with Rainfall(cm) of Jorhat District, Year 2004-2010

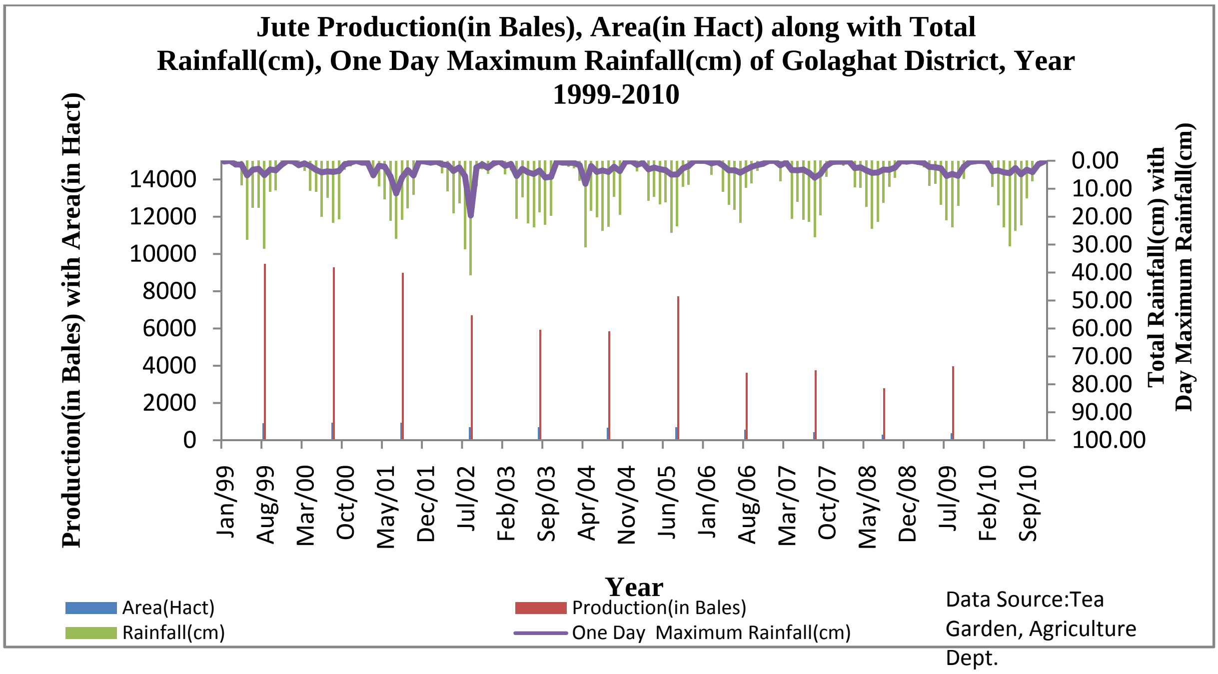

Fig. 3.40 Jute Production(in Bales), Area(in Hact) along with Total Rainfall(cm), One Day Maximum Rainfall(cm) of Golaghat District, Year 1999-2010

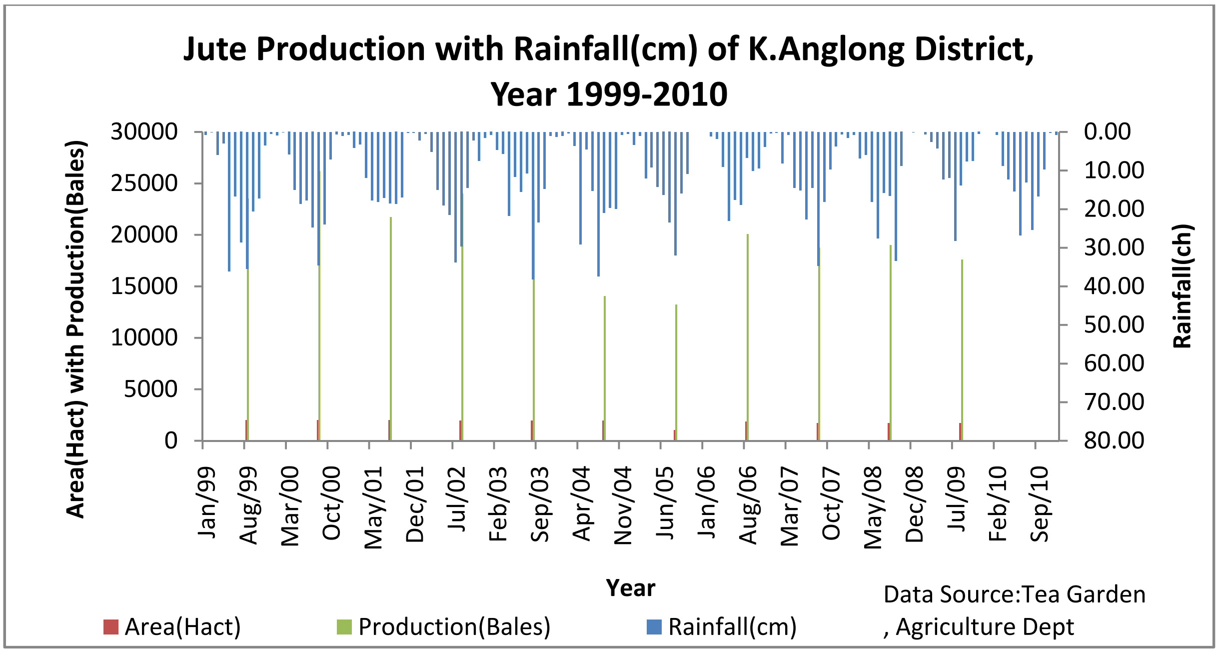

Fig. 3.41 Jute Production with Rainfall(cm) of K.Anglong District, Year 1999-2010

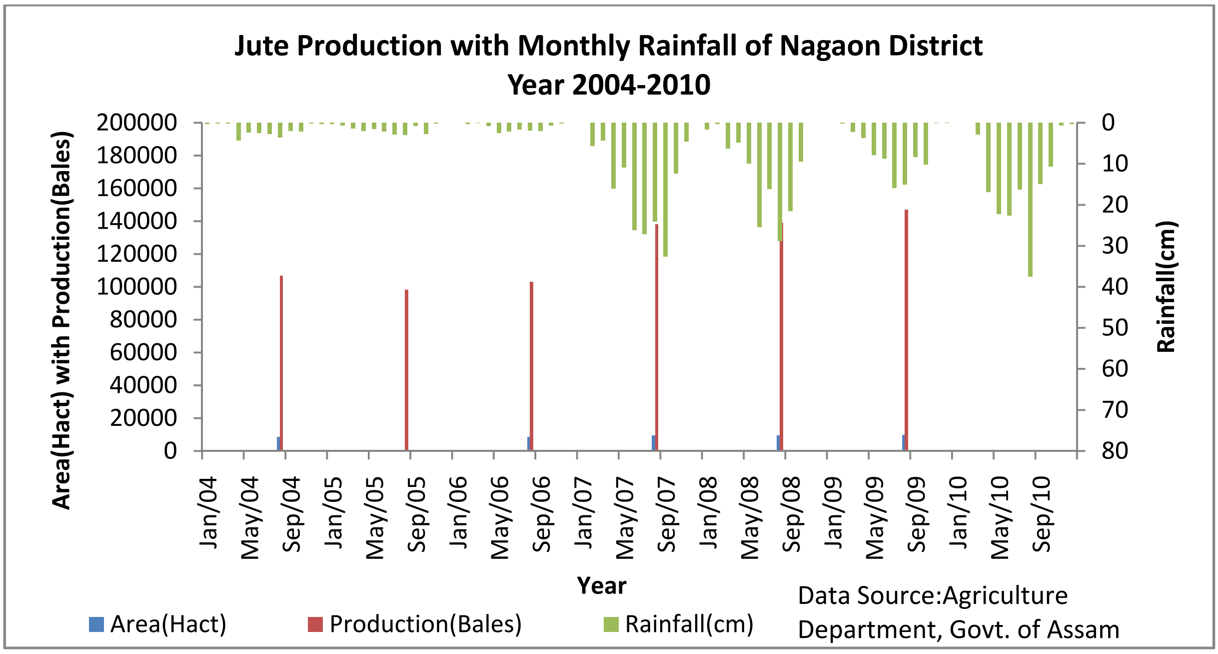

Fig. 3.42 Jute Production with Monthly Rainfall of Nagaon District Year 2004-2010

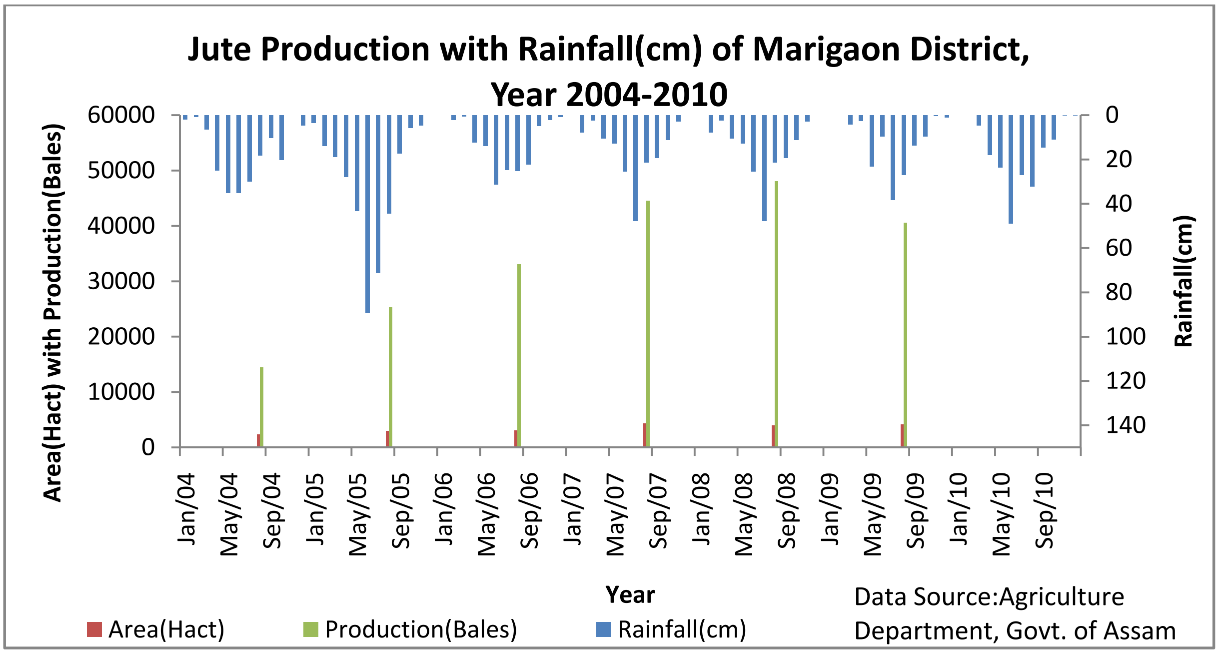

Fig. 3.43 Jute Production with Rainfall(cm) of Marigaon District, Year 2004-2010

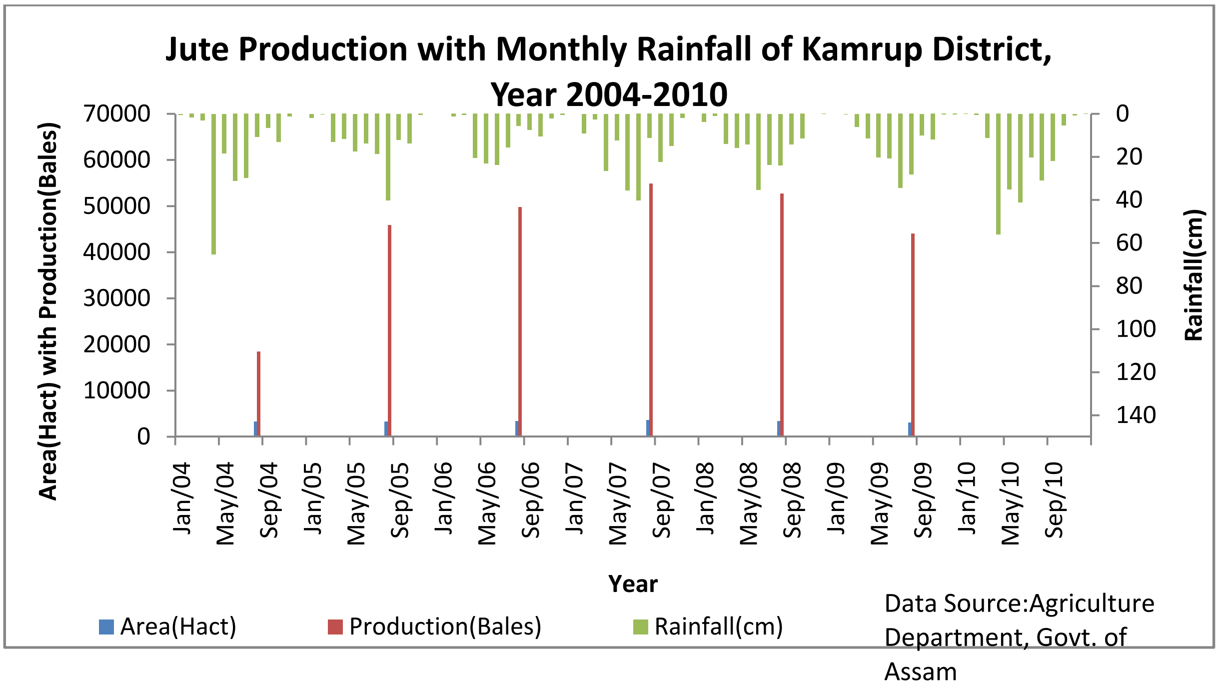

Fig. 3.44 Jute Production with Monthly Rainfall of Kamrup District, Year 2004-2010

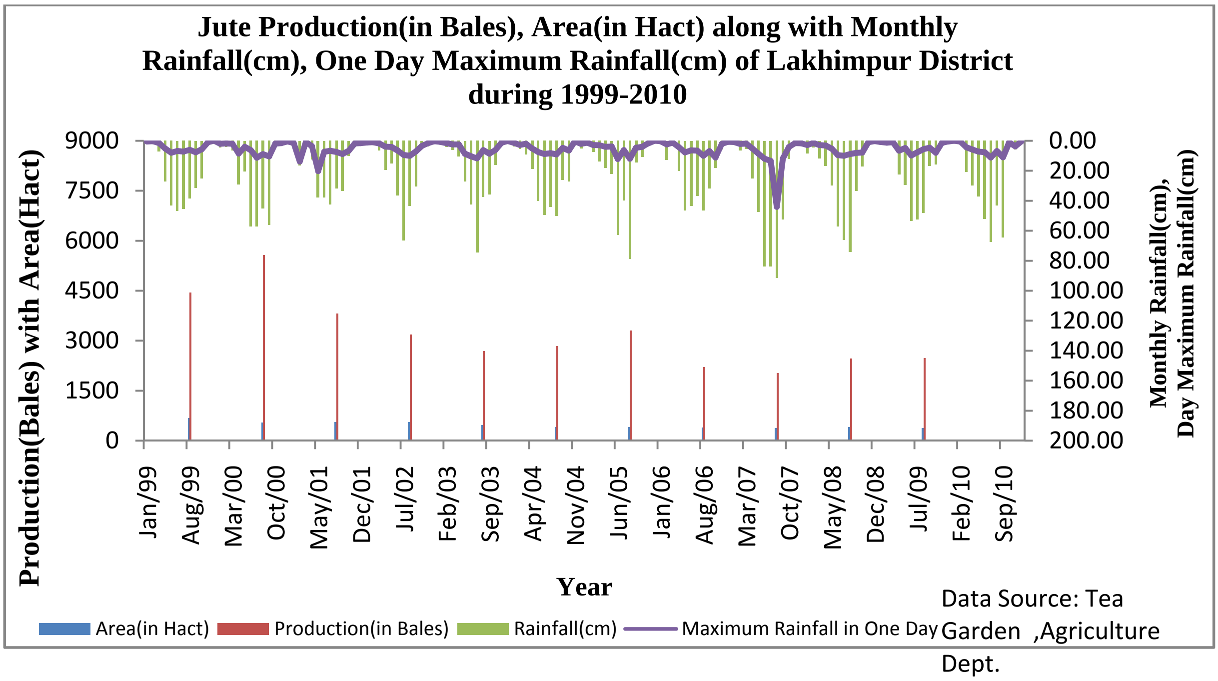

Fig. 3.45 Jute Production(in Bales), Area(in Hact) along with Monthly Rainfall(cm), One Day Maximum Rainfall(cm) of Lakhimpur District during 1999-2010

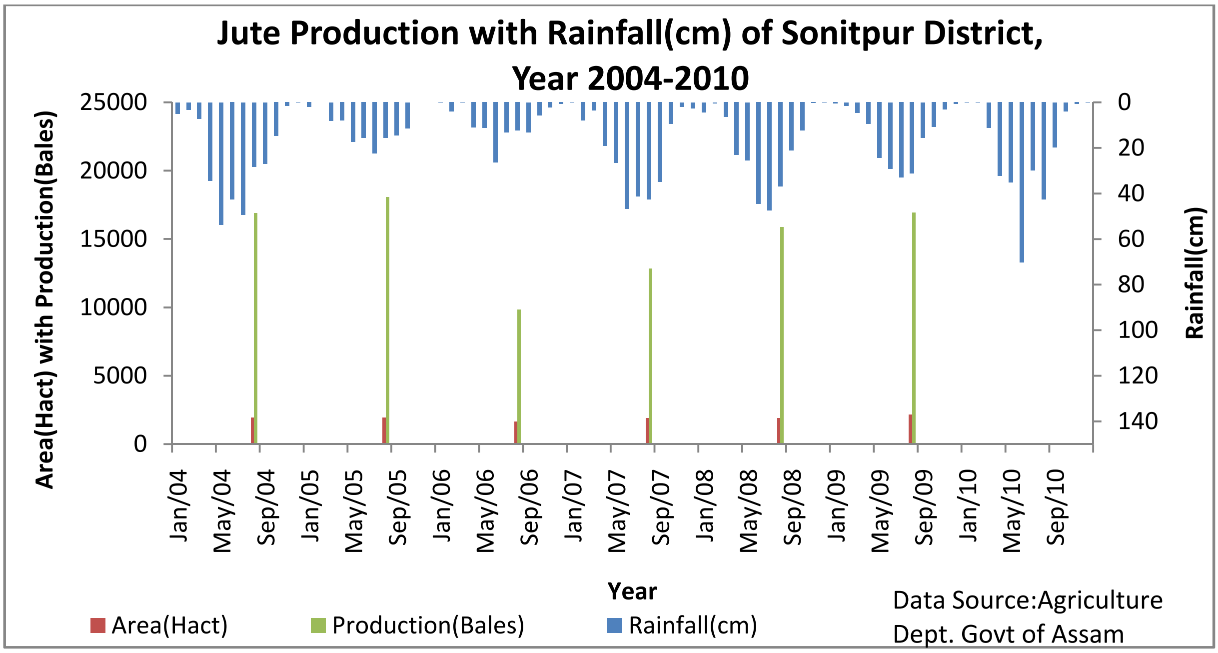

Fig. 3.46 Jute Production with Rainfall(cm) of Sonitpur District, Year 2004-2010

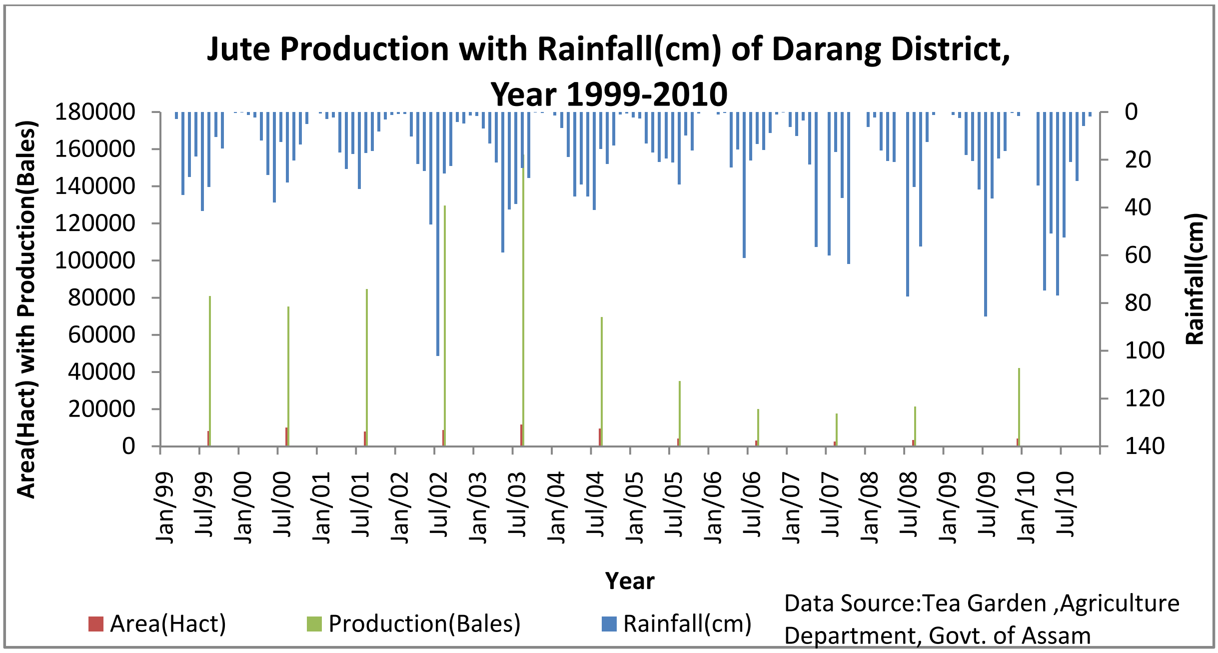

Fig. 3.47 Jute Production with Rainfall(cm) of Darang District, Year 1999-2010

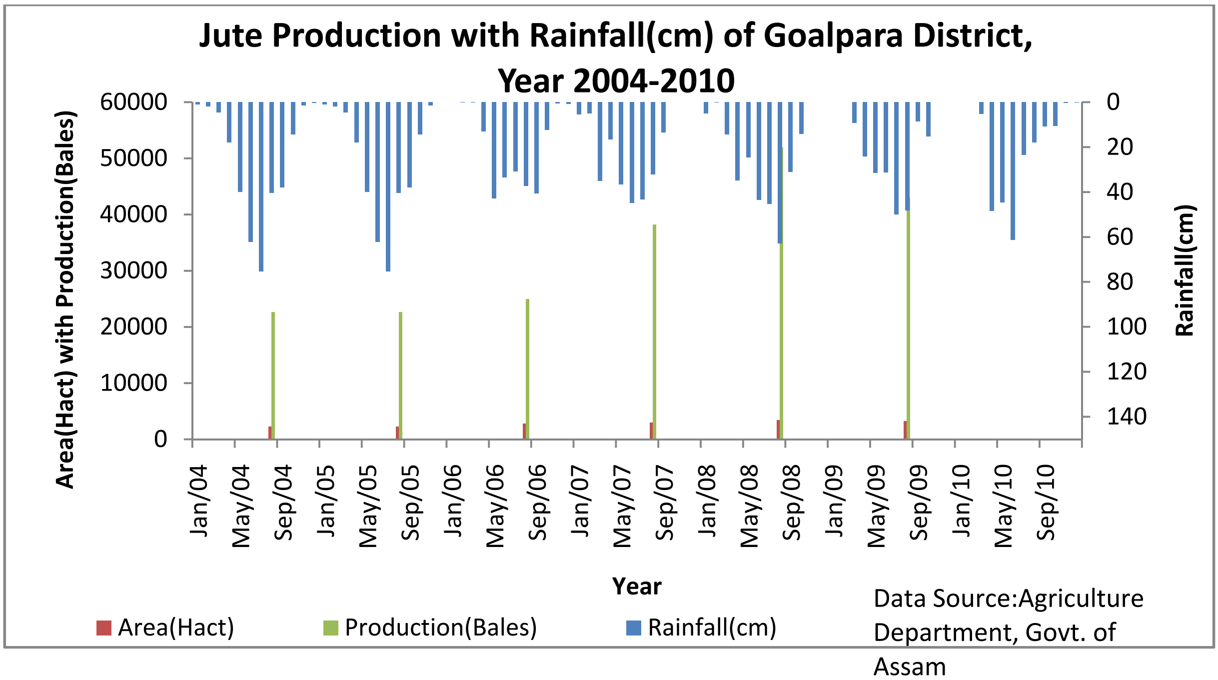

Fig. 3.48 Jute Production with Rainfall(cm) of Goalpara District, Year 2004-2010

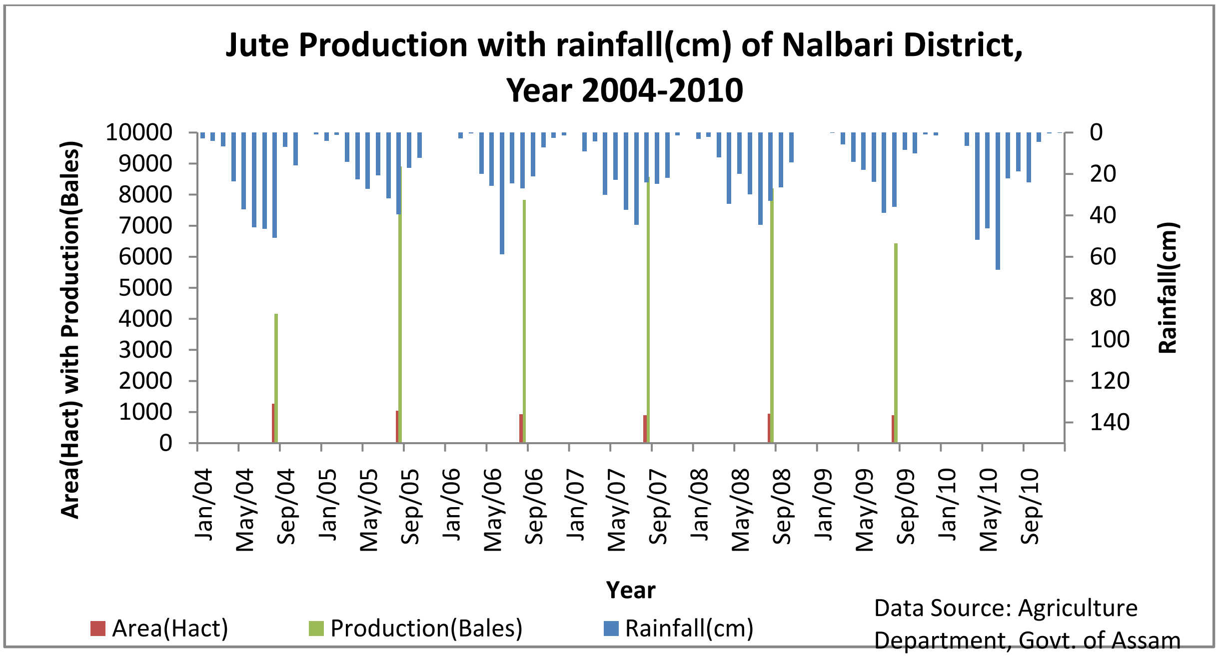

Fig. 3.49 Jute Production with rainfall (cm) of Nalbari District, Year 2004-2010

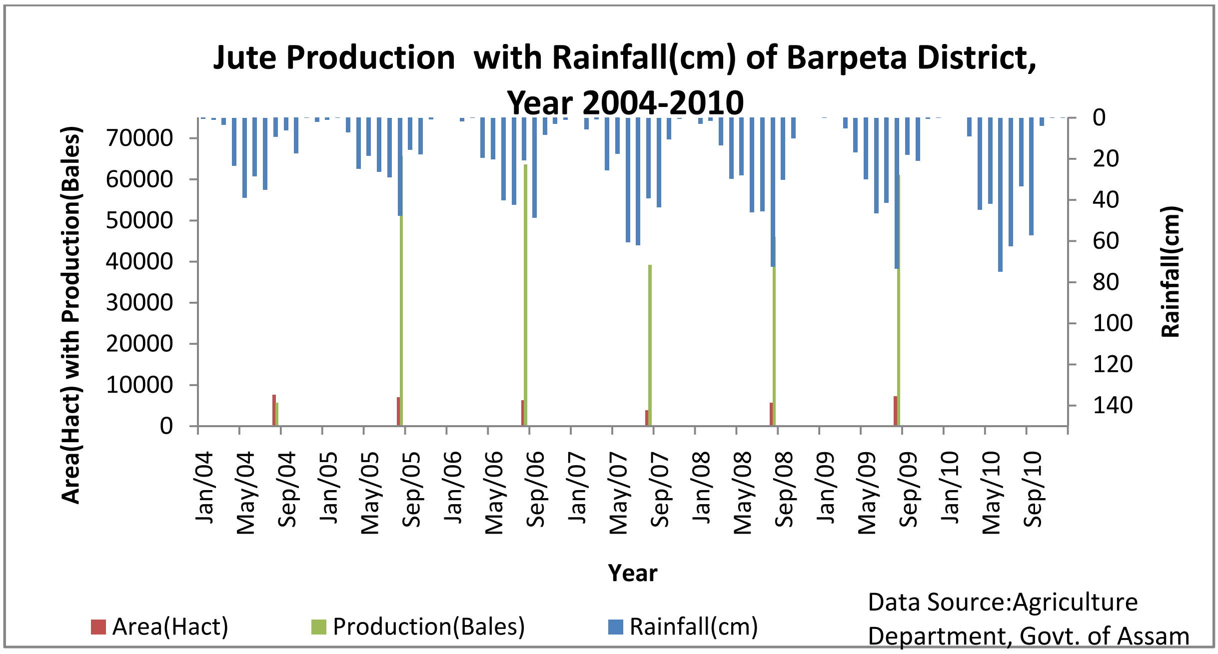

Fig 3.50 Jute Production with Rainfall(cm) of Barpeta District, Year 2004-2010

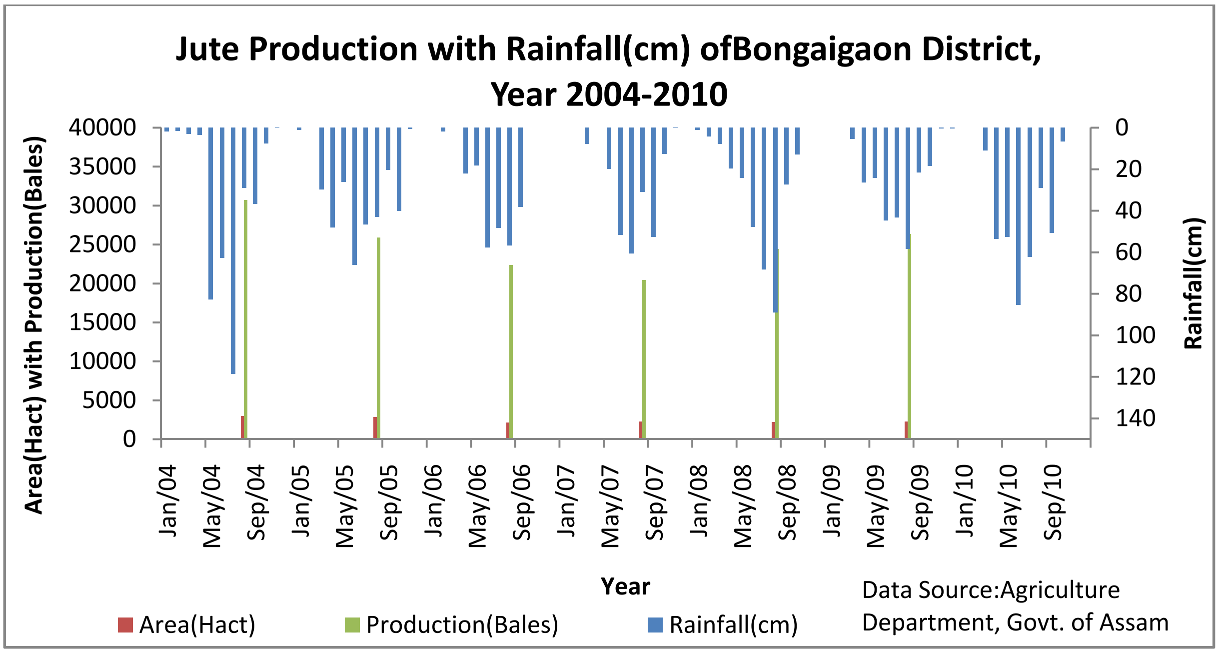

Fig 3.51 Jute Production with Rainfall(cm) ofBongaigaon District, Year 2004-2010

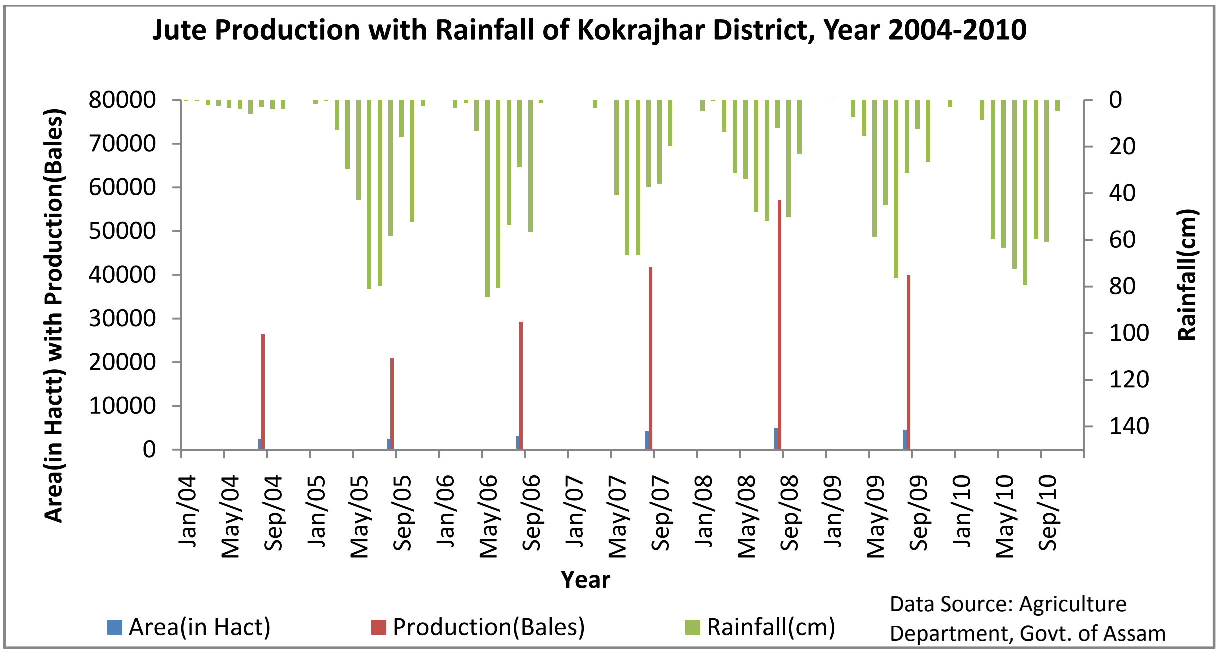

Fig. 3.52 Jute Production with Rainfall of Kokrajhar District, Year 2004-2010

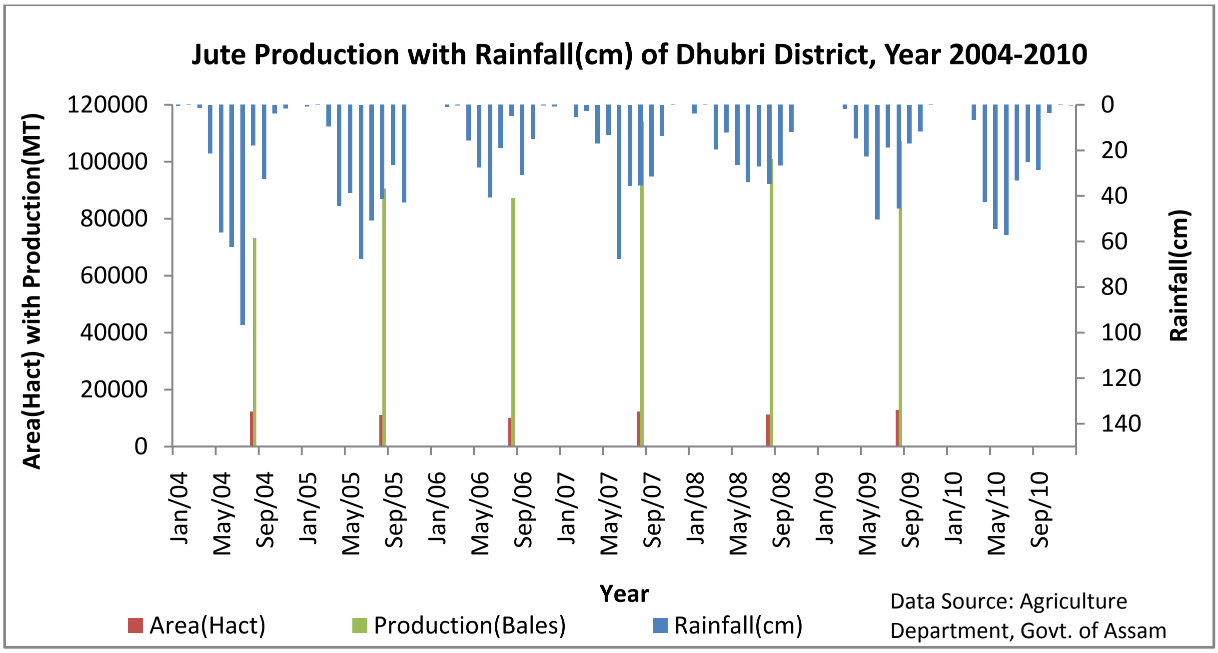

Fig. 3.53 Jute Production with Rainfall(cm) of Dhubri District, Year 2004-2010

3.2.4 Precipitation and Tea production

The production of Tea in various district are also analyzed with relation to rainfall and presented through figure 3.54 to fig 3.57

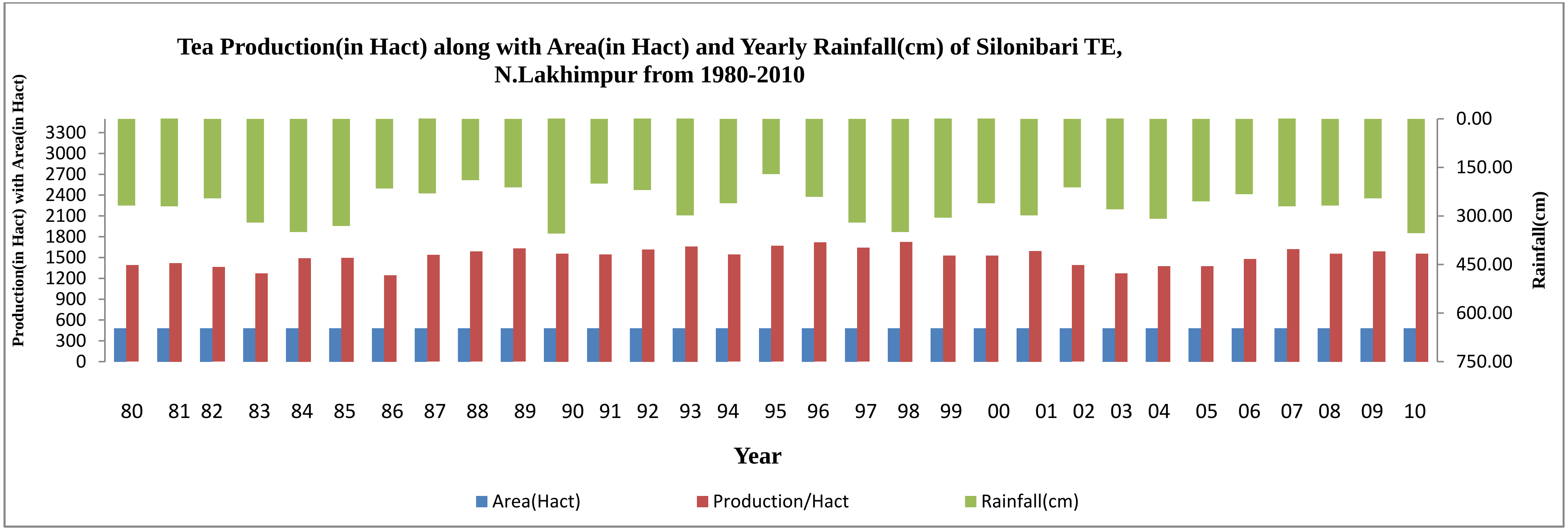

Fig. 3.54 Tea Production (in Hact) along with Area(in Hact) and Yearly Rainfall(cm) of Silonibari TE, N.Lakhimpur from 1980-2010

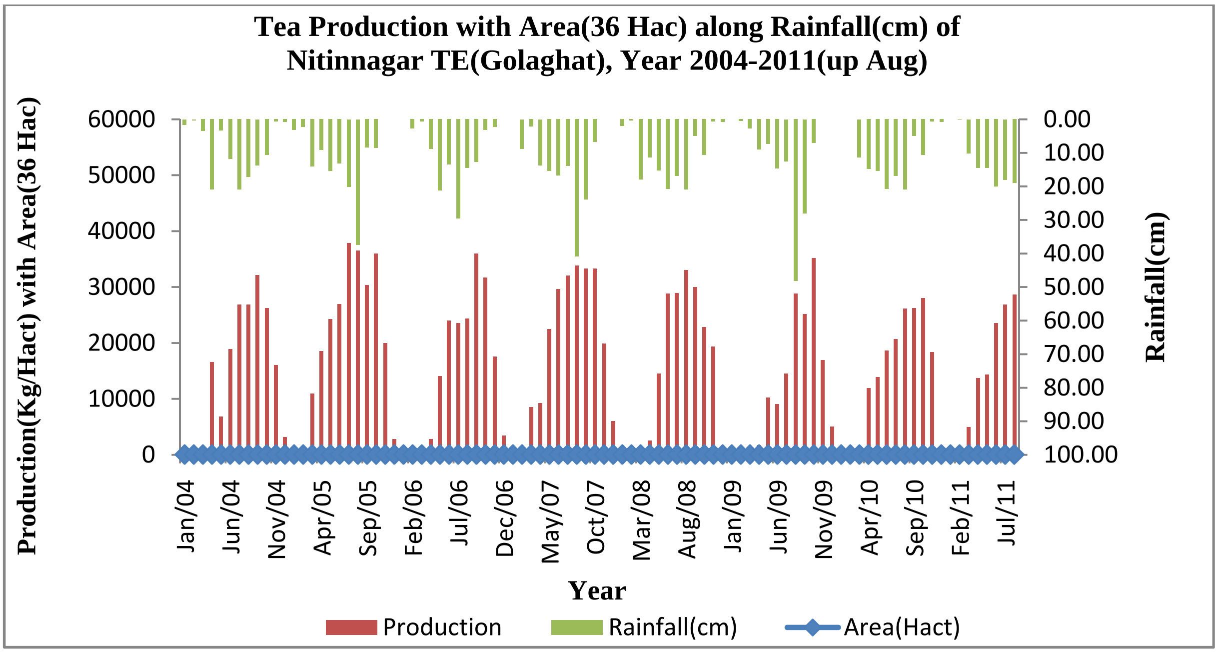

Fig. 3.55 Tea Production with Area(36 Hac) along Rainfall(cm) ofNitinnagar TE(Golaghat), Year 2004-2011(up Aug)

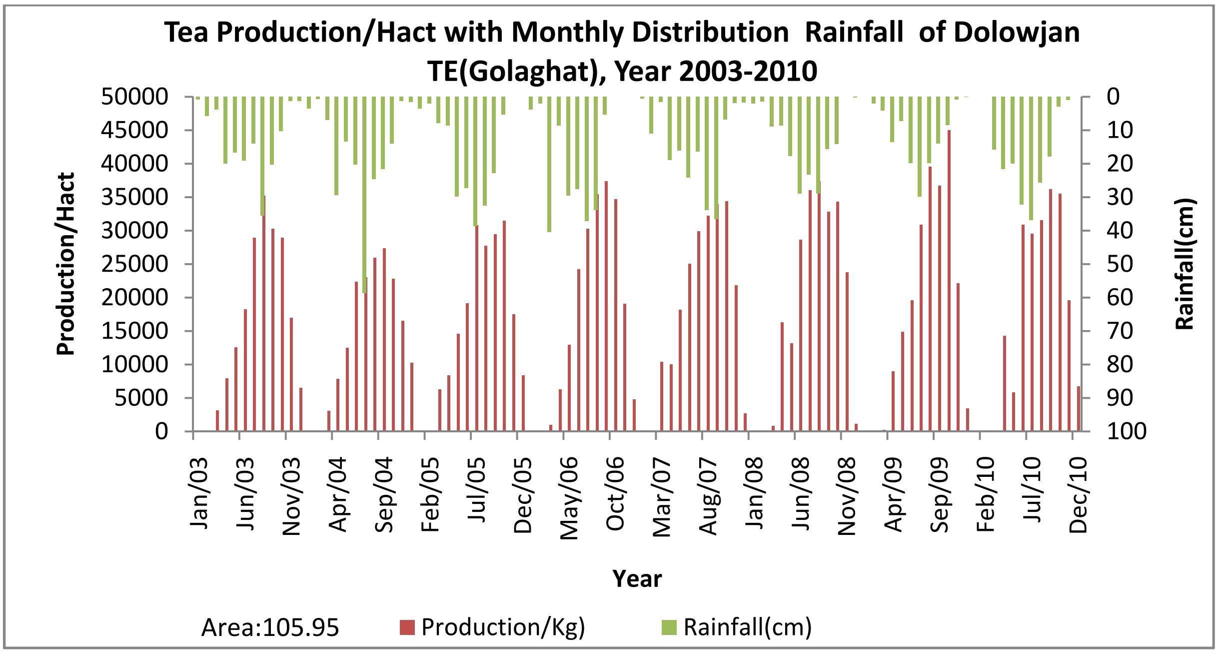

Fig. 3.56 Tea Production/Hact with Monthly Distribution Rainfall of Dolowjan TE(Golaghat), Year 2003-2010

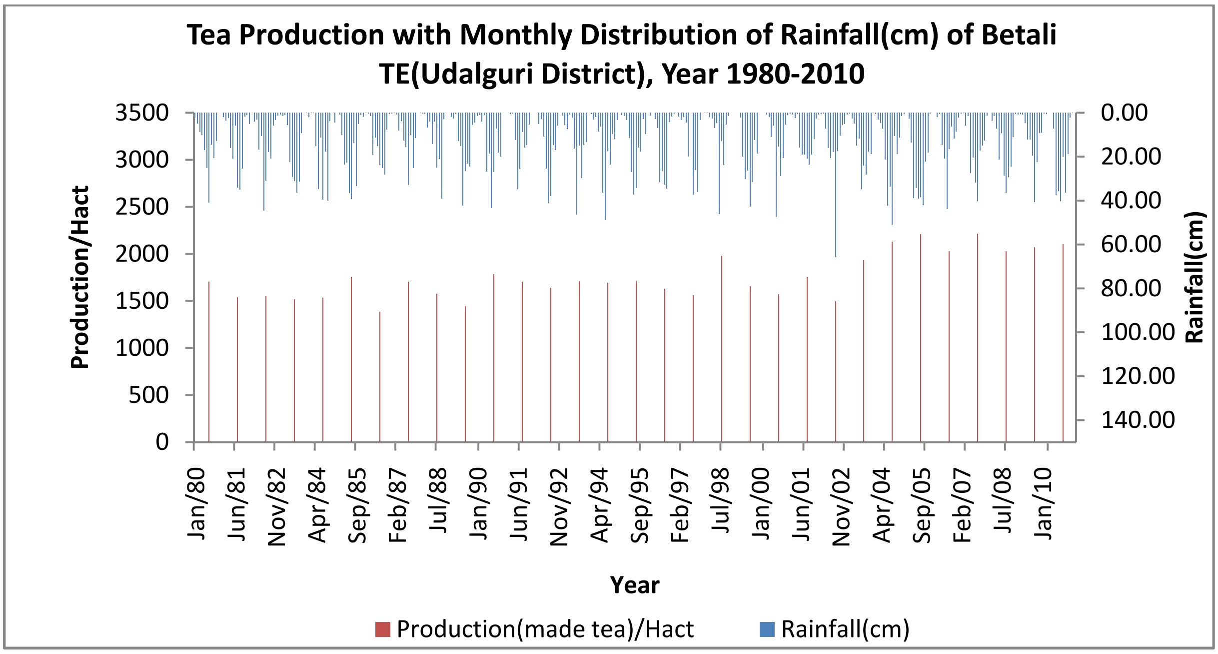

Fig. 3.57 Tea Production with Monthly Distribution of Rainfall(cm) of Betali TE(Udalguri District), Year 1980-2010

3.3 Conclusion

The production of rice in the year 2009-10 is high which may be due to improved agricultural practices, better seed quality, increase in cultivated area and better management practices. However, as stated by the cultivators of different parts of Assam during field visit that the production of Rice will be low in 2011-2012 due to low rainfall during land preparation and transplanting of seedlings. The area under cultivation and production of jute, wheat and mustard are in decreasing trend. Whether the reason for decreasing area under these crops is due to water related problem is an area of study. This matter was discussed with the Vice Chancellor, senior officials and professors of Assam Agriculture University (AAU) and it was observed more study in this regard is necessary which can be taken up through a collaborative project between IIT Guwahati and AAU on Impact of Climate Change on Agriculture related subjects.

From the above graphs of tea production and precipitation it is seen that the Silonibari TE has not been able to increase their production as the estate is suffering from flood during monsoon and also from water logging condition as the water can not go out from the estate easily.

As far as Nitin Nagar Tea Estate is concerned, because there was prolong drought less crop was harvested during early season. However in 2010 water was harvested and irrigated made it possible to harvest more crops in March and April. There is scope for further study on this subject.

Dolowjan Tea Estate harvested highest crop in 2009. This estate continued with uprooting replanting programme and their draining and other cultural operations are of good standard. This estate is also planning to irrigate through deep tube well and water harvesting .There is scope for further study on this subject.

The crop of Bateli Tea Estate is in increasing trend as they have taken various development measures like uprooting replanting programme, various cultural operations, proper draining using underground pipe drainage system, Irrigation etc. This estate has scope for water harvesting and further study on water related matter is expected to improve the production.

4 Other water related problems in tea estates

4.1 Introduction

During our visit to various tea gardens, we had interaction with garden authority about various other water related problems that may not apparently looked like mot effecting the crop yield directly. Basic objective of collecting such information was that many a time various other issues may have far reaching influence on the crop yield and can influence the economy. Proper water management taken up by the garden or concerned agencies can resolve such problem. We have given emphasis on those problems, which may farther aggravate because of climate change impact. Some of such problems are presented below.

4.2 Flood and erosion

High intensity rainfall of short duration many a time generates high unprecedented peak flow and changes the river morphology causing river bank erosion & flood. With the impact of climate change, it is expected that such high intensity rainfall of short duration will increase and unless proper precautions are not taken the river bank erosion will also increase and thus the present problem of river bank erosion should be considered as an alarming one. The photographs Fig. 4.1 to Fig. 4.4 shows the flood situation and photograph fig. 4.5 to fig. 4.8 shows the river bank erosion in tea garden and other areas.

Fig. 4.1 Flooding of factory and garden road

Fig. 4.2 Flood due to high intensity of rainfall

Fig. 4.3 Close view of flooding inside the garden

 

Fig. 4.4 Flooding in the gardens adversely effecting the yield

Fig. 4.5 Embankment failure due to erosion

Fig. 4.6 Erosion in the main outlet drain

 

Fig. 4.7 Erosion of garden area located in relatively high land

Fig. 4.8 Erosion in the embankment by a major tributary

4.3 POOR DRAINAGE BECAUSE OF INADEQUATE CULVERT AND BLOCKAGE OF OUTLET DRAINS

Due to placing of inadequate culvert (in some cases no culvert at all) in the road many a time the upstream area faces water logging problem while the downstream area faces erosion problem. In some cases, as these culverts are not under the jurisdiction of the concerned tea garden they do not have the right to temper with such culvert. As such design of culvert in government as well as in private road should be done by considering the actual drainage capacity computed with consideration of climate change.

The construction of new roads and rail bridges are in progress throughout Assam. The railway department is also constructing new railway line in the north bank of Assam. It appears that in many places the culvert and bridges are not put in correct places as a result of which these culverts and bridges cannot carry the required amount of water and the catchment area suffers from water logging condition. This problem required to be addressed properly. The following fig. 4.9 shows problems.

Fig. 4.9 Railway Culverts not carrying sufficient water

It is also observed in various places in tea gardens and agriculture fields that the outlet drains are blocked by villagers for various purposes without knowing that it will have adverse effects both on upstream and downstream. As a result, the areas are suffering from water logging conditions. This appears to be a serious matter as regards tea cultivation and also for some other crops. It is very necessary to clear the perennial stream to solve the above problems. The following fig. 4.10 to fig. 4.14 shows this problems.

Fig. 4.10 Inadequate Culvert causing afflux at upstream and damage at downstream

Fig. 4.11 Damage to Culvert during flood

Fig. 4.12 Bridge broken due to high intensity of rainfall

Fig. 4.13 Culvert damage during high intensity rainfall

Fig. 4.14 Erosion during high rainfall

5 Probable Solution to Water Related Problem

5.1 Introduction

Based on the observation made during the field visit to different tea gardens, some general solution strategies has been suggested to the problems that can be solved through proper management of water and by river training. However site specific study need to be carried out for detail design before implementation of any solution strategies.

5.2 Flood and Erosion control

Because of extensive loss due to erosion and flood, many gardens have put their effort to protect their garden from the river bank erosion as well as to prevent flooding. Bamboo spurs, sand bags, bamboo spur filled with boulder/sand bags, grass and other plantation are the common methods that are being tried in different gardens. Embankment construction has also been taken up by some gardens for preventing flooding and to avoid probable change of river course. Fig. 5.1 to fig. 5.5 presents the remedial measures taken so far in some of the tea gardens and other areas to prevent flood as well as river bank erosion. Thus it is clear that gardens are spending money to avoid losses due to flood and erosion. While some of these efforts were successful, most of them were not performing as per expectation because of lack of proper technical input. Following were suggested for achieving good performance.

1. Need of placing spurs of proper dimension in appropriate direction is of utmost importance.
2. The way of using spurs for promoting sedimentation was suggested for some locations.
3. Submerged vane in the form of bamboo fencing in proper direction can promote sedimentation and can be used for reclaiming land and for deflecting river of small dimension.
4. A new technique of using plastic net and bio-system implemented successfully by Polygon Foundation with technical backup of IIT Guwahati can be tried for bank protection.
5. For protection of bank erosion and embankment failure, more emphasis should be given on reducing toe cutting by the flowing stream. For this purpose toe protection measures should be taken up.

	
Fig. 5.1 Protection measure by planting tree	Fig. 5.2 Protection measure by putting bamboo spur
	
Fig.5.3 Embankment protection by using bamboo spur	Fig. 5.4 Embankment protection by putting sand bags

Fig. 5.5 Protection measure by using bamboo spur

5.3 Water Scarcity Problem

5.3.1 Field water harvesting

Water harvesting is the need of the hour in drought prone areas. For tea garden, water harvesting can help a lot in maintaining crop health particularly in hilly terrain and in low rainfall area.

The ultimate objective of the field control of soil water is the maintenance of an optimum moisture conditions for plants and other living organisms. A part of rainwater or irrigation water received by an agricultural field gets lost either through evaporation or as surface runoff. A part of it gets infiltrate into the subsoil and enriched the soil moisture. Plant utilizes this part of water for its growth. However, fully saturated subsoil is also not good for growth of most of the plants as without air in the soil pores most of the plant cannot survive. For crop like tea it is necessary to drain out the percolated water, so as to make the root zone free from water logging. Such drained out water if harvested along with the surface runoff can also be utilized for irrigating the field during non-rainy days. The situation is presented below in a diagrammatic form. Water drawn by the root system gets released to the atmosphere by transpiration and this process is very much essential for growth of plants. Again, more the surface runoff more is the loss of fertile top soil because of surface erosion by water. This also adversely affects the plant growth.

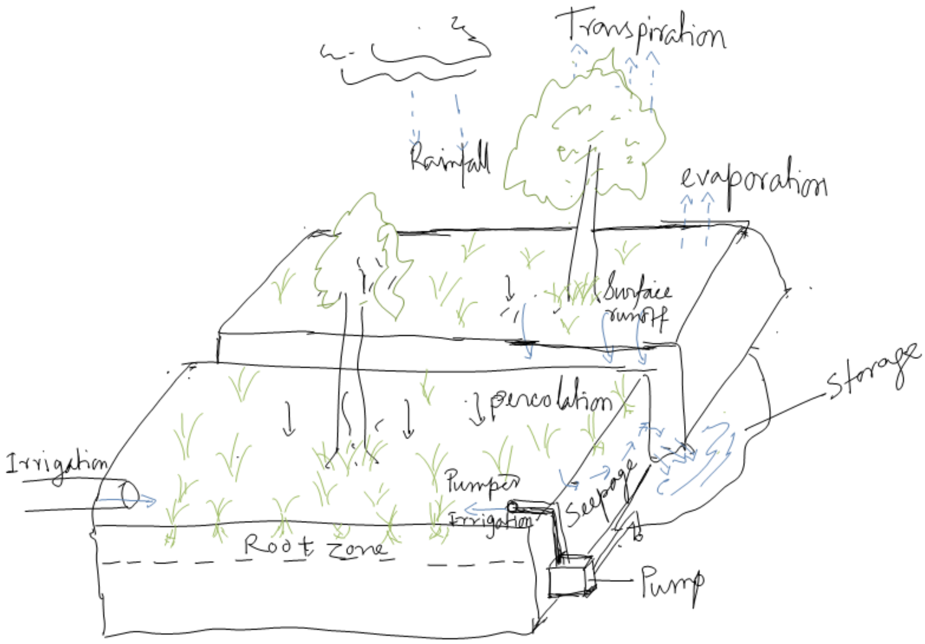

Fig. 5.6 Schematic diagram of the Hydrological cycle

It is observed that Karbi Anglong, Golaghat,Jorhat, Udalguri, Darang, Kokrajhar, Bongaigaon and part of Kamrup district receives very low post monsoon rainfall and suffer from drought. Therefore it is necessary for the tea gardens and other crop field to harvest water during rainy season and use it during drought period through irrigation. The following photographs in figure 5.7 show the water harvesting done in some of the tea garden areas and agriculture field.

Fig 5.7 Water Harvesting

There is scope for harvesting water throughout Assam in a large areas .It may be possible to identify and use those areas for double and triple cropping

5.3.2 Water harvesting in the factory and residential areas

The Factory roof Water can also be harvested as shown in the following drawings:

Advantages	Disadvantages
Reduction of peak flow	Pumping provision must be present.
Recharge of the ground water table	
Partial reduction in pumping costs	

Advantages	Disadvantages
Reduction of peak flow	Initial cost is more
Free use of water	
Reduction in pumping costs	
Recharge of ground water table	

Fig. 5.8 Rainwater harvesting system (Ref: - http://www.iitg.ac.in/coeiitg/Know%20Hub%20and%20Data.html)

This water could be used for humidification of fermentation room and also for washing. While using this water the hygiene aspect of water should be studied properly. The excess water could be used for recharging ground water through deep tube well.

In short, the water stored by harvesting can be very useful during water stress period for tea estates and agriculture fields.

5.4 Water Logging Problem

As a solution to water logging problem, emphasis should be given on proper drainage of the agricultural area. Effort should be made to ensure gravity draining as far as possible. Recourse should be made to dewatering by pumping only when gravity drainage is not possible. Design of cross drainage work, culvert etc. Need to be carried out by considering the rainfall to be 20% more than the present value to include impact of climate change. To ensure draining out of water no natural drain should be blocked till it reaches its ultimate outlet. To ensure that act should be passed at government level and local committee need to be formed for benefit of all.

5.5 Power Generation Scope

It was observed that some of the tea gardens are in hilly terrain and small streams are flowing nearby. Also lots of biomass gets generated in the tea gardens. Thus a study towards scope of generating water power and biogas plant for power generation can be taken up in future. Such in house power generation will also help the tea garden authority in using pumped irrigation from the harvested source during non rainy period with own power source. State Electricity Board of concerned state can also be consulted to explore a collaborative project on low cost power generation in small scale but is large number.

5.6 Soil Degradation at Foot hill Due to Leaching of Chemicals

Considering the need, special effort was made to collect primary and secondary data of soil from some of the tea garden facing serious problem in crop yield. The soils characteristics of Brahmaputra basin differ in plains and hills in respect of their agricultural productivity. While in the alluvial formation of the river valley hydrological regime, leaching and particle size composition influence the soil characteristic, degree of slope, intensity of leaching and vegetative cover influences the soil characteristics in the hills and foothills.

The production of Pabhojan Tea Estate was in declining trend for last two decade and the average production recorded during last few years is approximately 400 Kgs made Tea per Hectare. This is a very low production and alarming situation.

Soil samples were collected from this estate and tested in a soil and water testing research laboratory of Guwahati, recognized by Tea Board of India, AAU and Govt. of Assam.

From the soil testing report it was found that the P^H Value of the soil ranges from 8 to 9.2 against the TRA's recommended value of 4.5 to 5.5. The texture of the soil ranges from silty clay to clay as against TRA's recommendation of sandy loam soil. Lime deposit was also seen below 0.75 meter soil. The annual rainfall is also low measuring 1300mm. It is difficult to grow tea and other crops economically in this kind of soil.

The soil was reclaimed by adding compost, organic manure of various natures, adding river sand and also by deep plough. It was possible to improve the soil up to about 30cm depth and could reduce the P^H value to about 5.5. Iron pyrite can also be used to reduce the P^H by another one unit. Since the root system of tea plants goes up to about 90Cm deep, the bushes may again suffer once the root system extend below 30Cm deep.

This situation requires to be studied thoroughly and may be taken up as a separate project in collaboration with other relevant departments of IIT Guwahati, AAU and TRA.

5.7 Conclusion

Some measures have been suggested for mitigation of various water related agricultural problem. It is suggested that for complete management of water watershed based approach should be adopted, which calls for horizontal coordination between different group falling under the watershed a pre-requisite and management plan should be designed for mutual benefit of all concerns. Traditional concept of watershed management basically talks about soil, water and vegetation conservation practices for soil and water management to avoid flood, drought etc. However, to ensure economic sustainability and social acceptability, it can be redefine the concept of watershed management as management practices that help in soil and water conservation and also improve economic condition of the people of that locality, which in turn helps improving working and living conditions of human and other living being under various water scenario (Sarma 2005). Secondly, whatever expenditure is made by the Government and the people the breakeven point should reach in desired time as per the project proposal for the benefit of the society in general. Moreover there are lots of scope for alternative erosion control measures as against the presently practiced method of using high value logs at Nagaland and other hilly states of North East India. The cost of controlling soil erosion with the present system is very high. Therefore it is necessary to evolve a low cost method where Government, Tea gardens and public involvement is necessary. Scope of making tea garden self sufficient in energy sector can also be investigated as a separate project.

6 Impact of Climate Change and Future Water Scenario

6.1 Introduction

Utilizing the rainfall data collected from the tea garden and also using the data collected from Assam Agriculture University, a climate change study has been carried out in the Golaghat District, which is observed to be a drought effected area. Basic objective of this study is to understand the impact of climate change in general, so that need of strategic planning for future water management can be highlighted. Selection of an appropriate GCM for Brahmaputra Basin and deciding downscaling technique to downscale the climatic parameter to local hydrological parameter has been another objective of this study.

6.2 Study Area

The aim of this study is to predict the future stream flow variation in the southern region of Dhansiri River. Dhansiri is one of the tributary of Brahmaputra where the snow melt is absent. It originates from Laisang Peak of Nagaland and flows from south to north over a distance of 352km. The total catchment area is 1220km2. Before joining the south bank of Brahmaputra, the river passes through the Dimapur district of Nagaland and Golaghat district of Assam. The bank of Dhansiri River is rich in wild life with Itanki National Park on one side and Dhansiri Reserved Forest on the other side.

In this study, Dhansiri River (southern region) has been selected. For performing rainfall-runoff modelling, some of the stations in the catchment of Dhansiri River have been selected based on their contrasting features and also on the availability of data. The selected stations are Furkatting, Lengree, Rungagora, Sockieting, and Bokakhat. Lengree is in the upper reach of the river and Bokakhat in the lower reach. The stations are marked in Figure 6.1.

Fig.6.1 Stations selected for study

6.3 STATISTISTICAL DOWNSCALING

The statistical downscaling has been done by Multiple Linear Regression. Predictor selection has been based on the correlation and Stepwise Regression. These methods and results are briefly presented below.

6.3.1 Multiple Linear Regressions

Regression analysis is very helpful for forecasting, it is divided into two categories namely simple regression and multiple regression. In this study, the independent variables are more than one so multiple linear regression has been used. In the multiple linear regressions, the basic model has been designed by using least square method.

6.3.2 Assumptions

Following five fundamental assumptions are required for the least square procedure to work as the Gauss-Markov theorem expects

- The relationship between Y and X_1, X_2.... is linear
- The residuals are normally distributed with zero mean.
- The residuals have a constant variance σ^2.
- The successive residuals are not correlated. i.e., there is no autocorrelation.
- The X variables are fixed and are not correlated with the u_t values

6.3.3 Procedure

- In Multiple Linear Regression Analysis the basic steps have four categories, namely
- Specification: Here selection of predictor and model has been done.
- Calibration: This is used to form a relation between the output and input.
- Validation: This is used to find the accuracy of model.
- Forecasts: This uses the model from validation to predict the future variations

6.3.4 Data Processing

The large scale climate variables has to be pre-processed before using it for calibration

6.3.4.1 Interpolation

The geographic location of study area (latitude and longitude), NCEP grid points and GCM grid points vary; therefore interpolation is needed for processing of the data. Here two dimension linear interpolations by MATLAB programming have been used. The NCEP grid points and GCM grid points are interpolated to match the location of study area.

6.3.4.2 Standardization

Basically, the difference between observed and climate variables occur due to parameterization. The difference between observed and climatic variables is called bias. Standardization is used to reduce the biases in the mean and variance of GCM predictors relative to those of the observed or NCEP data. In this study AR4 and AR3 data has been used. The baseline period for AR4 is from 2001 to 2010, which is a very short time. The baseline period for AR3 is from 1965 to 2010. In this process of standardization, the mean is subtracted from the baseline period and divided by standard deviation for both NCEP and GCM outputs are performed as follows, given by Subimal Ghosh et al (2007)

$$v_{s\tan,t}(k) = \frac{v_t(k) - \mu_v(k)}{\sigma_v(k)}$$

Where, $V_t(k)$ =Original value of the k^{th} predictor variable at time t,

$\mu_t(k)$ = The mean value of the k^{th} predictor variable and

$\sigma_v(k)$ =Standard deviation of the k^{th} predictor variable

6.3.5 Selection of Predictors

The predictors are selected by Stepwise Regression method. Stepwise regression consists of two main approaches namely forward selection and backward elimination. Here combination of two approaches is used. The predictor selection carried out by automatic procedure includes simple correlation and partial correlation. The process will continue until it reaches the best f-test, t-test, adjusted R2 (co-efficient of determination), Akaike information criterion, Bayesian information criterion and Mallows'Cp. The equation for the data is given by

$$y_i = \beta_o + \beta_1 x_{i1} + \beta_2 x_{i2} + ...\beta_p x_{ip}$$

Where, yi is the predict ant, xi is the predictor and β is the constant. Simple Correlation is the correlation between two variables without the influence of other variables. When the correlation co-efficient between y and x is computed by first eliminating the effect of all other variables, it is called partial correlation.

6.3.5.1 Correlation

Correlation is a statistical relationship between two variables. It will show whether the two variables are strongly correlated, weakly correlated or independent of each other. How precipitation is correlated with other variables is discussed below:

6.3.5.1.1 Physical correlation

Precipitation is mainly affected by sea level pressure, humidity,temperature and wind speed. In atmospheric circulation pattern, the first process is evaporation and precipitation forms through condensation. Due to increase in temperature, the evaporation will take place and due to low pressure, the warm air containing water vapour will lift up, which increases moisture content in the air i.e., humidity. So it clearly indicates that temperature, humidity and wind speed are directly proportional to precipitation. And sea level pressure is inversely proportional to precipitation.

6.3.5.1.2 *Pearson correlation*

It is statistical technique to calculate the correlation coefficient for two variables. Precipitation data have been taken from recorded data at Furkatting, Lengree, Rungagora, Sockieting, and Bokakhat. Predictors have been collected from IPCC and NCEP reanalysis data. Correlation between precipitation and predictors with respect to different models are tabulated below.

Predictors	Correlation Coefficient			
	NCEP	HadCM3	CGCM3	MRCGCM2
ta	0.572	0.505	0.504	0.503
pressure	-0.569	-	-	-
rhum	0.476	-	-	-
slp	-0.593	-0.498	-0.520	-0.494
u-wind	0.443	0.253	0.332	0.420
v-wind	0.619	0.261	0.524	0.347
ta850	0.588	0.506	-	-
ta500	0.552	0.468	-0.309	-
ta200	0.583	-	0.423	-
Zg850	-0.566	-0.428	-	-
Zg500	0.493	0.474	-	-
Zg200	0.558	0.449	-	-
ua850	0.472	-0.100	-	-
ua500	-0.590	-0.481	-	-
ua200	-0.596	-0.496	-	-
va850	0.674	0.099	-	-
va500	0.299	0.169	-	-
va200	-0.401	-0.271	-	-
hur850	0.495	0.372	-	-
hur500	0.566	0.466	-	0.451

Table 6.1 Correlation coefficient for NCEP data compared with GCM data at Furkatting

It clearly indicates that slp, ta, v-wind have stronger correlation than the other predictors. CGCM3 and HadCM3 models have been chosen based on the correlation coefficient. Without comparing NCEP data, the correlation coefficients for different models are computed, as shown below.

Predictors	Correlation coefficient	
	Precipitation	Dry Days
Specific Humidity	0.507	-0.755
Total Precipitation	0.541	-0.561
Sea level Pressure	-0.525	0.877
Surface Down welling Shortwave Radiation	-0.055	-0.272
Zonal Surface Wind Speed	0.332	-0.547
Meridional Surface Wind Speed	0.524	-0.780
Surface Air Temperature	0.504	-0.821

Convective Precipitation	0.212	-0.448
Air Temperature @ 500hpa	-0.309	-0.029
Air Temperature @ 500hpa	0.422	-0.133

Table 6.2 Correlation coefficient for Furkatting using CGCM3 model

Predictors	**Correlation coefficient**	
	Precipitation	**Dry Days**
Total Soil Moisture Content (mrso)	0.362	-0.458
Total Precipitation	0.351	-0.701
Convective Precipitation	0.386	-0.757
Sea Level Pressure	-0.498	0.858
Surface Downscaling Shortwave Radiation	0.143	-0.421
Snow Melt	-0.293	0.445
Surface Air Temperature	0.505	-0.866
Surface Temperature	0.506	-0.865
Zonal Surface Wind Speed	0.253	-0.605
Meridional Surface Wind Speed	0.261	-0.622
Zonal Wind Speed@200hpa	-0.496	0.724
Zonal Wind Speed @500hpa	-0.481	0.725
Zonal Wind Speed @850hpa	-0.101	-0.069
Meridional Wind Speed@200hpa	-0.271	0.466
Meridional Wind Speed@500hpa	0.169	-0.086
Meridional Wind Speed@ 850hpa	0.099	-0.456
Relative Humidity @ 200hpa	0.469	-0.683
Relative Humidity @ 500 hpa	0.466	-0.711
Relative Humidity @ 850hpa	0.372	-0.529
Temperature @ 500hpa	0.468	-0.868
Temperature @ 850hpa	0.506	-0.689
GeopotentialHeight @ 500hpa	0.474	-0.665
GeopotentialHeight @ 850hpa	-0.428	-0.781

Table 6.3 Correlation coefficient for Furkatting using HadCM3 model

Predictors	**Correlation coefficient**	
	Precipitation	**Dry Days**
Total Precipitation	0.397	-0.698
Sea level Pressure	**-0.494**	0.839
Specific Humidity	**0.507**	-0.815
Surface Downscaling Shortwave Radiation	0.297	-0.624
Zonal Surface Wind Speed	0.420	-0.807
Meridional Surface Wind Speed	0.347	-0.781
Surface Air Temperature	**0.503**	-0.839
Convective Precipitation	0.435	-0.742
Relative Humidity @ 200hpa	0.429	-0.582

Relative Humidity @ 500hpa	**0.451**	-0.697

Table 6.4 Correlation coefficient for Furkatting using MRI_CGCM2 model

Predictors	**Correlation coefficient**	
	Precipitation	**Dry Days**
Specific Humidity	0.749	-0.799
Total Precipitation	0.624	-0.603
Sea level Pressure	-0.718	0.856
Surface Down welling Shortwave Radiation	0.084	-0.306
Zonal Surface Wind Speed	0.713	-0.844
Meridional Surface Wind Speed	0.579	-0.619
Surface Air Temperature	0.631	-0.748
Air Temperature @ 200hpa	0.157	-0.200
Air Temperature @ 500hpa	0.047	-0.103
Convective Precipitation	0.136	-0.265

Table 6.5 Correlation coefficient for Lengree using CGCM3

Predictors	**Correlation coefficient**	
	Precipitation	**Dry Days**
Total Soil Moisture Content (mrso)	0.547	-0.481
Total Precipitation	0.601	-0.707
Convective Precipitation	0.650	-0.760
Sea Level Pressure	-0.731	0.828
Surface Downscaling Shortwave Radiation	0.173	-0.315
Snow Melt	-0.287	0.382
Surface Air Temperature	0.742	-0.850
Surface Temperature	0.743	-0.849
Zonal Surface Wind Speed	0.496	-0.644
Relative Humidity @ 200hpa	0.676	-0.693
Relative Humidity @500hpa	0.680	-0.710
Relative Humidity @ 850hpa	0.601	-0.615
Temperature @ 500hpa	0.703	-0.708
Temperature @ 850hpa	0.734	-0.849
GeopotentialHeight @ 500hpa	0.706	-0.704
GeopotentialHeight @ 850hpa	-0.630	0.722
Zonal Wind Speed @ 200hpa	-0.705	0.693
Zonal Wind Speed @ 500 hpa	-0.710	0.712
Zonal Wind Speed @ 850hpa	-0.189	0.043
Meridional Wind Speed@200hpa	-0.431	0.506
Meridional Wind Speed@500hpa	0.276	-0.150
Meridional Wind Speed@ 850hpa	0.571	-0.692
Meridional Surface Wind Speed	0.457	-0.620

Table 6.6 Correlation coefficient for Lengree using HadCM3

Predictors	Correlation coefficient	
	Precipitation	Dry Days
Specific Humidity	0.685	-0.707
Total Precipitation	0.502	-0.577
Sea level Pressure	-0.680	0.776
Surface Downwelling Shortwave Radiation	0.132	-0.243
Zonal Surface Wind Speed	0.692	-0.750
Meridional Surface Wind Speed	0.534	-0.519
Surface Air Temperature	0.590	-0.677
Air Temperature @ 200hpa	0.152	-0.181
Air Temperature @ 500hpa	0.043	-0.081
Convective Precipitation	0.196	-0.327

Table 6.7 Correlation coefficient for Rungagora using CGCM3 model

Predictors	Correlation coefficient	
	Precipitation	Dry Days
Total Soil Moisture Content (mrso)	0.521	-0.489
Total Precipitation	0.545	-0.627
Convective Precipitation	0.576	-0.667
Sea Level Pressure	-0.653	0.751
Surface Downscaling Shortwave Radiation	0.173	-0.284
Snow Melt	-0.347	0.395
Surface Air Temperature	0.674	-0.751
Surface Temperature	0.675	-0.750
Zonal Surface Wind Speed	0.451	-0.559
Relative Humidity @ 200hpa	0.371	-0.582
Relative Humidity @500hpa	0.540	-0.606
Relative Humidity @ 850hpa	0.544	-0.515
Temperature @ 500hpa	0.509	-0.652
Temperature @ 850hpa	0.638	-0.755
GeopotentialHeight @ 500hpa	0.678	-0.648
GeopotentialHeight @ 850hpa	0.640	-0.613
Zonal Wind Speed @ 200hpa	0.630	0.677
Zonal Wind Speed @ 500 hpa	-0.545	0.658
Zonal Wind Speed @ 850hpa	-0.627	0.631
Meridional Wind Speed@200hpa	-0.608	0.095
Meridional Wind Speed@500hpa	-0.206	0.367
Meridional Wind Speed@ 850hpa	-0.270	-0.109
Meridional Surface Wind Speed	0.134	-0.323

Table 6.8 Correlation coefficient for Rungagora using HadCM3 model

Predictors	Correlation coefficient	
	Precipitation	Dry Days
Specific Humidity	0.761	-0.871
Total Precipitation	0.657	-0.652
Sea level Pressure	-0.810	0.759
Surface Downwelling Shortwave Radiation	0.159	-0.012
Zonal Surface Wind Speed	0.759	-0.837
Meridional Surface Wind Speed	0.559	-0.760
Surface Air Temperature	0.729	-0.661
Air Temperature @ 200hpa	0.173	-0.244
Air Temperature @ 500hpa	0.051	-0.078
Convective Precipitation	0.251	-0.125

Table 6.9 Correlation coefficient for Sockietting using CGCM3 model

Predictors	Correlation coefficient	
	Precipitation	Dry Days
Total Soil Moisture Content (mrso)	0.594	-0.721
Total Precipitation	0.632	-0.610
Convective Precipitation	0.683	-0.648
Sea Level Pressure	-0.784	0.777
Surface Downscaling Shortwave Radiation	0.222	0.002
Snow Melt	-0.431	0.499
Surface Air Temperature	0.779	-0.834
Surface Temperature	0.780	-0.837
Zonal Surface Wind Speed	0.374	-0.345
Relative Humidity @ 200hpa	0.415	-0.752
Relative Humidity @500hpa	0.718	-0.776
Relative Humidity @ 850hpa	0.720	-0.757
Temperature @ 500hpa	0.561	-0.828
Temperature @ 850hpa	0.704	-0.807
GeopotentialHeight @ 500hpa	0.776	-0.839
GeopotentialHeight @ 850hpa	0.699	-0.823
Zonal Wind Speed @ 200hpa	0.659	0.613
Zonal Wind Speed @ 500 hpa	-0.700	0.844
Zonal Wind Speed @ 850hpa	-0.741	0.837
Meridional Wind Speed@200hpa	-0.731	0.297
Meridional Wind Speed@500hpa	-0.080	0.496
Meridional Wind Speed@ 850hpa	-0.391	-0.307
Meridional Surface Wind Speed	0.195	-0.095

Table 6.10 Correlation coefficient for Sockietting using HadCM3 model

The above correlation coefficients have been computed using IPCC AR4 dataset. In this study two types of approaches have been used,

1) Initially,three GCM models have been compared for Furkatting station using IPCC AR4, without using NCEP data. But, later MRI-CGCM2 model has been eliminated for other stations due to the weak correlation and also dataset is not available for future,
2) NCEP reanalysis data have been used for calibration and validation, and this model has been used to project the future precipitation using HadCM3 model in IPCC AR3. This approach has been used in Bokakhat. This approach has been applied for precipitation model only.

Predictors	Correlation coefficient	
	NCEP	HadCM3(IPCC-AR3)
Surface Air Temperature	0.769	-0.779
Pressure	-0.774	-
Relative Humidity	0.552	0.797
Sea level Pressure	-0.808	-0.692
Zonal Surface Wind Speed	0.541	-0.813
Meridional Surface Wind Speed	0.755	-
Air Temperature @ 850hpa	0.789	-0.753
Air Temperature @ 500hpa	0.754	-0.621
Air Temperature @ 200hpa	0.758	-0.525
Geo-potential height @ 850hpa	-0.760	-
Geo-potential height @ 500hpa	0.644	-
Geo-potential height @ 200hpa	0.746	-
Zonal Wind Speed @ 850hpa	0.577	-
Zonal Wind Speed @ 500hpa	-0.729	-
Zonal Wind Speed @ 200hpa	-0.760	-
Meridional Wind Speed @850hpa	0.817	-
Meridional Wind Speed @500hpa	0.288	-
Meridional Wind Speed @200hpa	-0.488	-
Relative Humidity @ 850hpa	0.598	-
Relative Humidity @ 500hpa	0.689	-

Table 6.11 Correlation coefficient for Bokakhat using Third assessment data

A few numbers of predictors for each station has been chosen based on the above test of correlation and stepwise regression. The chosen predictors are tabulated below.

Station	Predictands	Predictors	
		CGCM3	HadCM3
Furkatting	Precipitation	Specific Humidity Total Precipitation Sea Level Pressure Meriodional surface win d speed Surface air temperature	Sea level Pressure Surface air temperature Air temperature @ 850hpa Geo-potential height @500hpa Zonal wind speed @ 200hpa
	No. of Dry	Sea level pressure	Sea level pressure

	Days	Total precipitation	
Lengree	Precipitation	Specific Humidity Sea level pressure Air temperature	Sea level pressure Surface air temperature Air temperature @ 850hpa
	No. of Dry Days	Sea level pressure	Sea level pressure
Rungagora	Precipitation	Specific Humidity	Air temperature @ 500hpa
	No. of Dry Days	Sea level pressure	Sea level pressure
Sockieting	Precipitation	Sea level pressure	Zonal wind speed @ 500hpa
	No. of Dry Days	Specific Humidity Total precipitation	Zonal wind speed @ 500hpa

Table 6.12 Predictor selection using forth assessment data

Station	**Predictands**	**Predictors**	
		NCEP	**HadCM3**
Bokakhat	Precipitation	Sea level Pressure Air temperature @ 500hpa	Sea level Pressure Air temperature @ 500hpa

Table 6.13 Predictor selection using third assessment data

6.3.6 Model Calibration and Validation

The Calibration of the models has been done by three approaches with the following relations.

1) Multiple Linear Regressions without additive residual

$$y_i = \beta_1 x_{i1} + \beta_2 x_{i2} + ...\beta_p x_{ip}$$

2) Multiple Linear Regressions with residuals

$$y_i = \beta_1 x_{i1} + \beta_2 x_{i2} + ...\beta_p x_{ip} + r_i$$

3) Multiple Linear Regressions with a multiplying factor.

$$y_i = (\beta_1 x_{i1} + \beta_2 x_{i2} + ...\beta_p x_{ip})m$$

Where,y_i=precipitation, x_i=predictors, β =coefficient, r_i = residual, m=multiplying factor. The calibration and validation for each station has been explained below with the graphical plots.

6.3.7 Precipitation Model

Above mentioned (5.3.1.2) approaches have been applied for the precipitation model. The model has been developed for first four stations (Furkatting, Lengree, Rungagora, and Sockieting) by IPCC-AR4 data, which is available only for a short time period (2001-2010) therefore, alternative years has been chosen for calibration and remaining years for validation. The AR3 data have been used for Bokakhat station. This station has data for long time period and therefore the model developed by using NCEP data is more reliable.

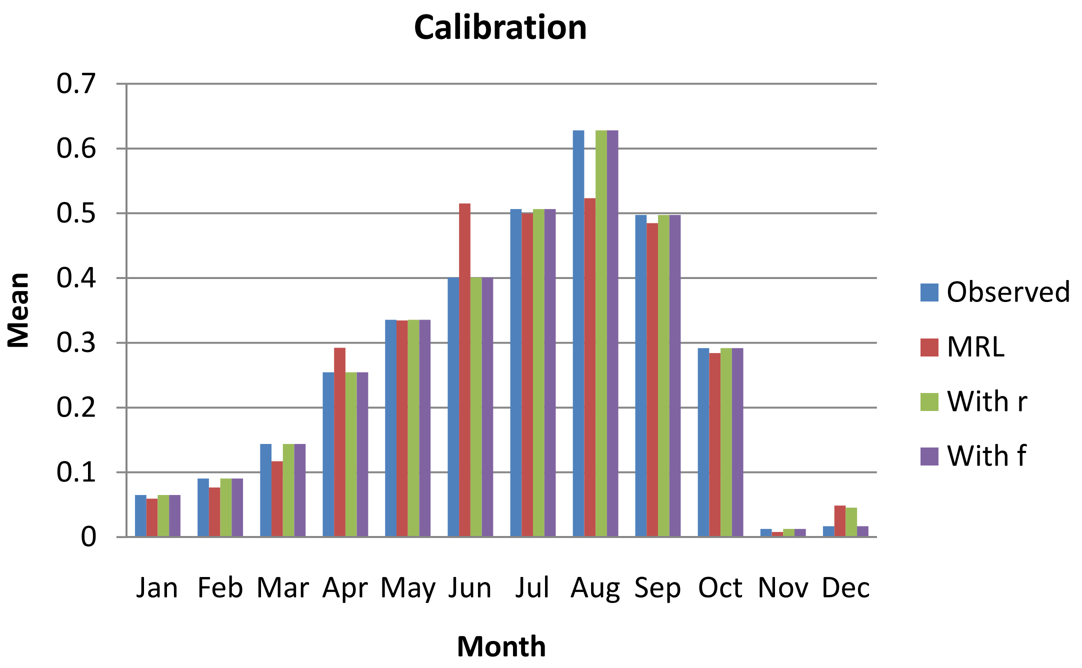

Fig 6.2 Calibration for Furkatting using CGCM3 model

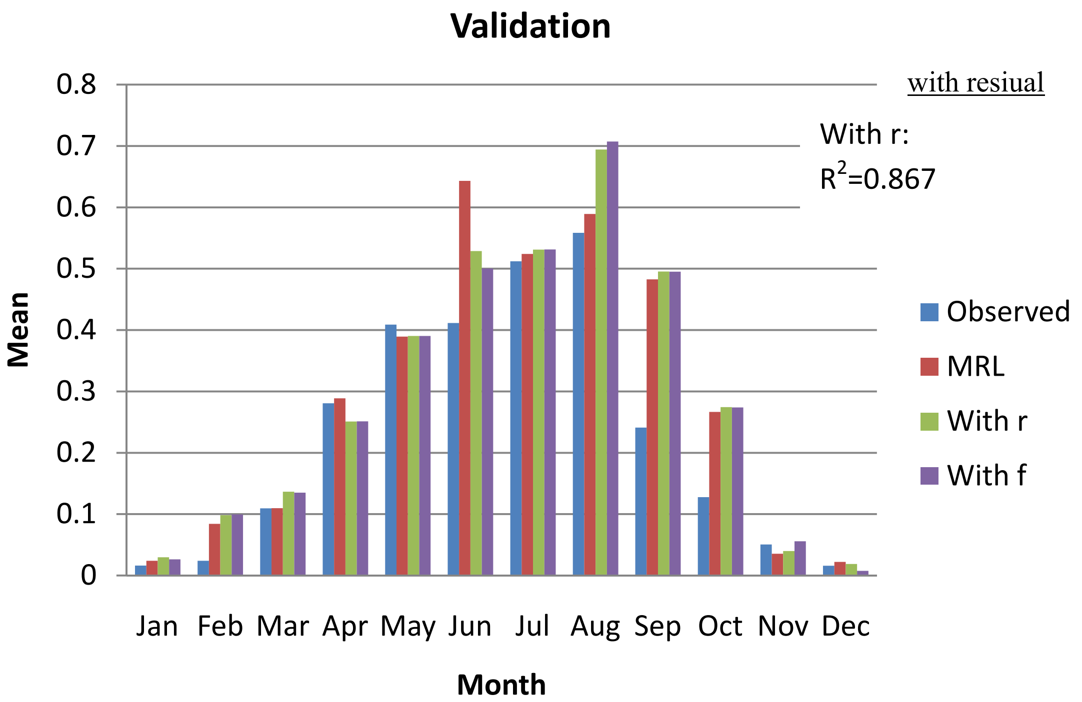

Fig. 6.3 Validation for Furkatting using CGCM3 model

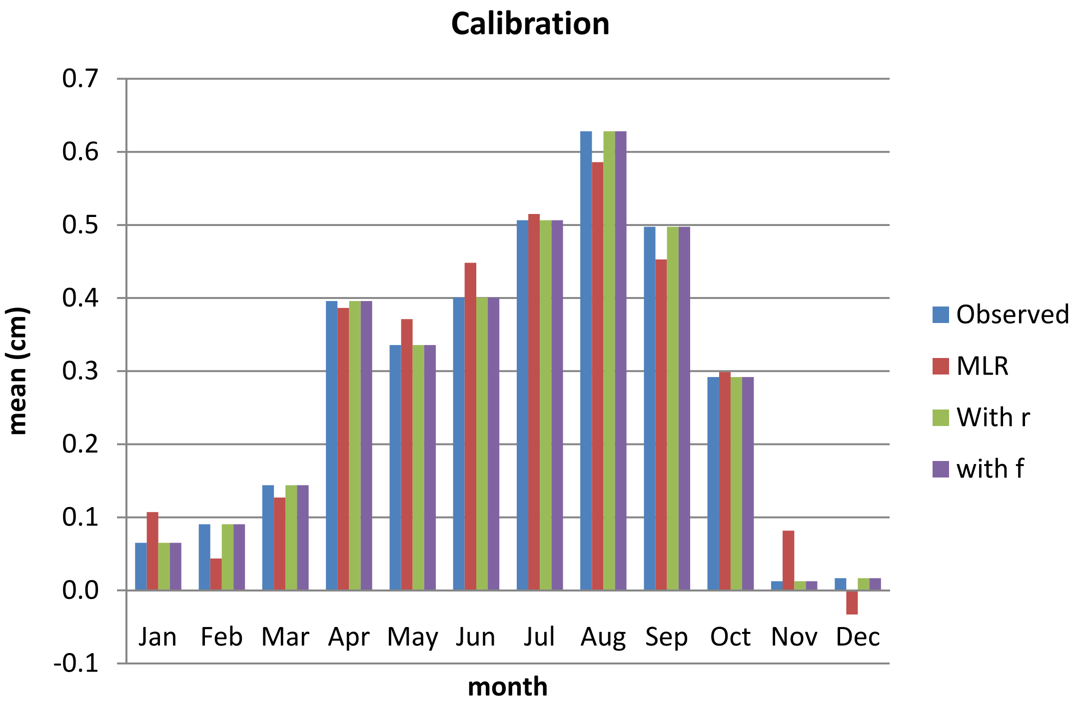

Fig 6.4 Calibration for Furkatting using HadCM3

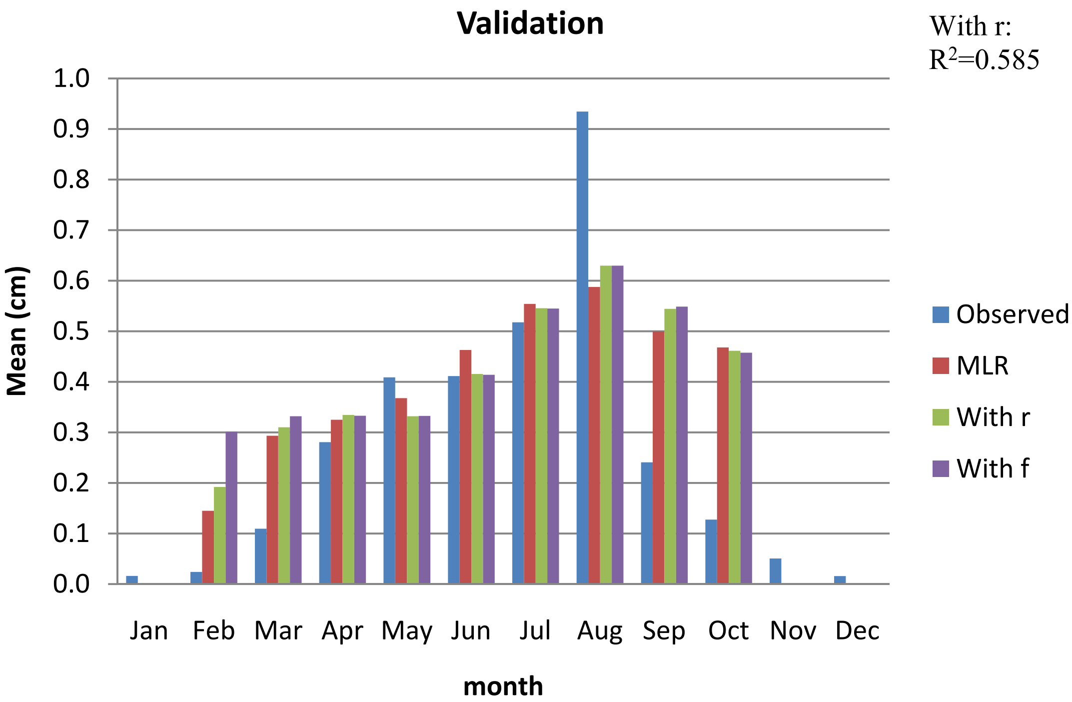

Fig 6.5 Validation for Furkatting using HadCM3

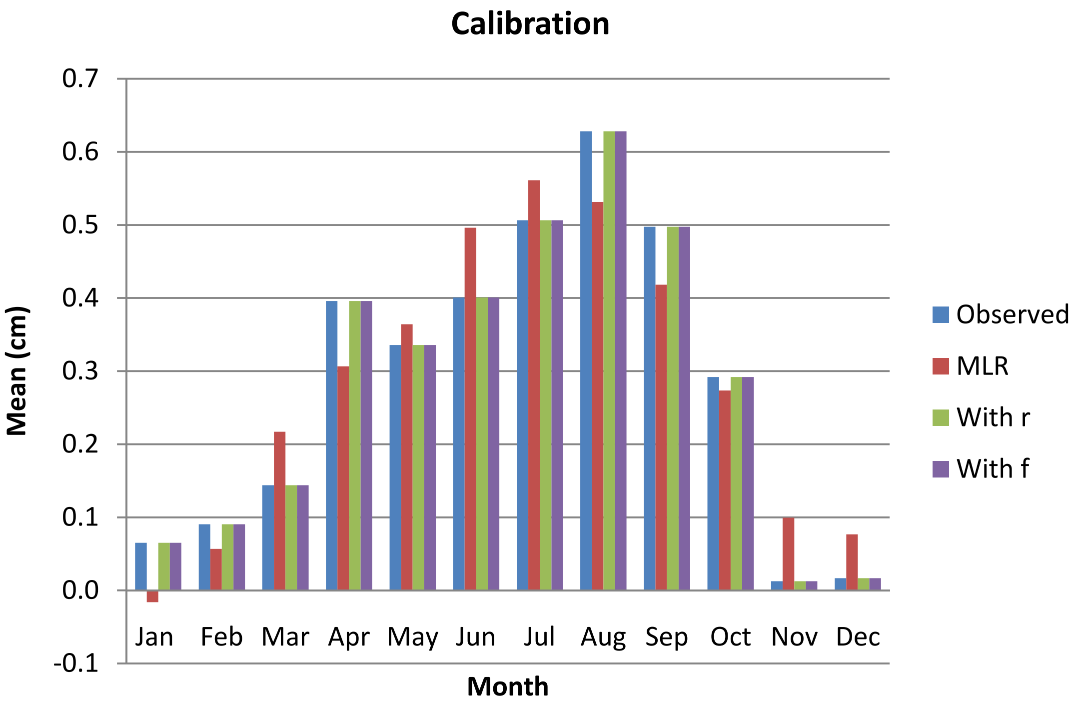

Fig 6.6 Calibration for Furkatting using MRI-CGCM2

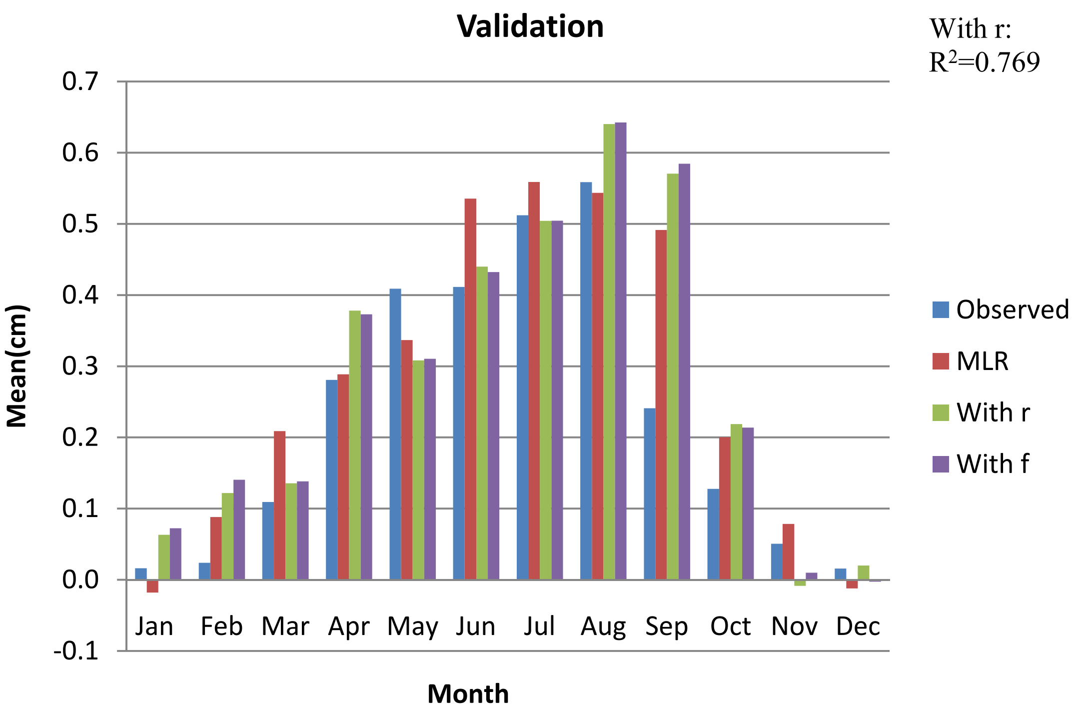

Fig 6.7 Validation for Furkatting using MRI-CGCM2

The above graph clearly shows that Multiple Linear Regression with residuals gives good calibration and validation. MRI-CGCM3 model has been eliminated for further station due to weak correlation and also unavailability of future data.

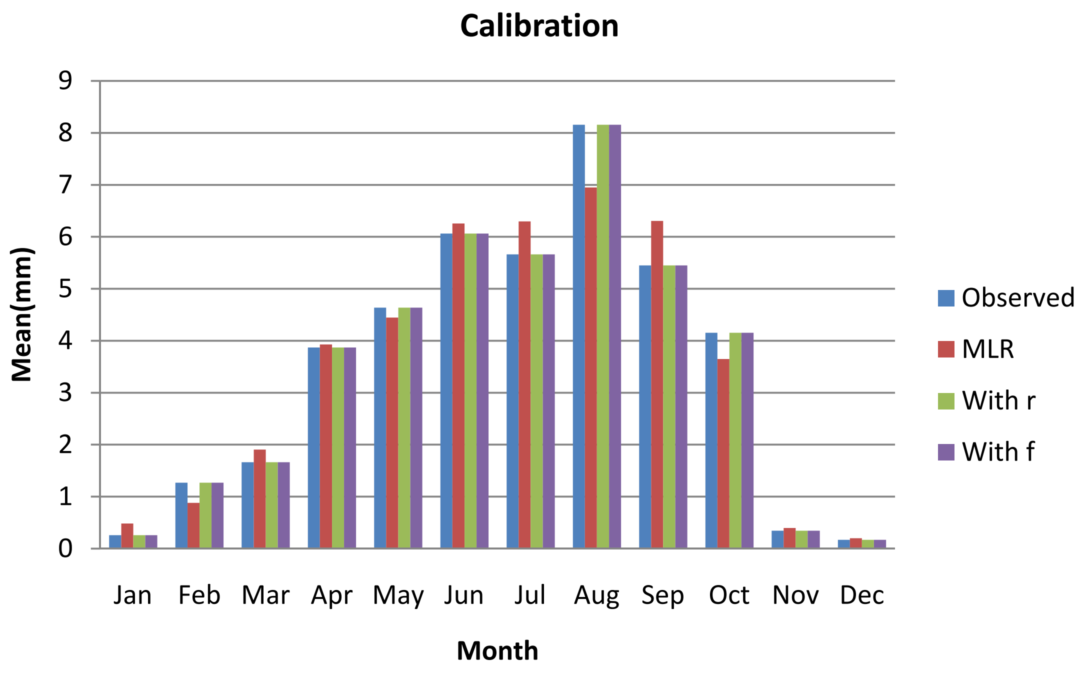

Fig 6.8 Calibration for Lengree using CGCM3

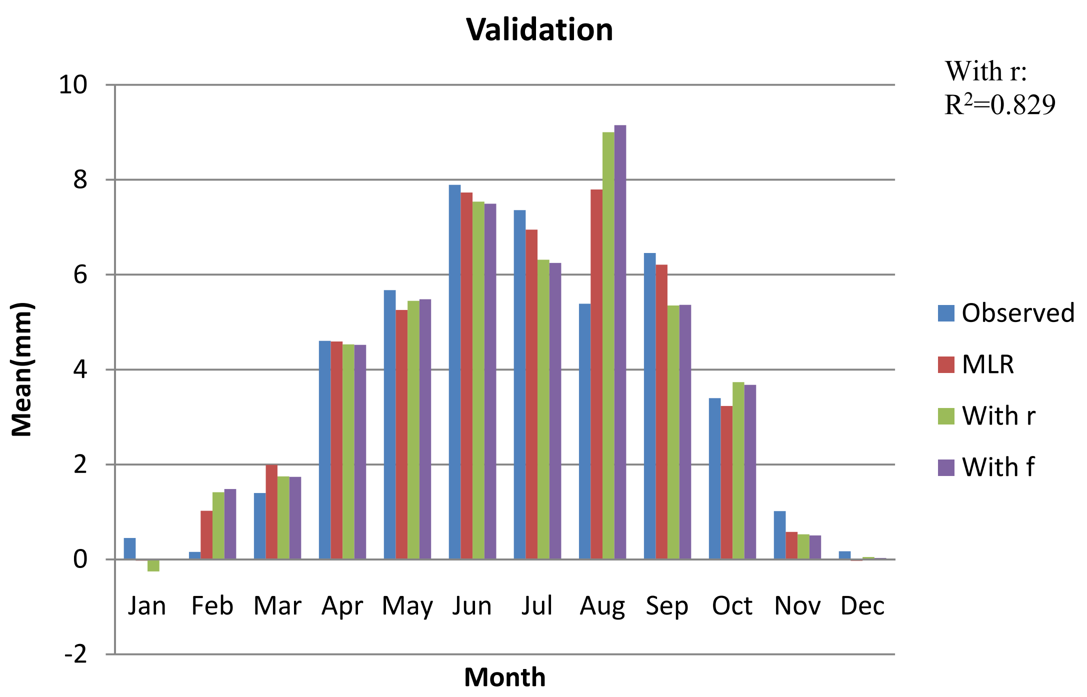

Fig 6.9 Validation for Lengree using CGCM3

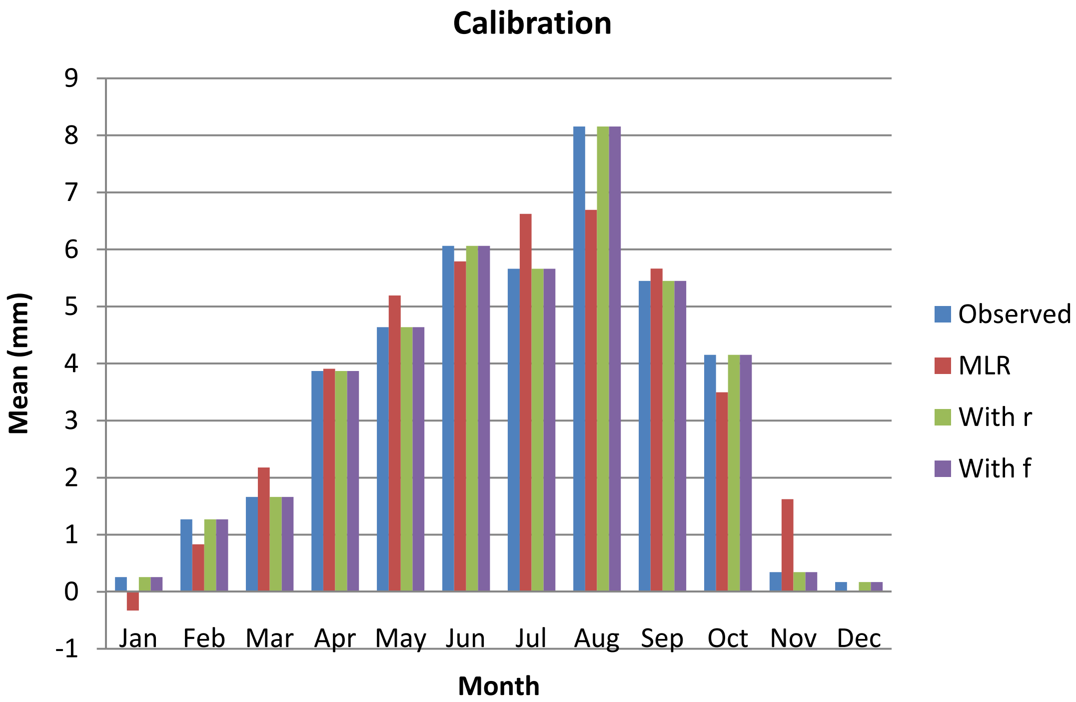

Fig 6.10 Calibration for Lengree using HadCM3

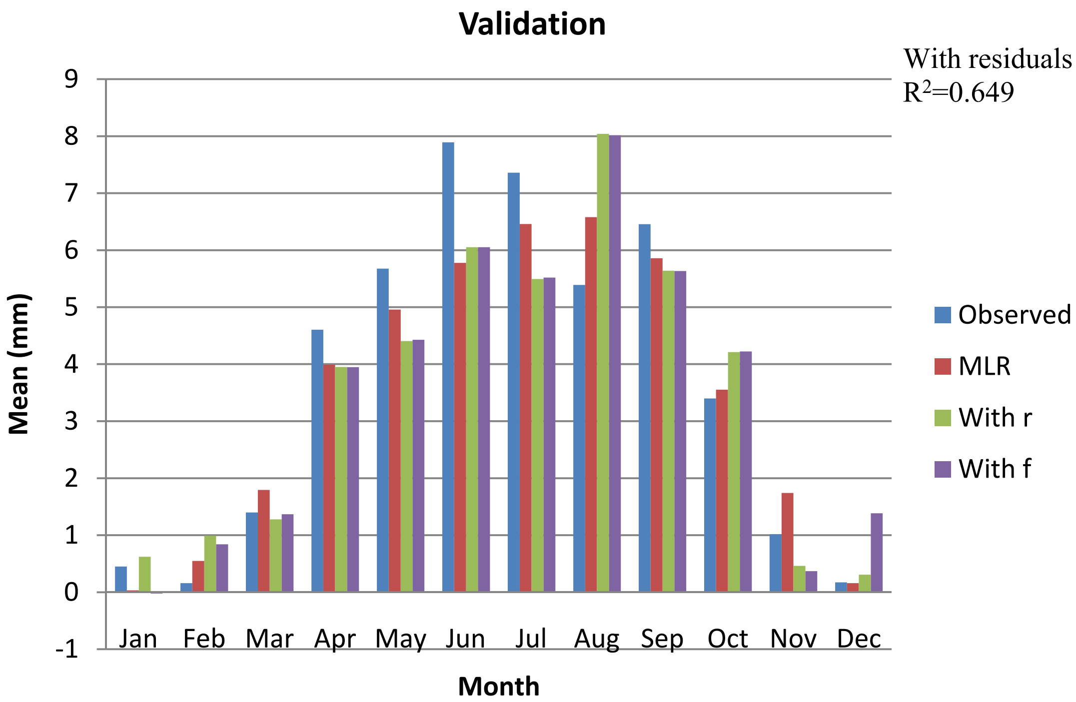

Fig 6.11 Validation for Lengree using HadCM3

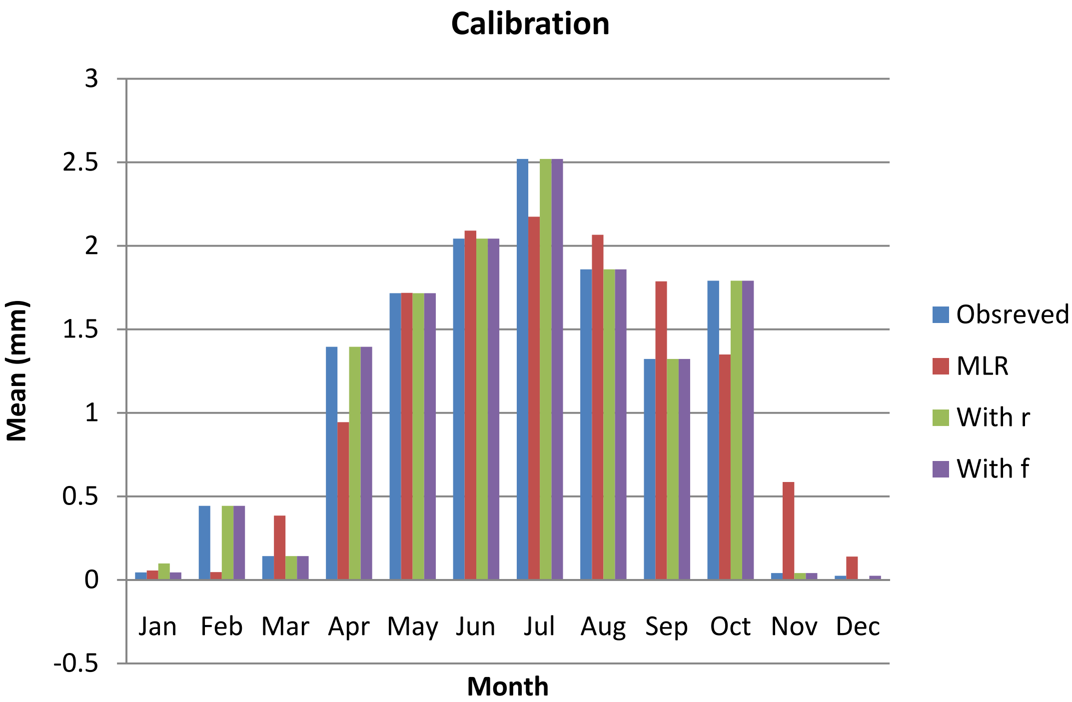

Fig 6.12 Calibration for Rungagora using CGCM3

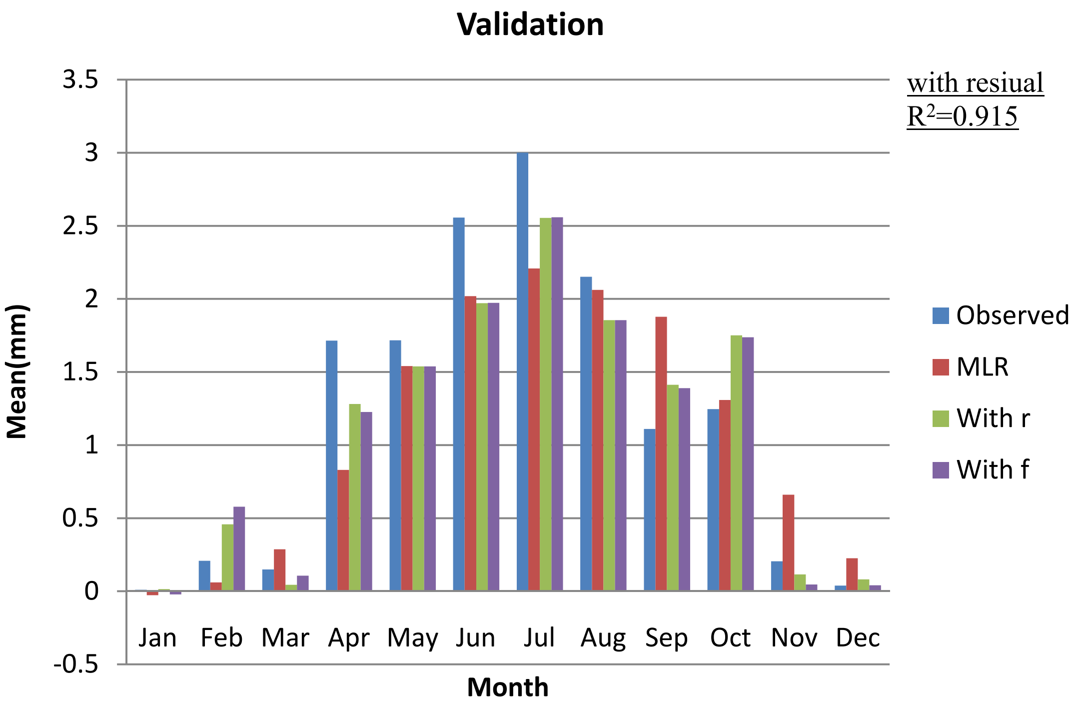

Fig 6.13 Validation for Rungagora using CGCM3

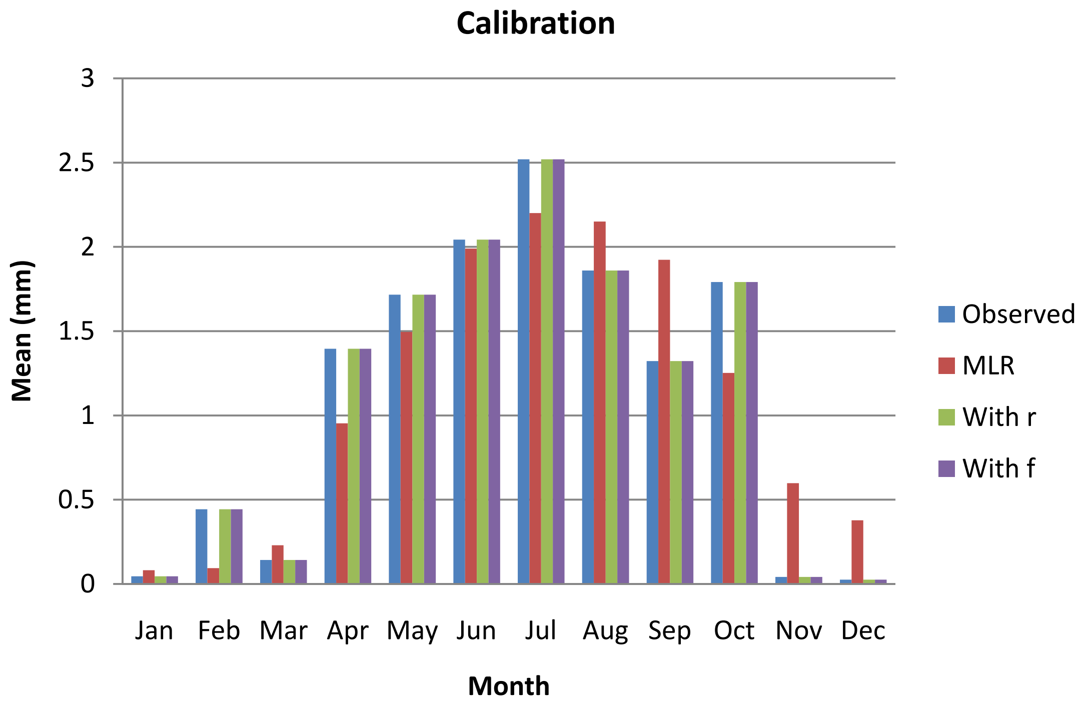

Fig 6.14 Calibration for Rungagora using HadCM3

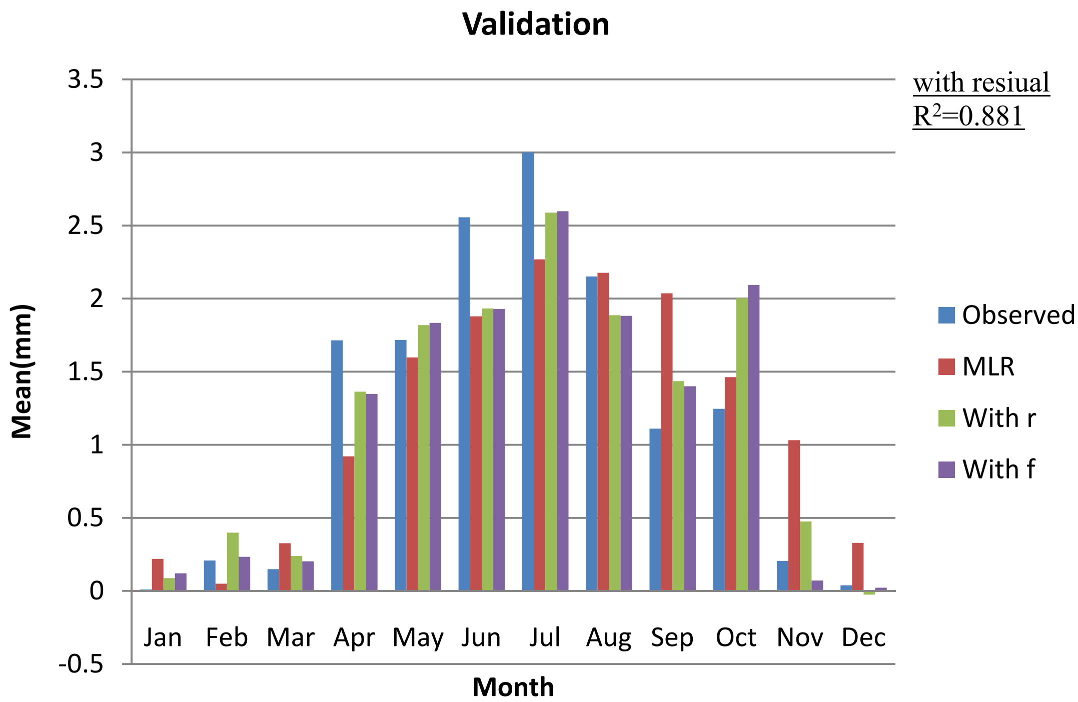

Fig 6.15 Validation for Rungagora using HadCM3

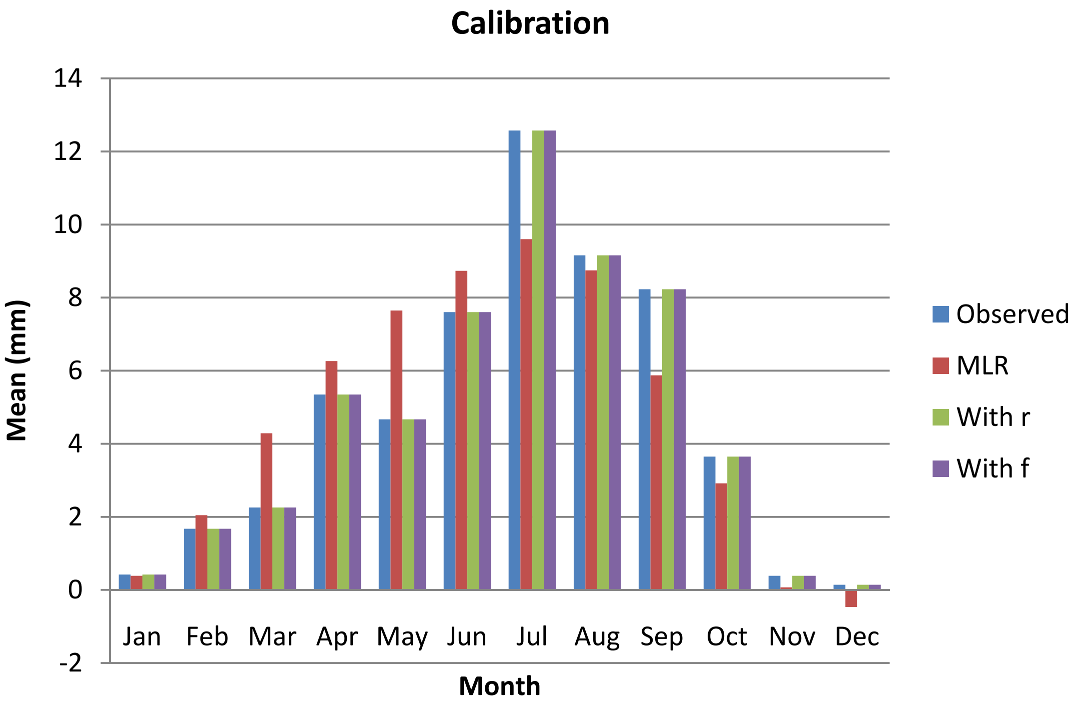

Fig 6.16 Calibration for Sockieting using CGCM3

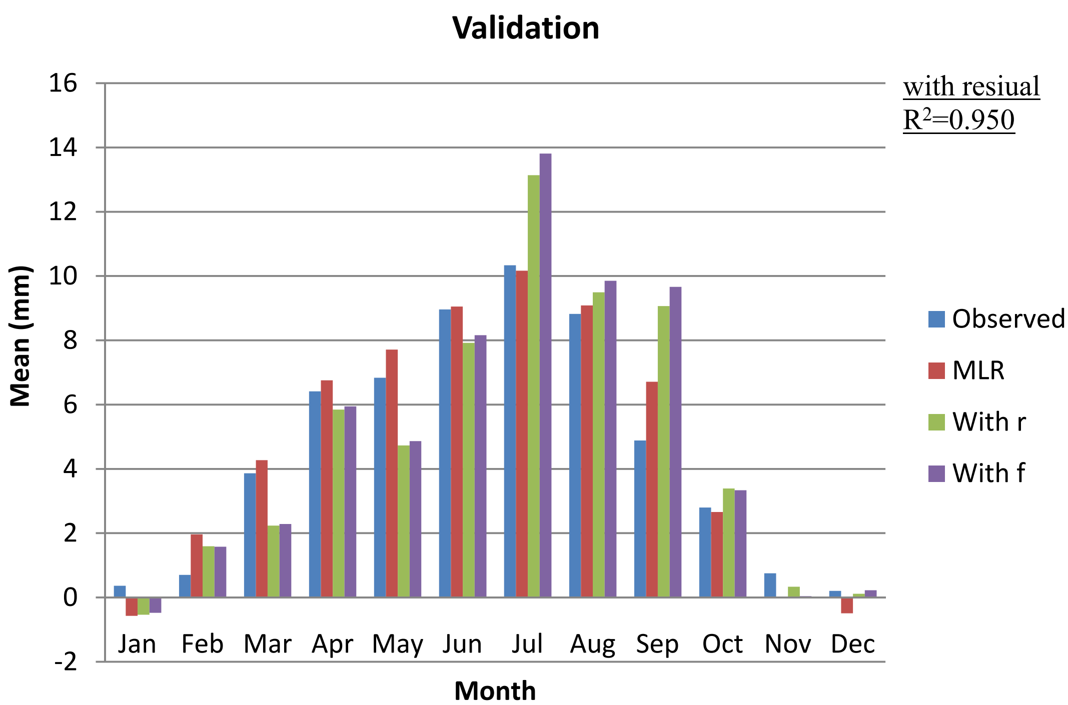

Fig 6.17 Validation for Sockieting using CGCM3

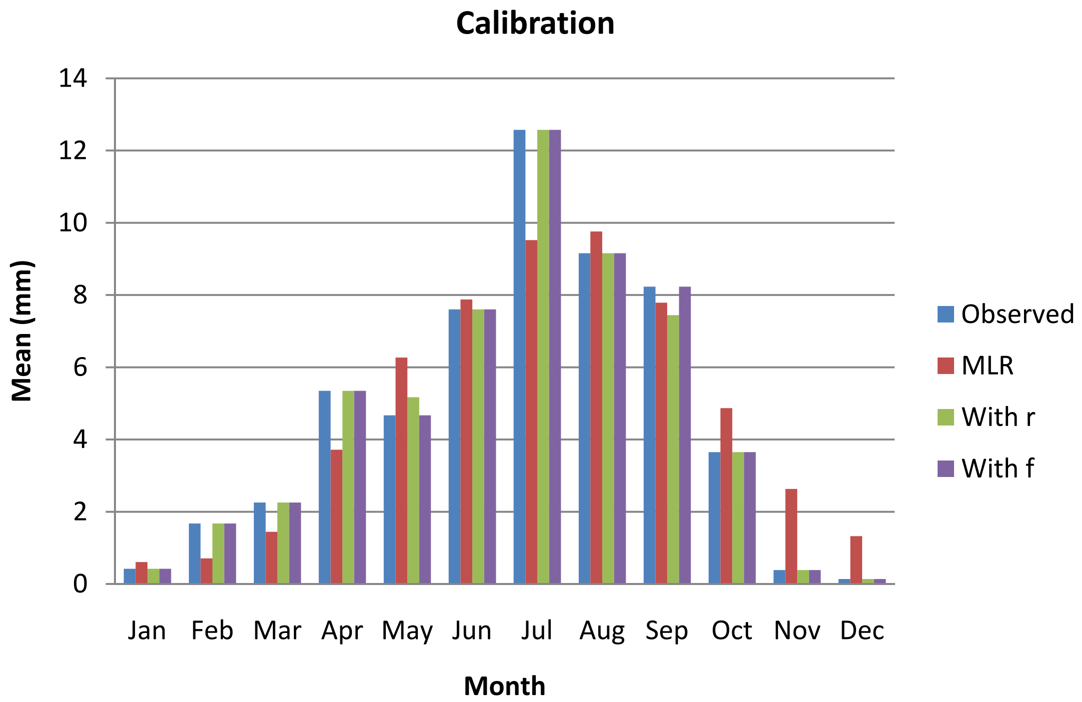

Fig 6.18 Calibration for Sockieting using HadCM3

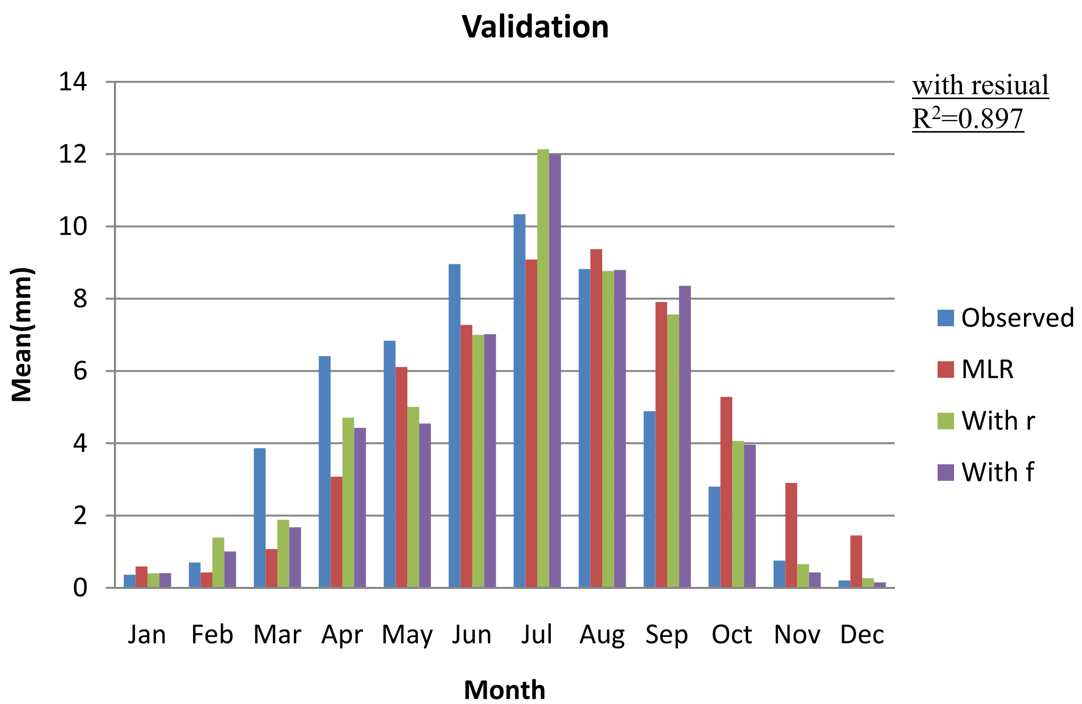

Fig 6.19 Validation for Sockieting using HadCM3

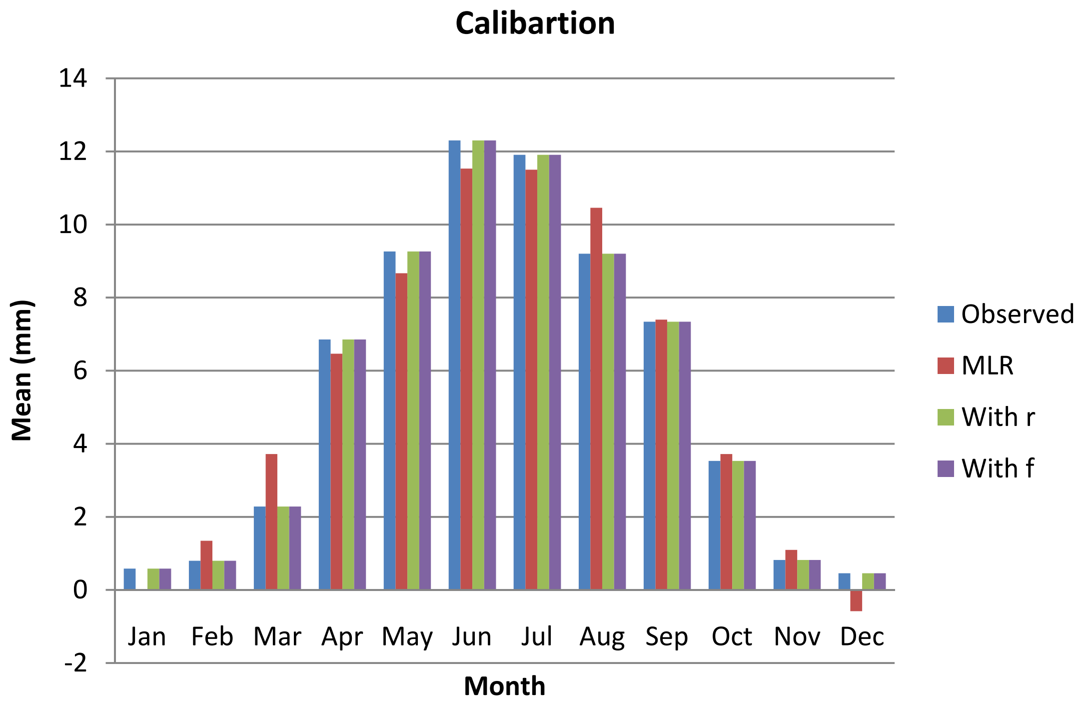

Fig 6.20 Calibration for Bokakhat using NCEP

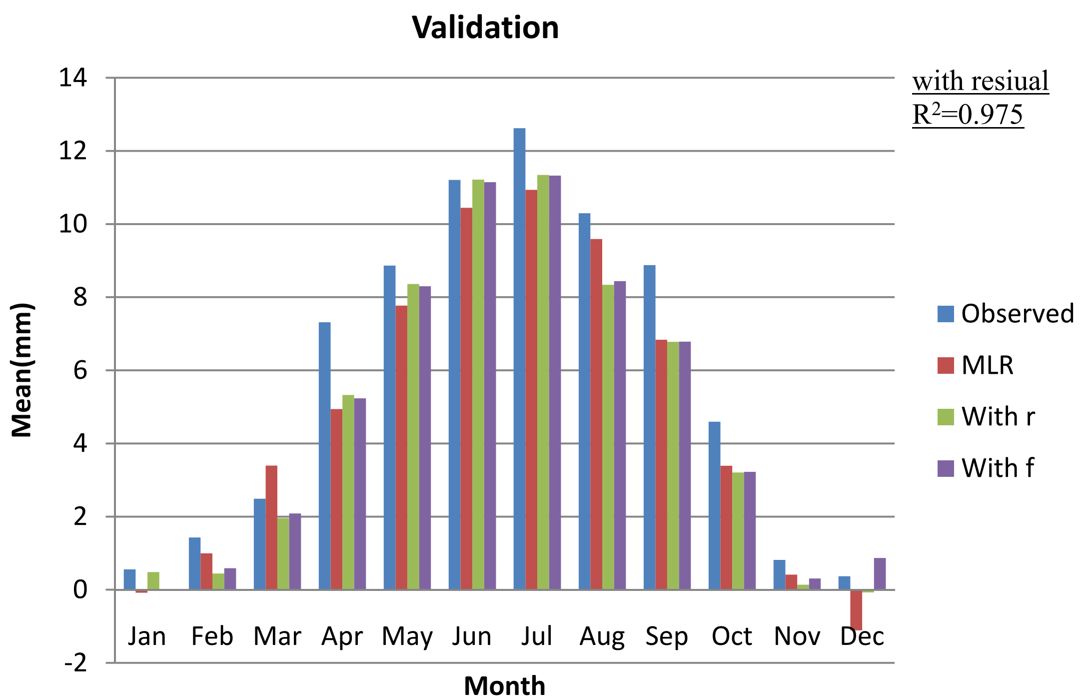

Fig 6.21 Validation for Bokakhat using NCEP

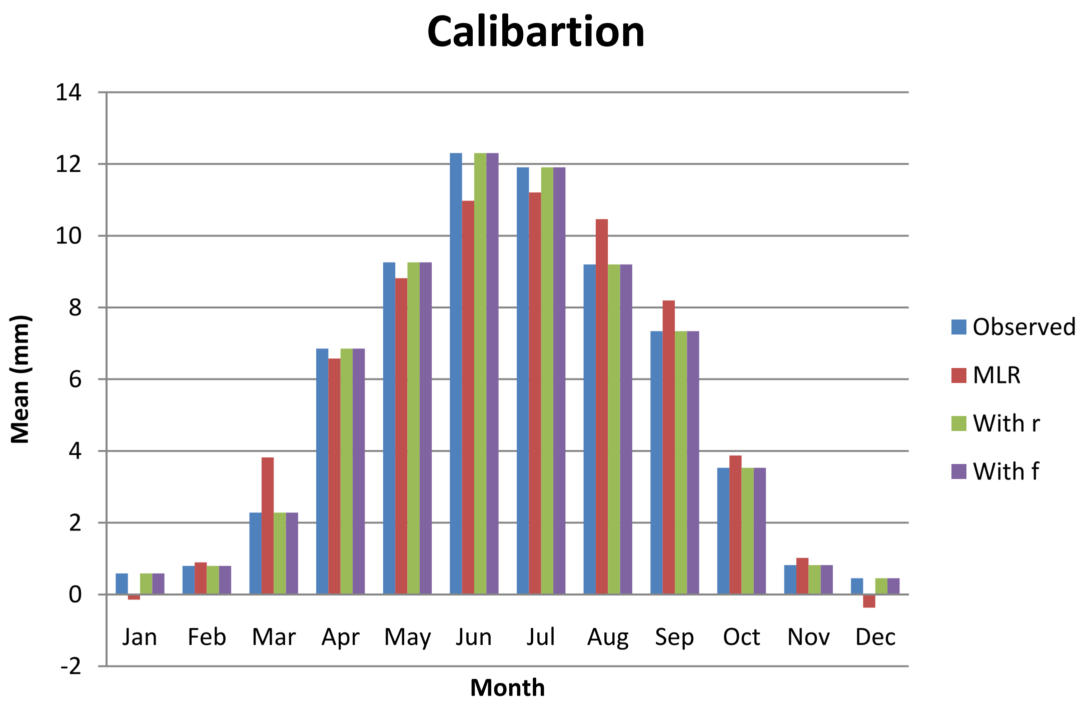

Fig 6.22 Calibration for Bokakhat using HadCM3

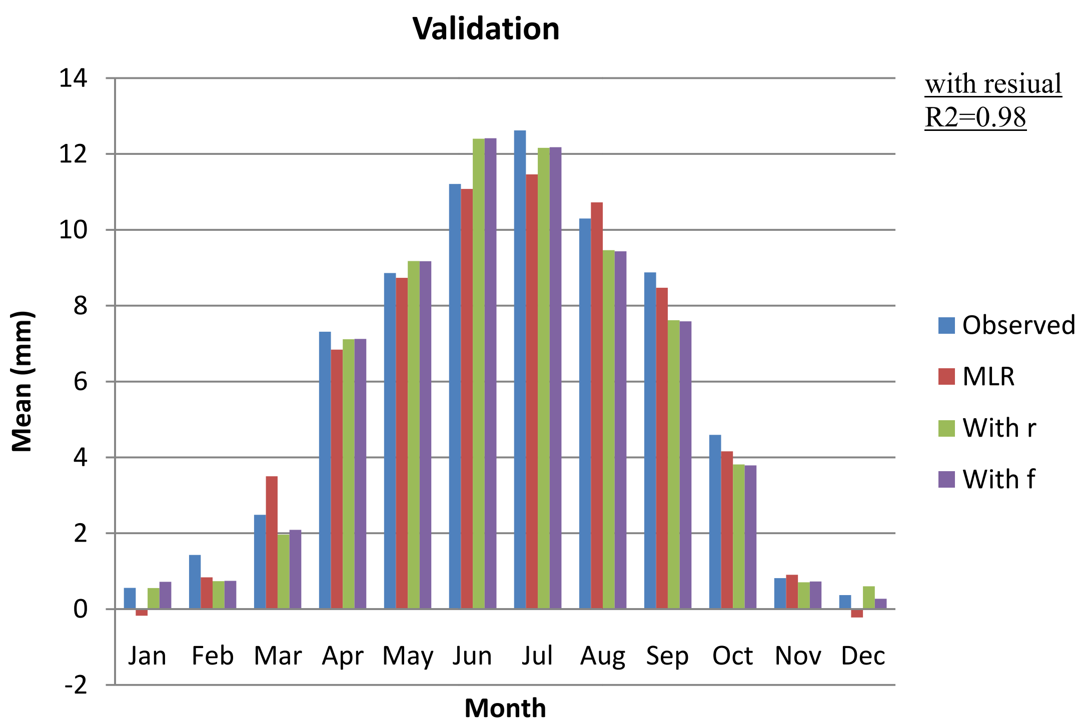

Fig 6.23 Validation for Bokakhat using HadCM3

The above results clearly show that CGCM3 is better than HadCM3 for Furkatting, Lengree, Rungagora, and Sockieting. NCEP model for Bokakhat is suitable for HadCM3. Therefore for future prediction CGCM3 Model has been used for first four stations and HadCM3 (IPCC_AR3) has been used for Bokakhat station.

6.3.8 Model for dry days

No. of dry days has been computed for Furkatting, Lengree, Rungagora and Sockieting. The time period is 2001 to 2010 for both observed and GCM data. Alternative years have been chosen for calibration and remaining years for validation. The results are presented below.

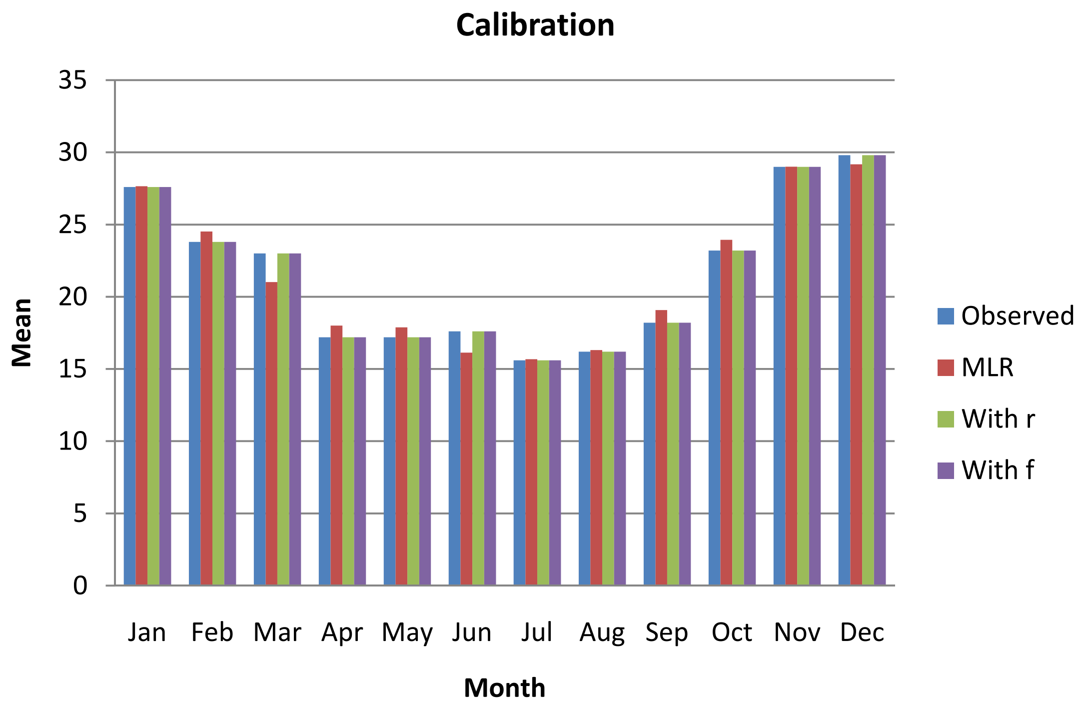

Fig. 6.24 Calibration for Furkatting Using CGCM3

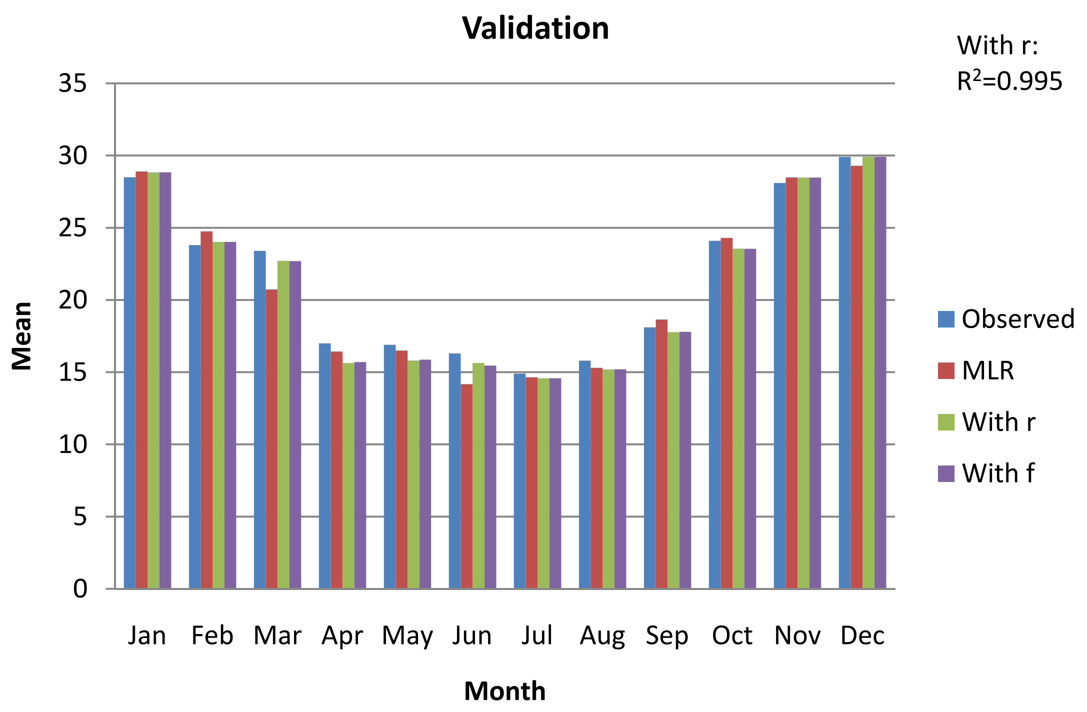

Fig. 6.25 Validation for Furkatting Using CGCM3

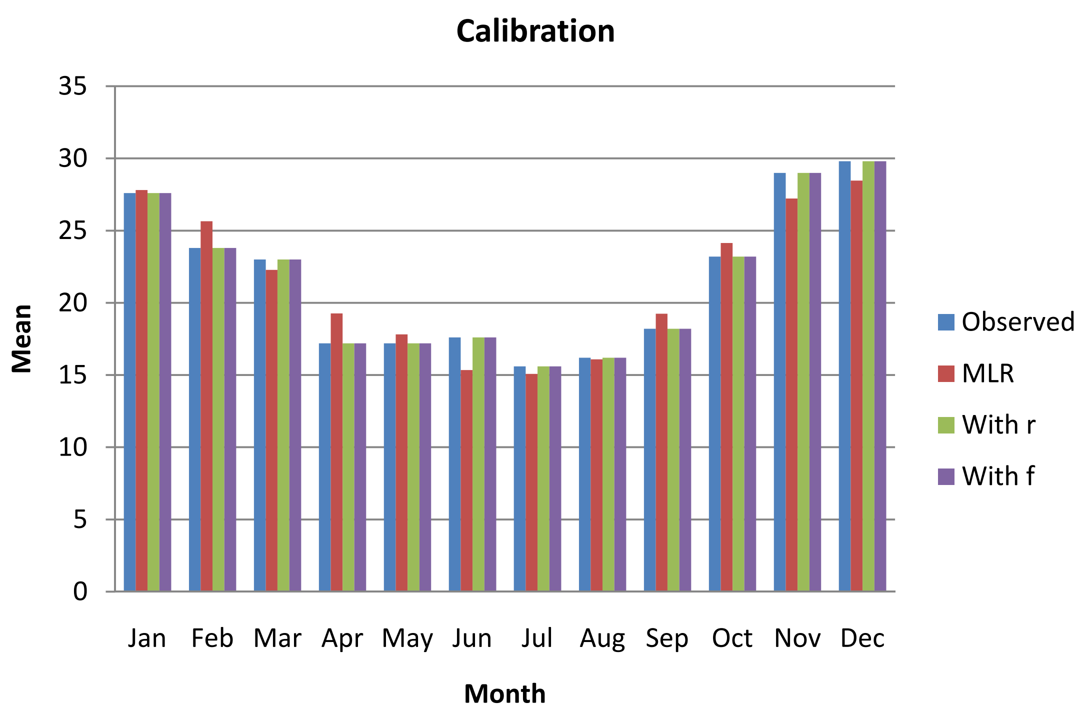

Fig. 6.26 Calibration for Furkatting using HadCM3

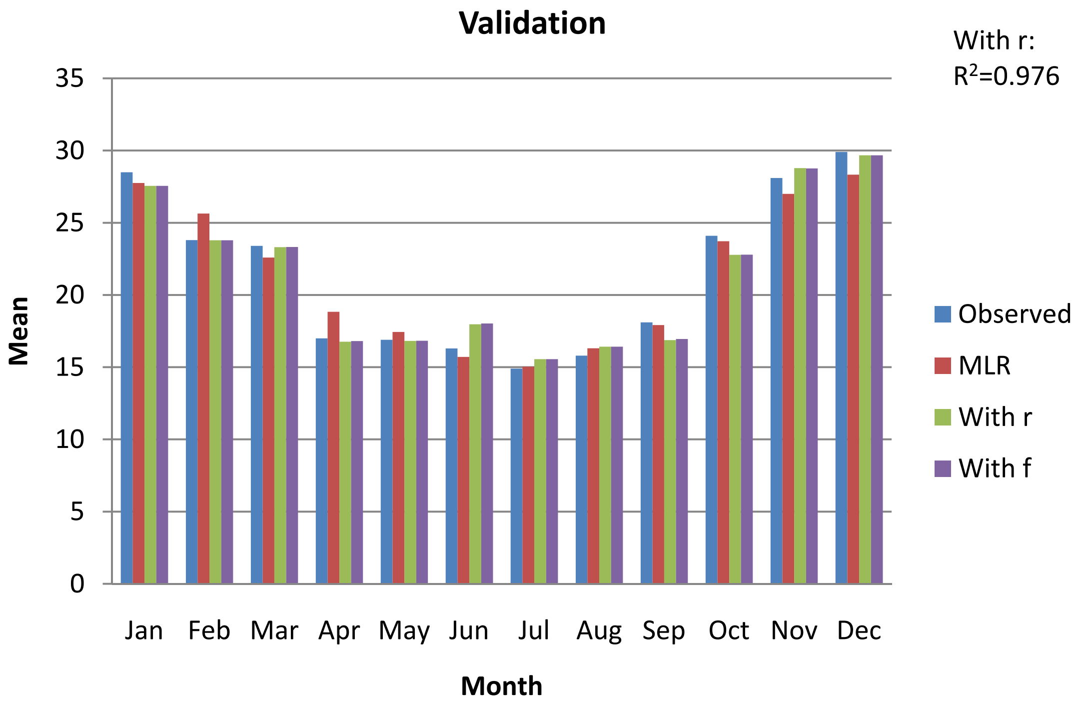

Fig. 6.27 Validation for Furkatting using HadCM3

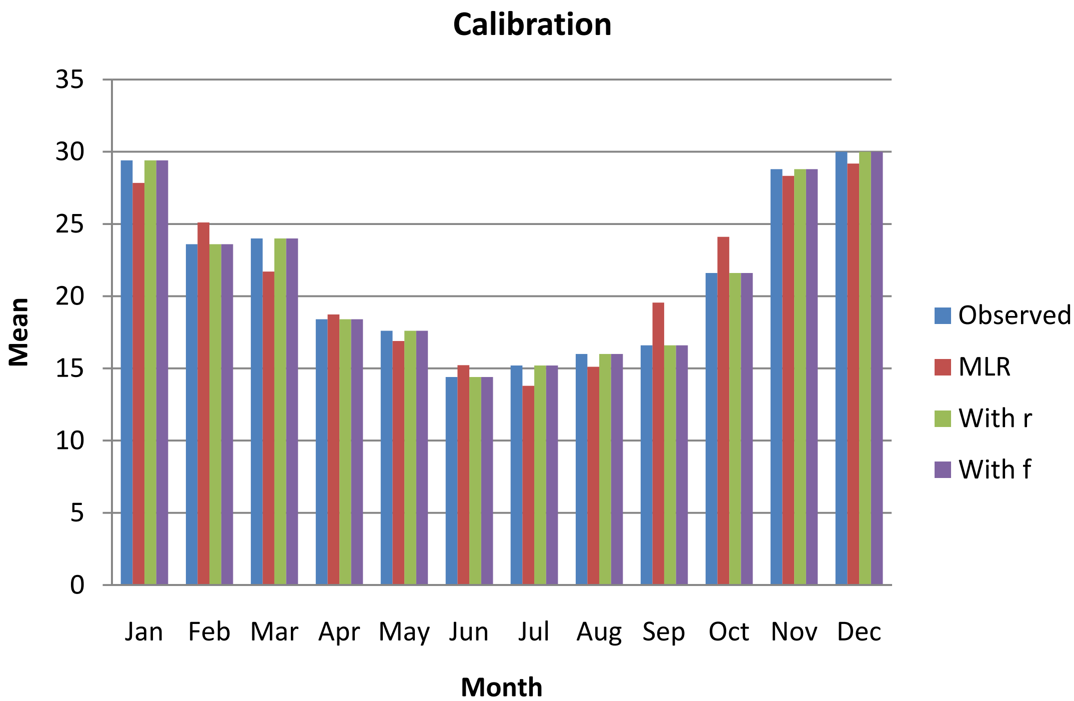

Fig. 6.28 Calibration for Lengree using CGCM3

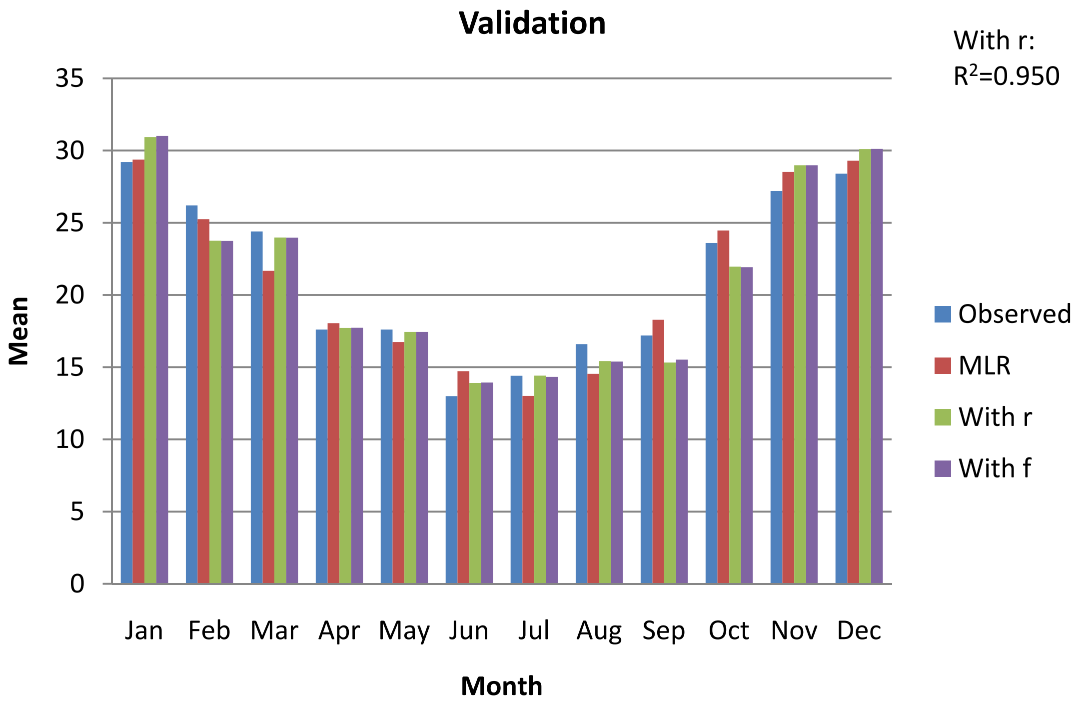

Fig. 6.29 Validation for Lengree using CGCM3

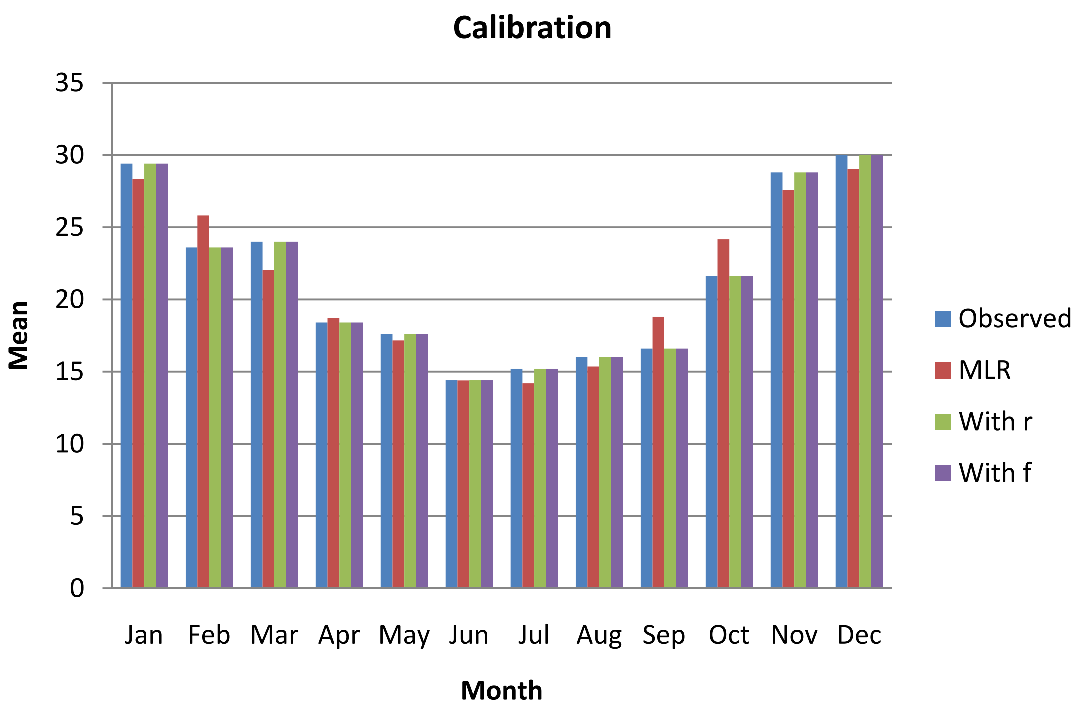

Fig. 6.30 Calibration for Lengree using HadCM3

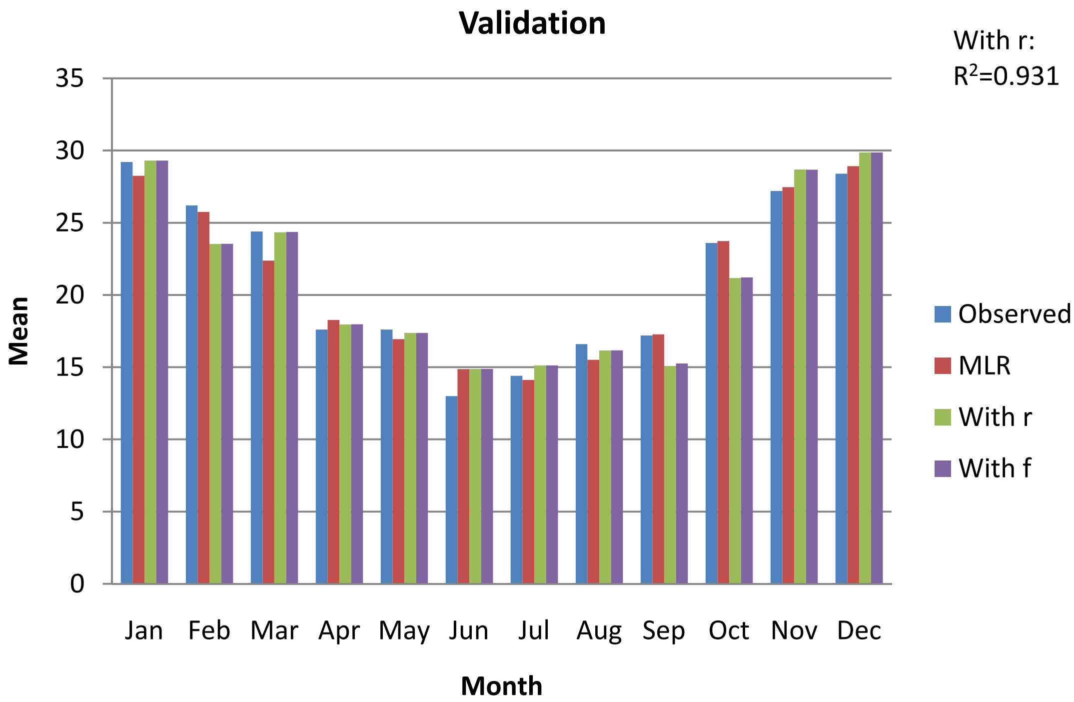

Fig. 6.31 Validation for Lengree using HadCM3

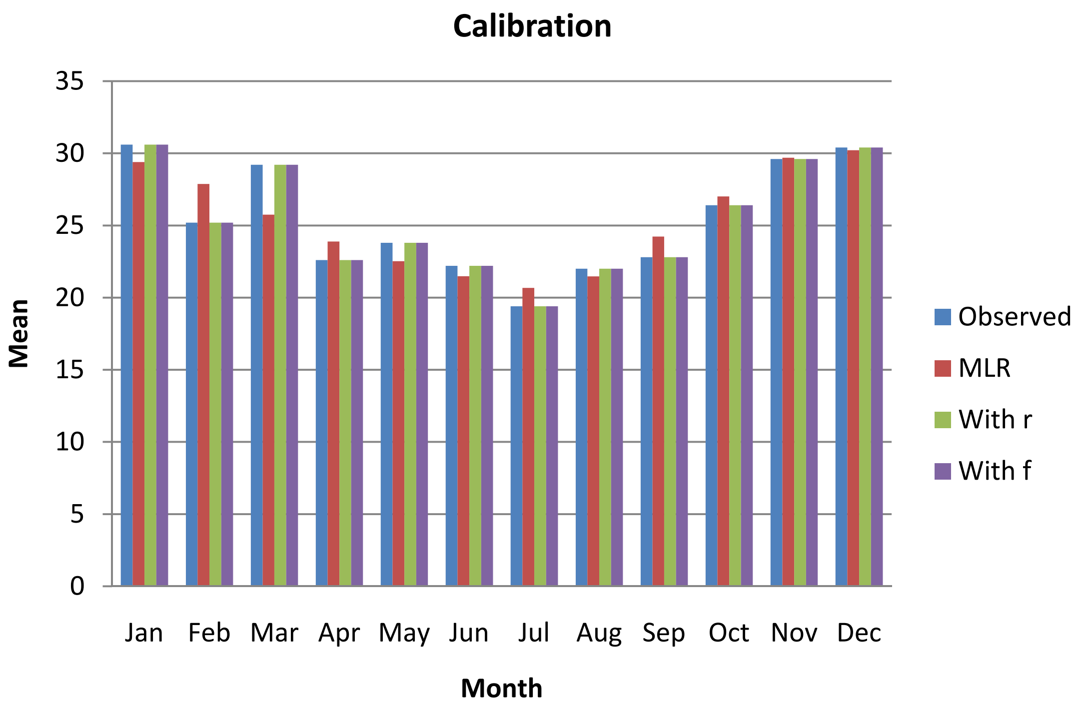

Fig 6.32 Calibration for Rungagora using CGCM3

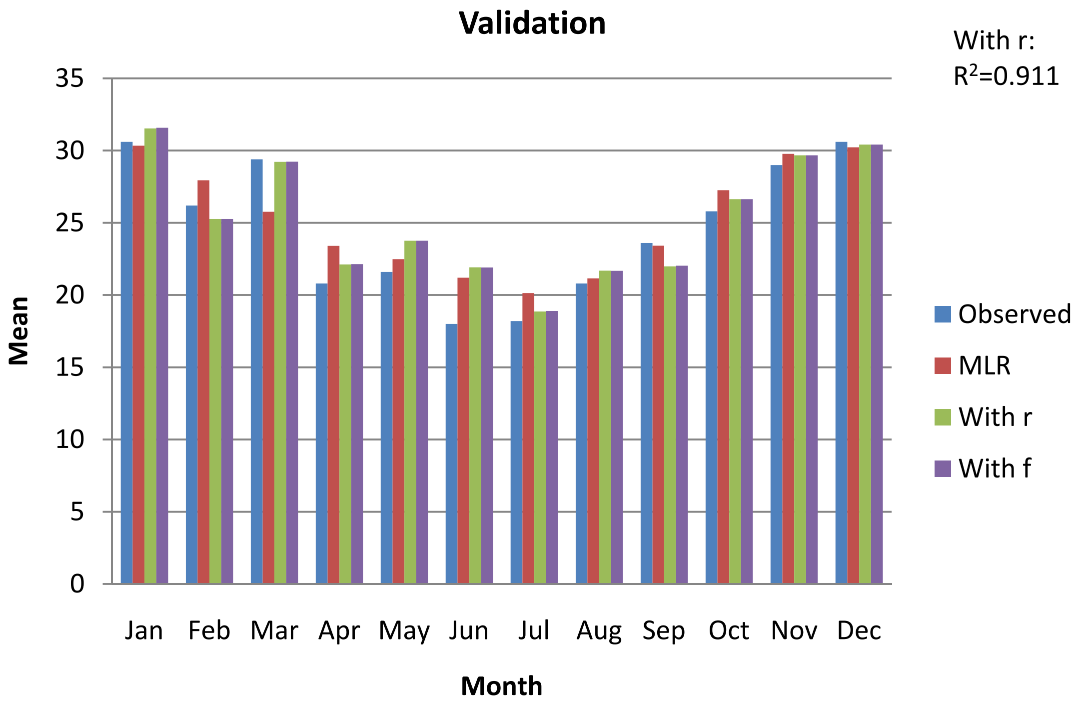

Fig 6.33 Validation for Rungagora using CGCM3

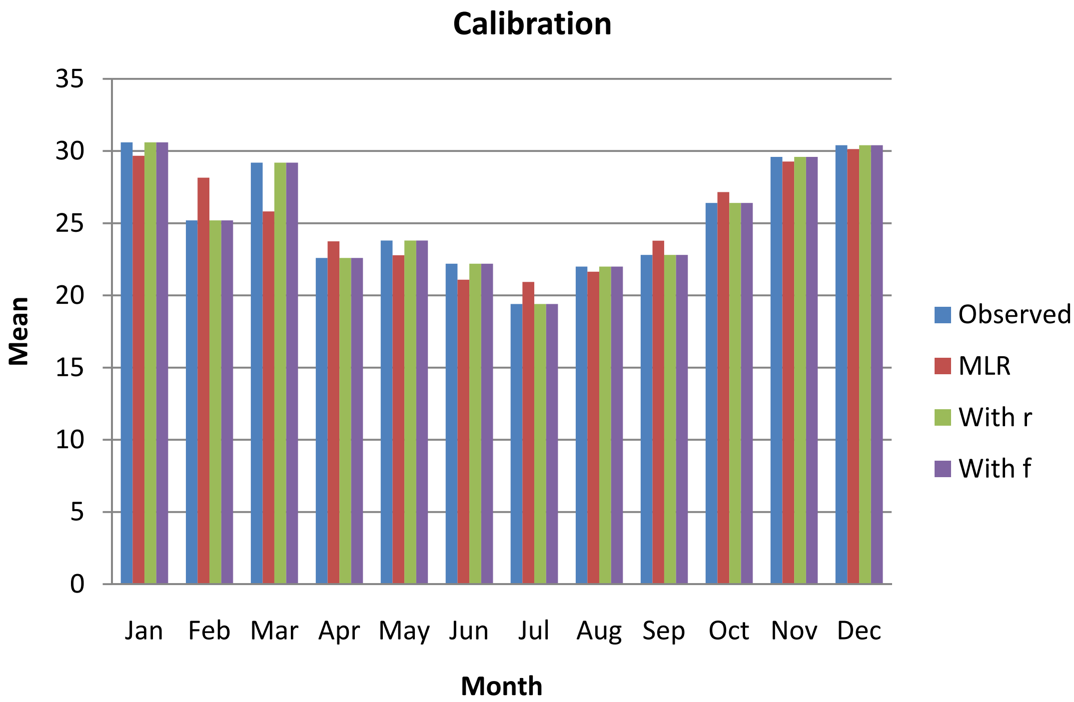

Fig 6.34 Calibration for Rungagora using HadCM3

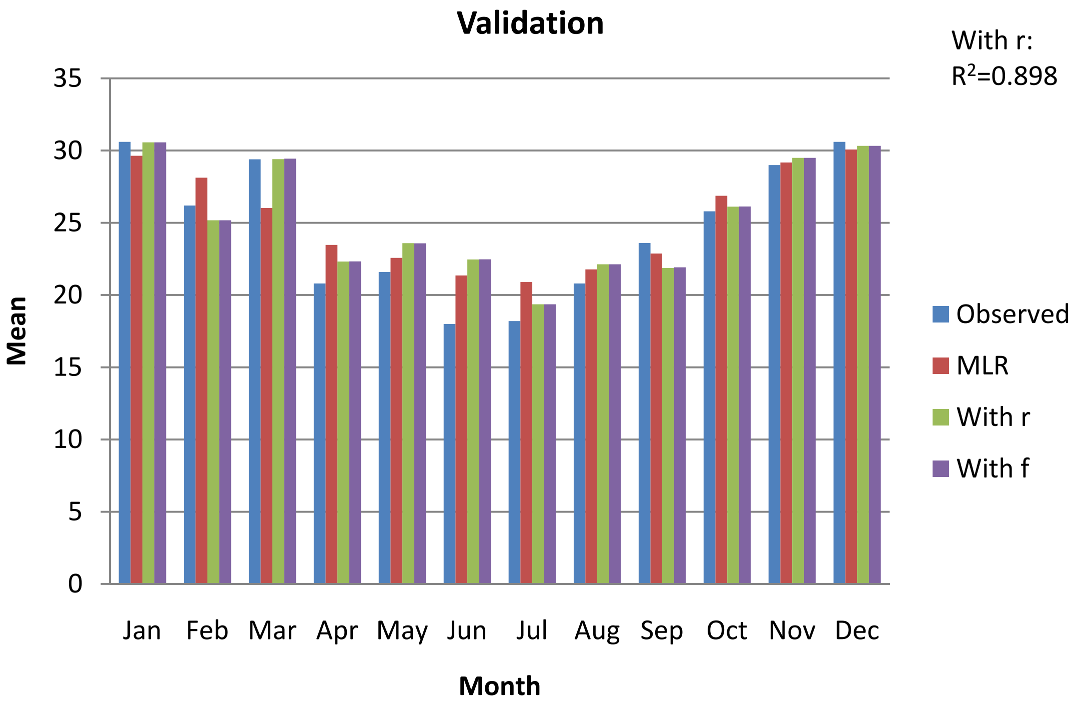

Fig 6.35 Validation for Rungagora using HadCM3

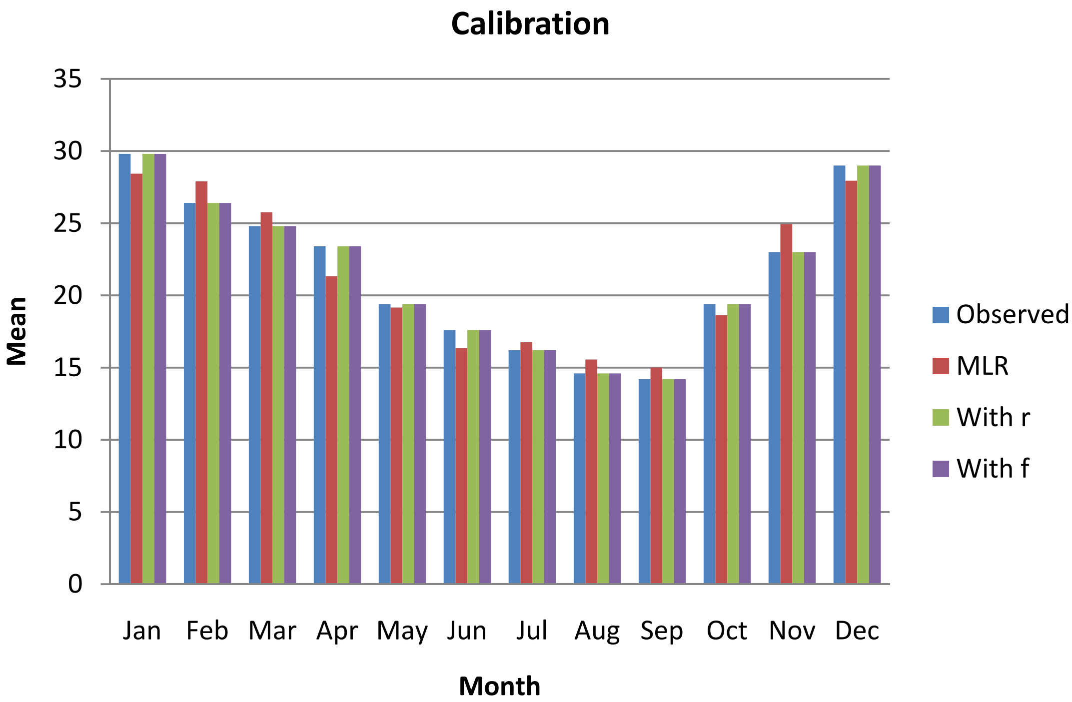

Fig. 6.36 Calibration for Sockieting using CGCM3

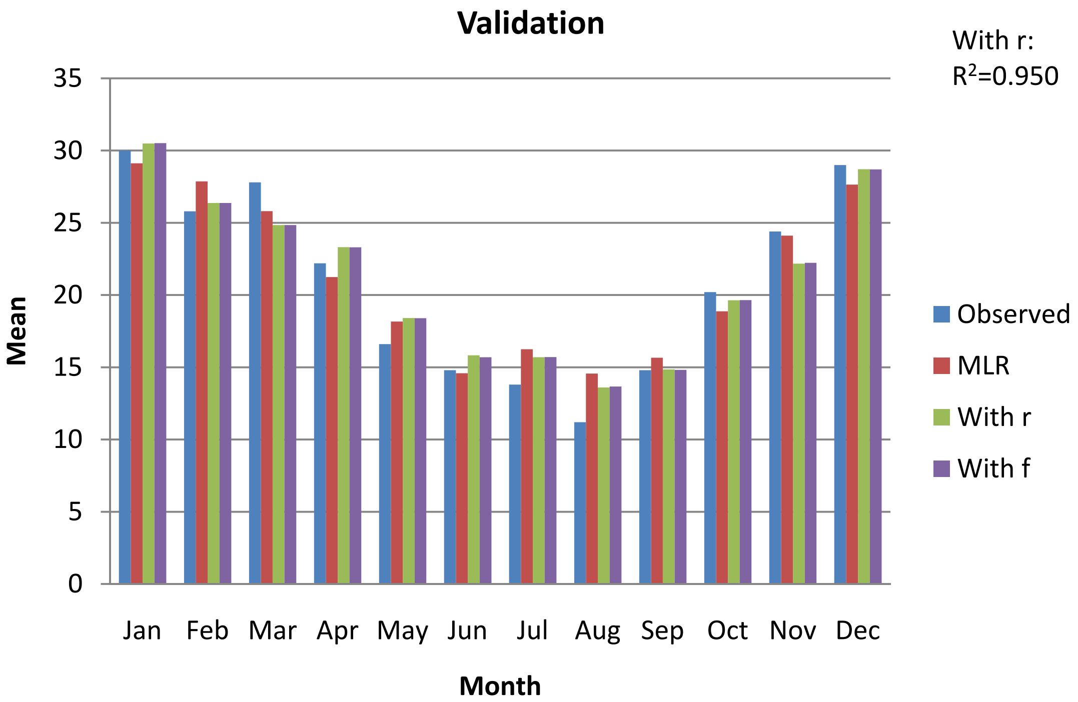

Fig. 6.37 Validation for Sockieting using CGCM3

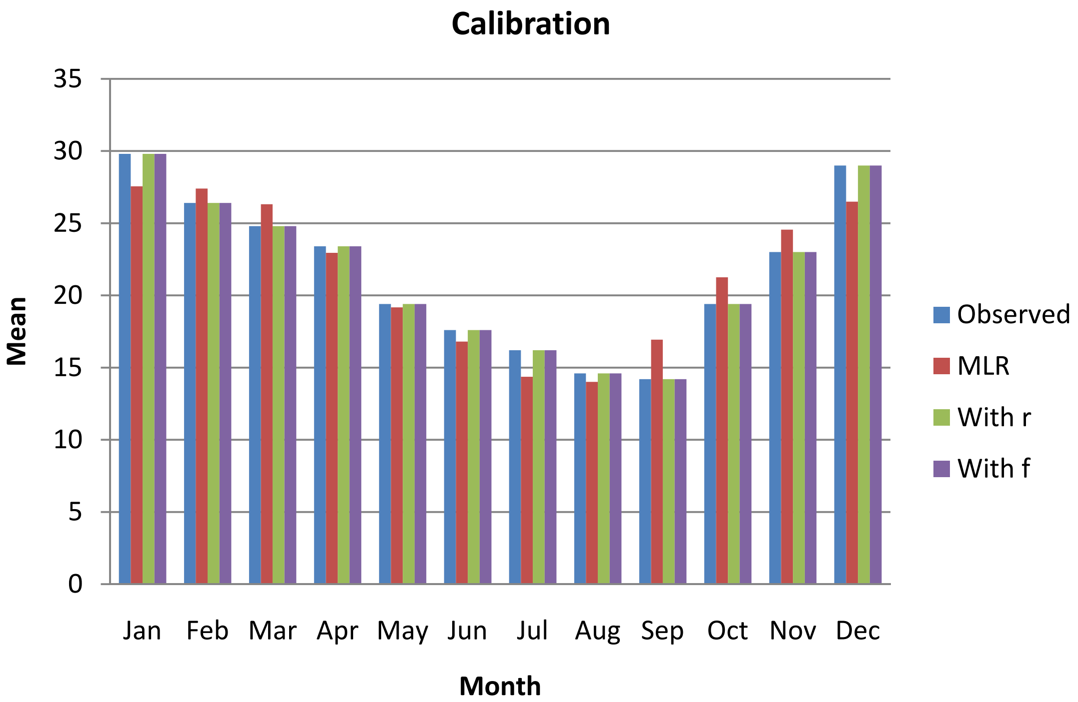

Fig. 6.38 Calibration for Sockieting using HadCM3

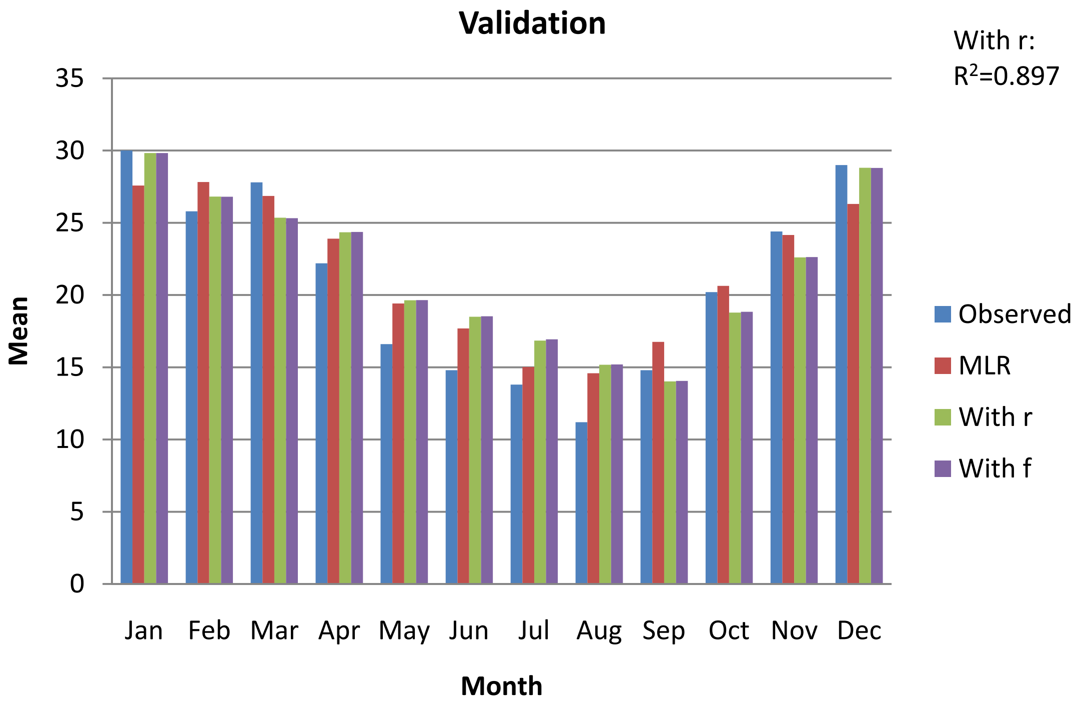

Fig. 6.39 Validation for Sockieting using HadCM3

The validation on the model for number of dry days with CGCM3 is better the HadCM3. Therefore CGCM3 model has been used for predicting future numbers of dry days.

6.4 Future Genaration

The precipitation and number of dry days has been forecasted. The statistical downscaling models have been used to predict the future three set of data 2011 to 2040, 2041to 2070, 2071 to 2100. CGCM3 model with A2 Scenario has been used for the forecasting. The outputs are plotted below.

6.4.1 Forecasting Precipitation

The precipitation has been forecasted using the model and presented below.

In the below graphs, fig. 6.40 shows that the precipitation in the monsoon period for **Furkatting** station decreases but increases in the post-monsoon period. Past data shows that precipitation occurs more in July than in September and the predicted future data shows that the precipitation occurs more in September than in July but predicted peak flow occurs in August in both the cases and increases by 48% in the future.Fig. 6.41 shows that the peak flow for **Lengree** station occurs in June for the past data and in August for the predicted future data. The predicted data shows that the peak flow decreases by 9% in June but increases by 21% in August. This implies that the total shift in the rainfall season towards the post-monsoon period.

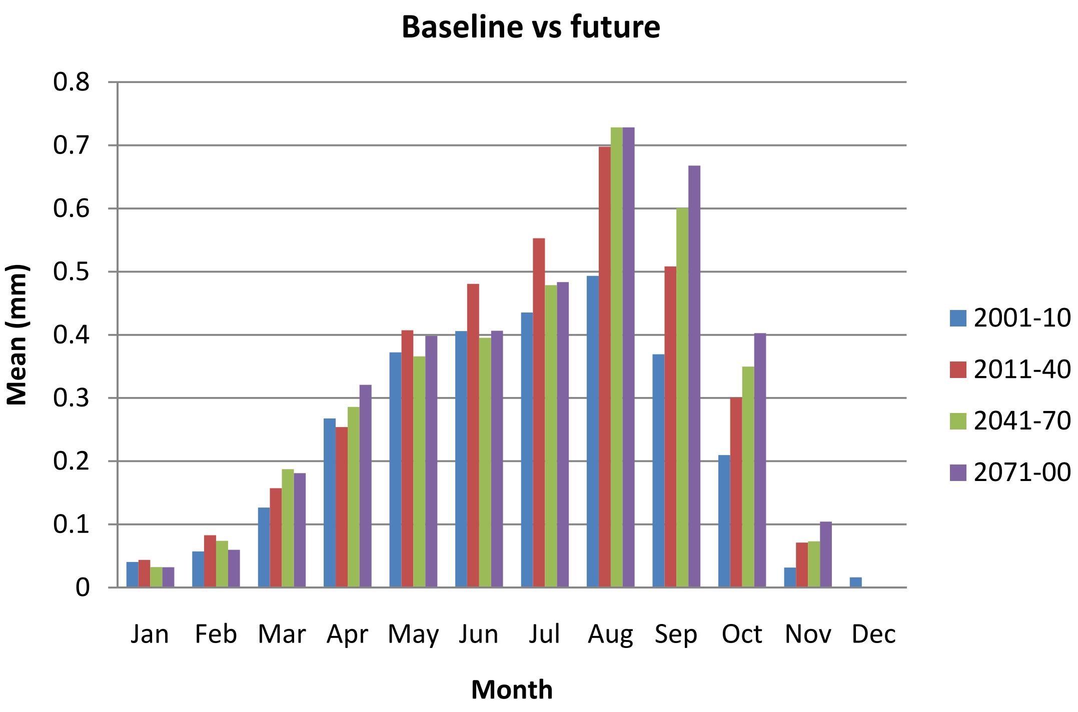

Fig. 6.40 Comparison of baseline and future precipitation in Furkatting Station

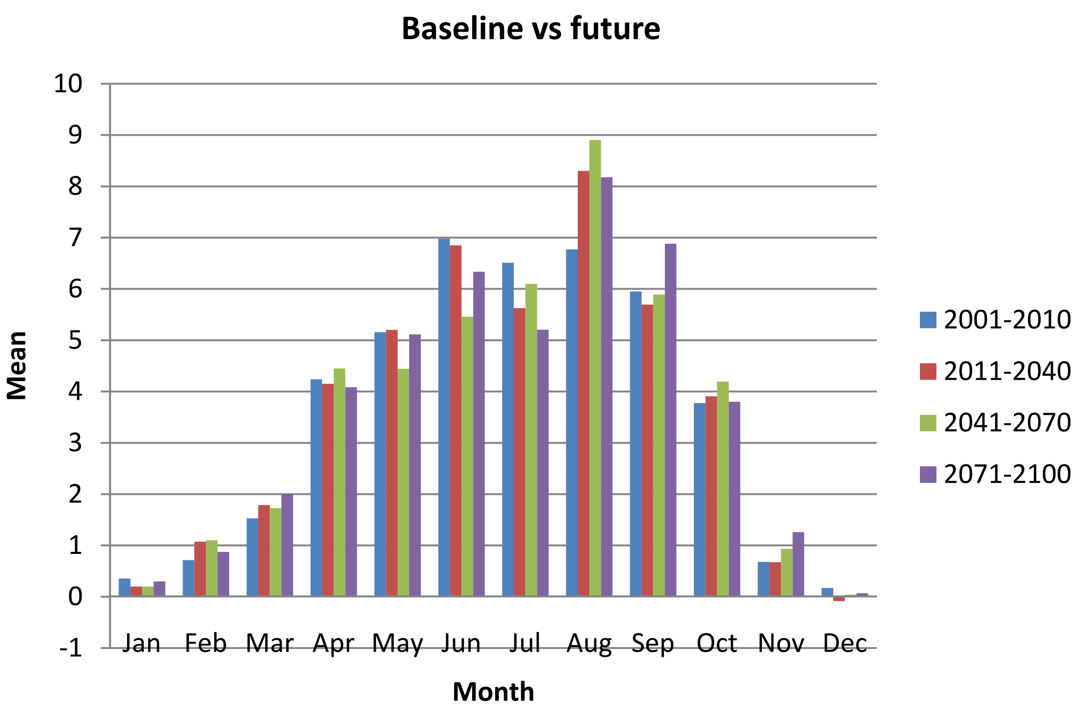

Fig. 6.41 Comparison of baseline and future precipitation in Lengree Station

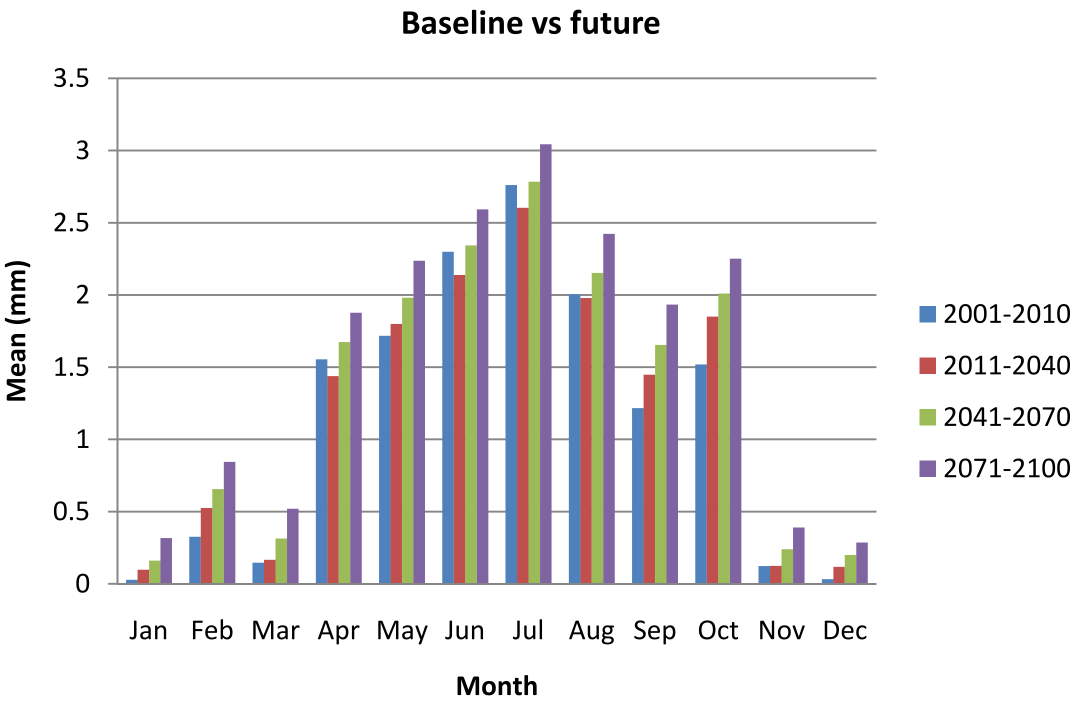

Fig 6.42 Comparison of baseline and future precipitation in Rungagora Station

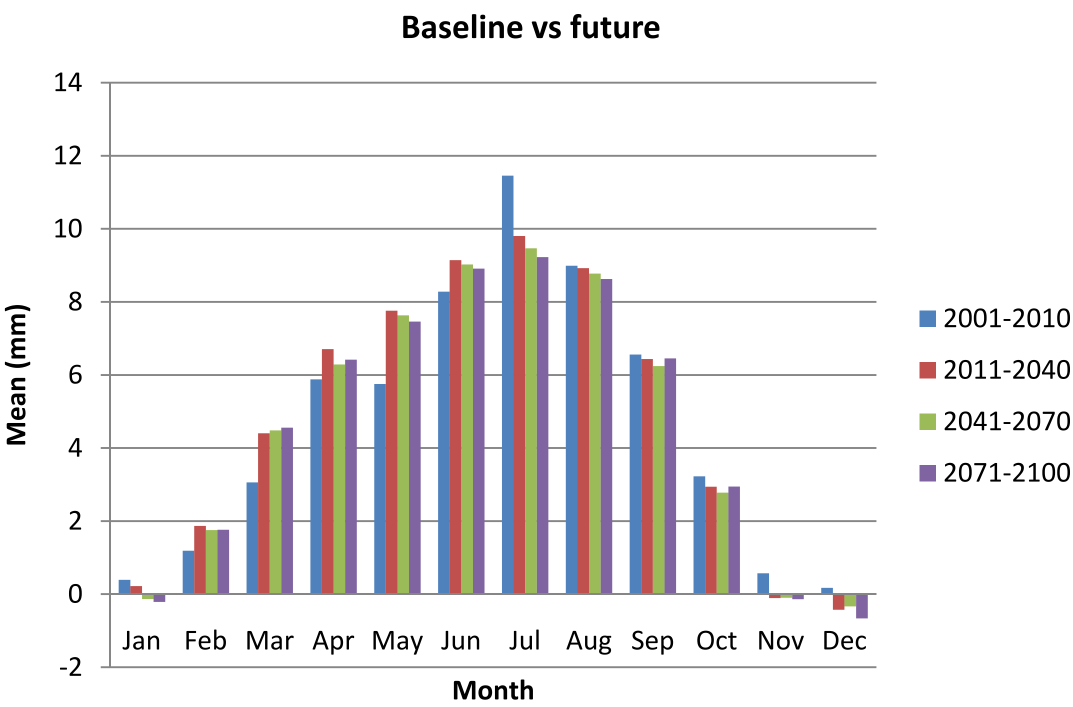

Fig. 6.43 Comparison of baseline and future precipitation in Sockieting Station

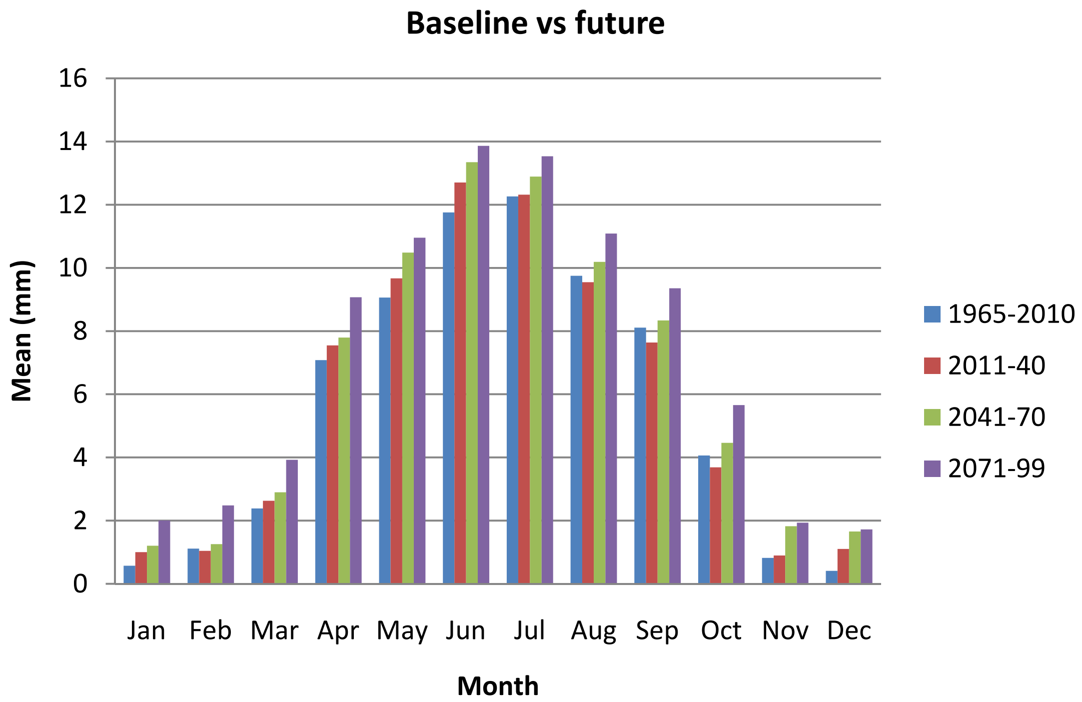

Fig. 6.44 Comparison of baseline and future precipitation in Bokakhat Station

Fig. 6.42 shows the variation of predicted and past precipitation. This graph shows that the precipitation for **Rungagora** decreases in the months January till August for the first three decades and increases in the months September till December for the same period. But the precipitation increases in all the months for the next six decades. The peak flow occurs in July for all the decades. The decrease in peak flow for the first three decades is 5.6% and the increase in the peak flow for the next last decades is 10%.

Fig 6.43 shows that the precipitation for **Sockieting** increases in the months January till June but decreases in the months July till December. Peak rainfall occurs in July and decreases by 19%.

Fig 6.44 shows that the precipitation for **Bokakhat** increases for all the months. Peak rainfall occurs in the month of June with an increase of 18%.

6.4.2 Forecasting dry days

The Number of dry days has been forecasted using the model and presented below.

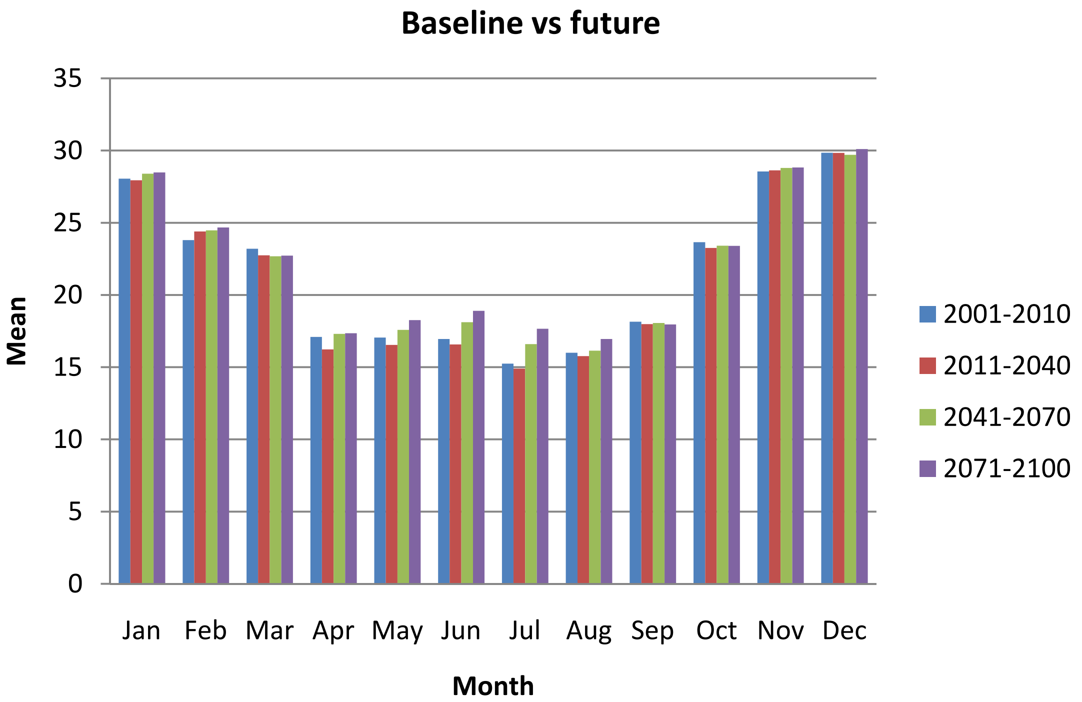

Fig. 6.45 Comparison of baseline and future number of dry days in Furkatting

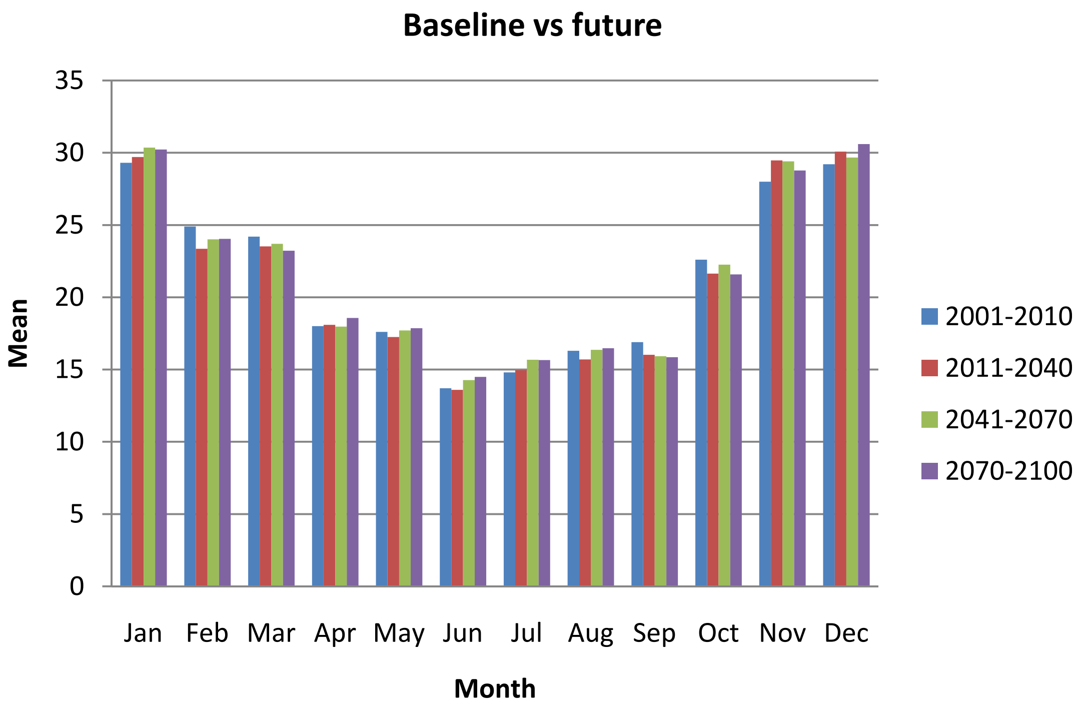

Fig. 6.46 Comparison of baseline and future number of dry days in Lengree

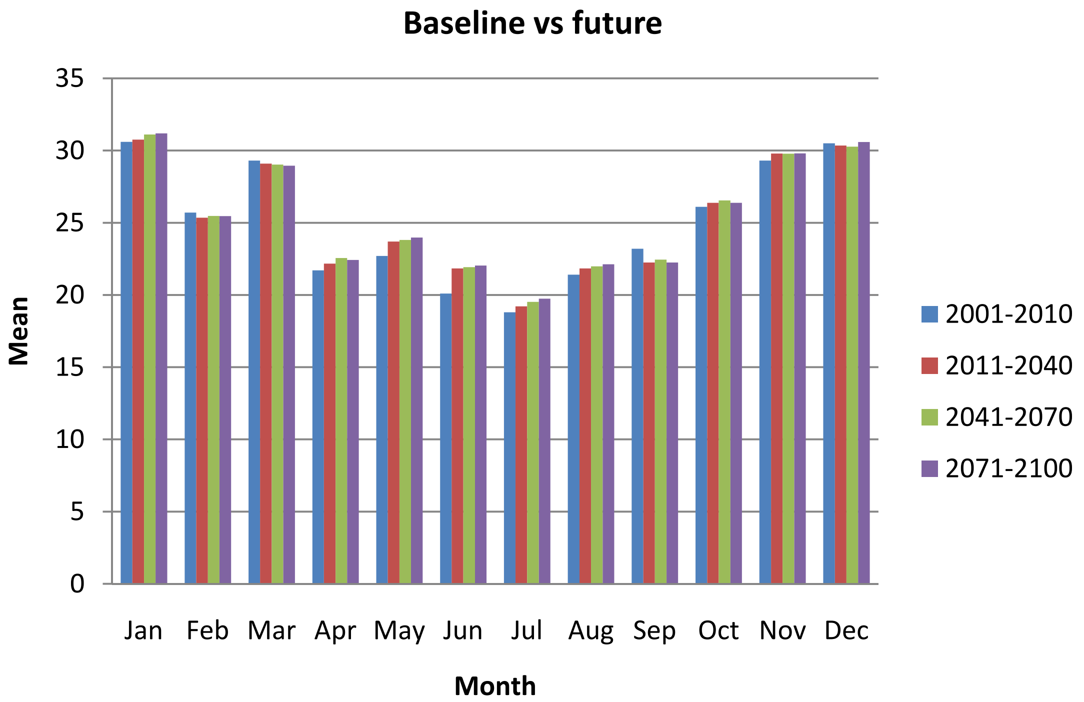

Fig 6.47 Comparison of baseline and future number of dry days in Rungagora

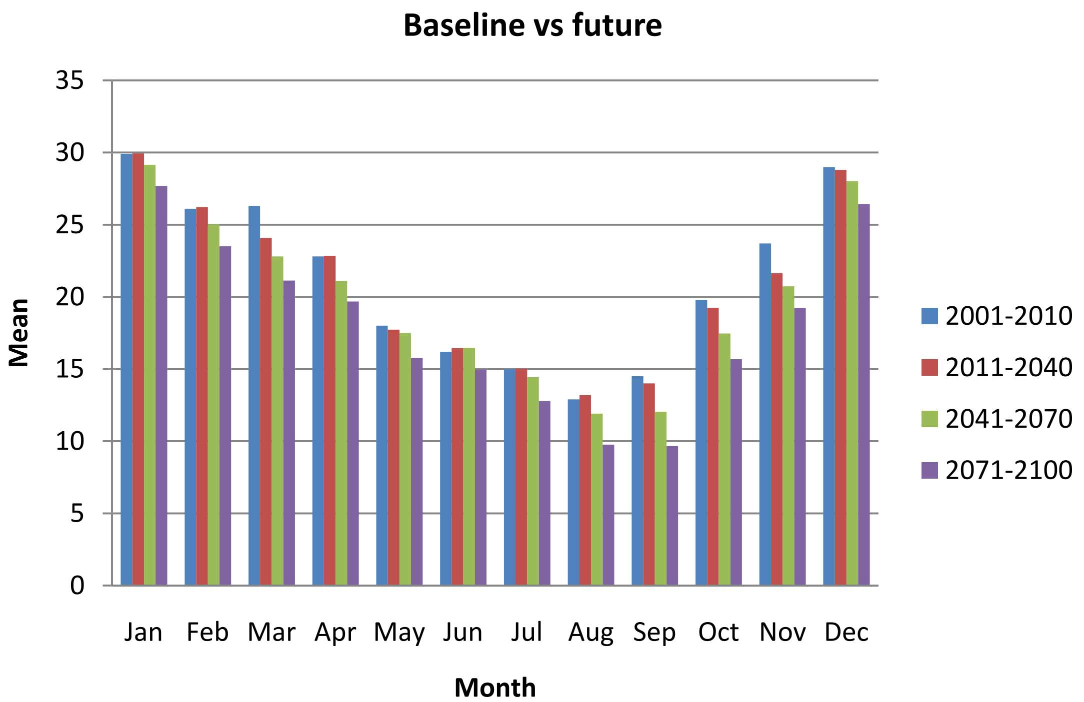

Fig. 6.48 Comparison of baseline and future number of dry days in Sockieting

The above figures show that the number of dry days increases in the future, as the peak flows increases, except in Sockieting where the number of dry days decreases in future with the decrease in the peak flow.

6.5 Forecasting Intensity of Rainfall

The above plot shows clearly that in the future, the total precipitation increases and at the same time number of dry days also increases. Due to this phenomenon, the variation of average rainfall intensity in future rainfall in the future has been computed for each station.

The average intensity of rainfall (i_{avg}) is calculated by dividing the monthly average precipitation to the number of rainy days. Number of rainy days has been computed through the subtraction of number of dry days from the total number of days in a month.

$$i_{avg} = \frac{monthly\ average\ daily\ precipitation\ depth \times 30}{(total\ no.\ of\ days\ in\ a\ month - no.\ of\ dry\ days\ in\ a\ month)}$$

The average rainfall intensity for each station has been given below.

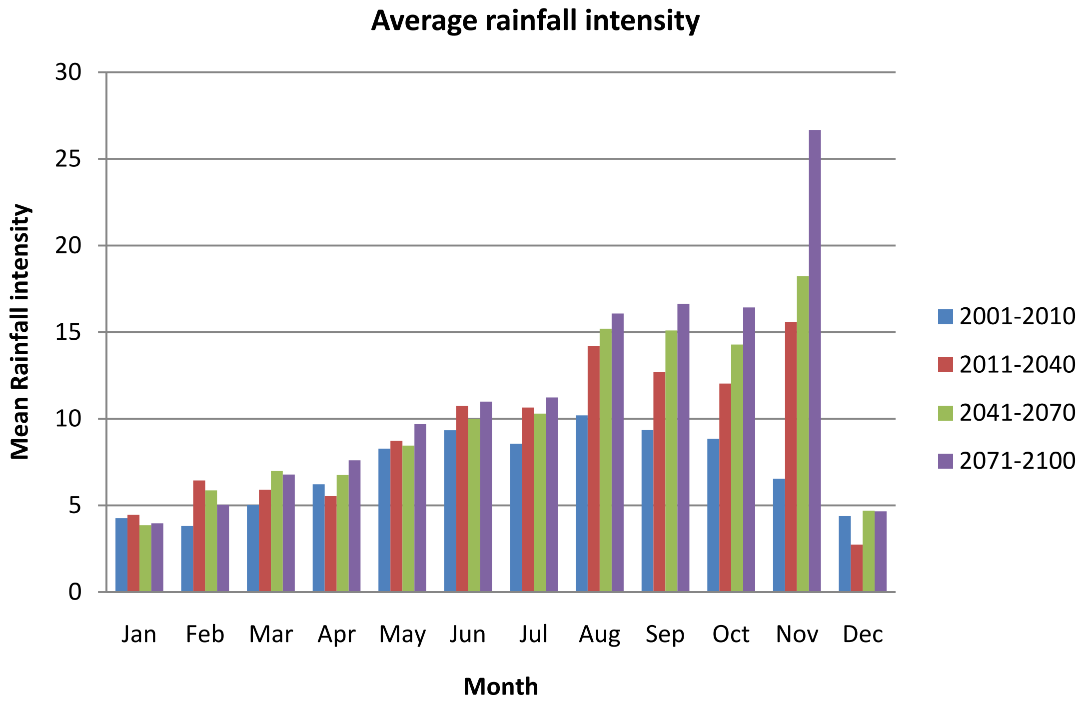

Fig. 6.49 Comparison of present and future i_{avg} for Furkatting station

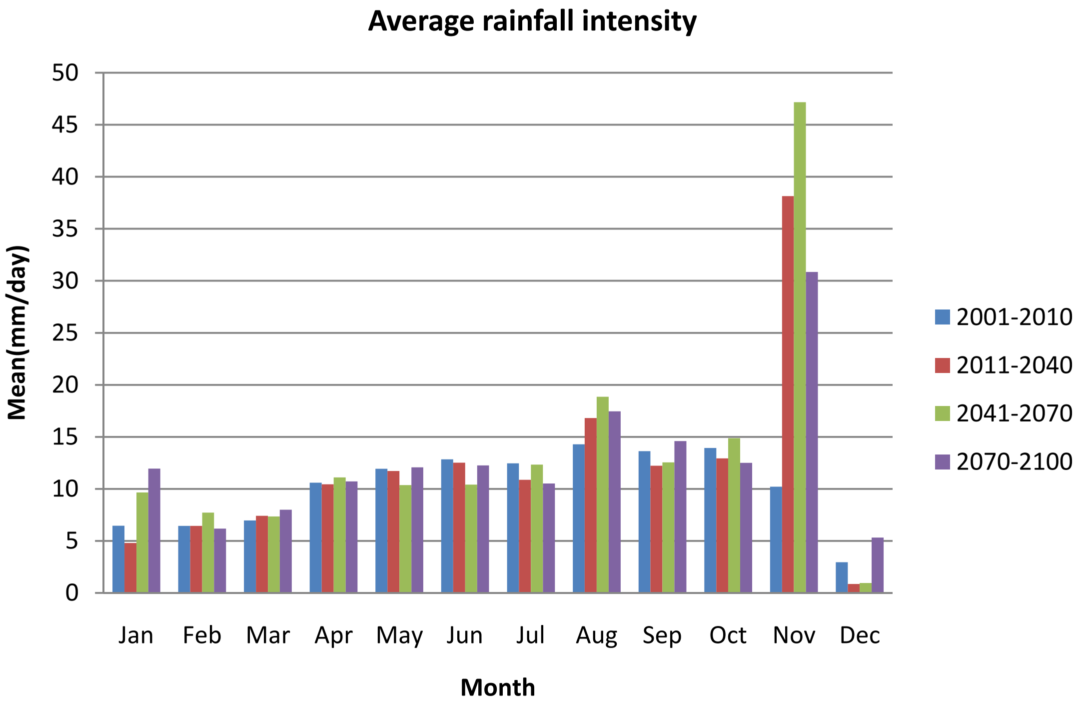

Fig. 6.50 Comparison of present and future i_{avg} for Lengree station

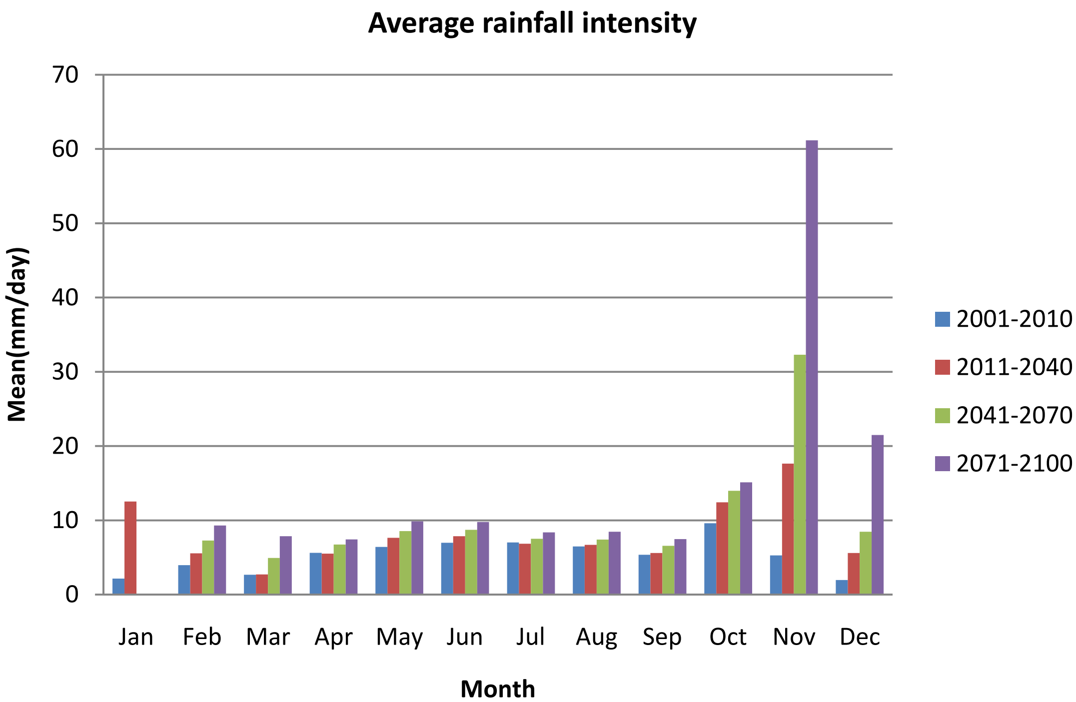

Fig. 6.51 Comparison of present and future i_{avg} for Rungagora station

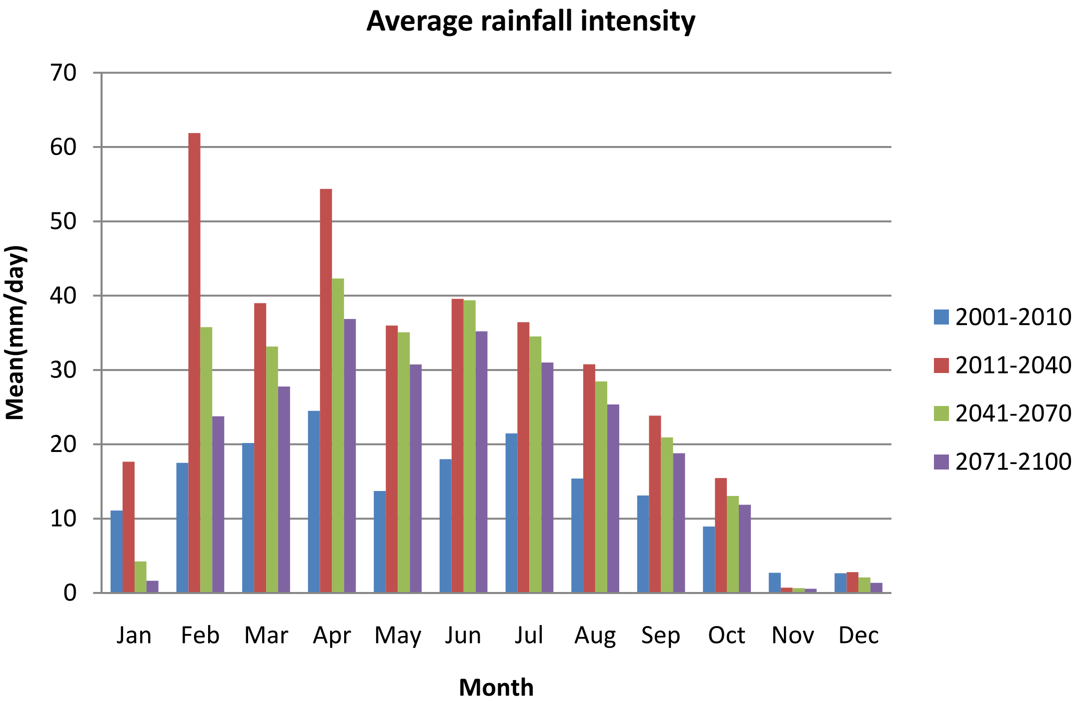

Fig. 6.52 Comparison of present and future i_{avg} for Sockieting station

In Furkatting station, the average intensity of rainfall slightly decreases in January and February but increases in rest of the months, in the future. In August, September, October and November, the rainfall intensity is too high, which may lead to flood. In Lengree the intensity of rainfall slightly decreases in monsoon period but increases in non-monsoon period. In Rungagora, the rainfall intensity increases throughout the year and in Sockieting the rainfall intensity increases in the first 30 years and decreases in the later years. But, in all the stations, the future rainfall intensity increases due to the climate change. Therefore, the increasing trend of rainfall intensity will increase the runoff in future, which increases the flow in the river that affects the river morphology.

6.6 Conclusion

From the climate change study of Golaghat district it is seen that rainfall intensity (mm/day) will increase in future causing more erosion and flood. At the same time number of dry day will also increase, as such this will lead to drought situation. So, planning of water management needs to be done more conservatively for both flood and drought situations. An increase of 20% in rainfall intensity is recommended for the design and irrigation planning and water supply planning need to be done considering the fact that number of dry day will increase in future. While it is difficult to say the length of continuous dry spell, it is expected that with the increase of dry day length of dry spell will also increase.

7. Conclusion, General Discussion and Scope of Future Works

7.1 INTRODUCTION

Although critical comments on various findings are given in different chapters, a general conclusion and summarization of all such critical comments is attempted in this chapter. Scope of further study and future collaboration with different organizations and a Procedure for disseminating the climatic data collected under this study is also laid down in this chapter.

7.2 CONCLUSIONS

7.2.1 From the analysis of rainfall data collected from the different district it can be concluded that:

7.2.1.1 A significant variation in total yearly rainfall with time has been seen in almost all districts during the past. However, it cannot be said to follow an increasing or decreasing trend. Many a time a continuous drop in annual rainfall has been observed for 5 to 6 years and then a rising trend has been seen. Therefore, a decision regarding rainfall trend should not be taken based on observation of rainfall series of small length.

7.2.1.2 Monthly distribution of rainfall also varies from time to time. Therefore, in agricultural planning, possibility of having unexpected adverse condition should always be kept in mind.

7.2.1.3 Observation of maximum daily rainfall has revealed that extremely high daily rainfall as compared to its normal value can occur during the monsoon period. Such high intensity rainfall can cause devastating erosion and flood.

7.2.2 From the trend analysis carried out on past data of temperature, it is seen that maximum and minimum temperature have a increasing tends to in Tinsukia, Golaghat and K.Anglong District. On the other hand for North Lakhimpur district, visible change is not there in maximum temperature, but minimum temperature is showing an increasing trend. The impacts of these changes need to be studied for different sectors of economy.

7.2.3 Some measures have been suggested for mitigation of various water related agricultural problem. It is suggested that for efficient and comprehensive water management, watershed based approach should be adopted, which calls for horizontal coordination between different group falling under the watershed and such coordination becomes a pre-requisite. Therefore, management plan should be designed for mutual benefit of all concerns.

7.2.4 Rain water harvesting can not only benefit the agricultural area, but can also contribute towards flood mitigation at downstream. Some effort of rainwater harvesting has been made on experimental basis with support of some tea gardens. After analysing economic aspects such methods can be replicated in different gardens.

7.2.5 Traditional concept of watershed management basically talks about conservation practices for soil, water and vegetation to avoid flood, drought etc. However, to ensure economic sustainability and social acceptability, the concept of watershed management can be redefined as management practices that help in soil and water conservation as well as improve economic condition of the people of that locality, which in turn helps improving working and living conditions of human and other living being under various water scenario (Sarma 2005).

7.2.6 Whatever expenditure is made by the Government and the people, the breakeven point should reach in desired time. The project planning should consider this aspect for the benefit of the society in general.

7.2.7 There are lots of scopes for alternative erosion control measures as against the presently practiced method. The measures of controlling soil erosion with the present system many a time is not cost effective. Therefore it is necessary to evolve a cost effective method where Government, Tea gardens and public involvement is necessary. Method of using plastic net and bio system for erosion control as implemented by Polygon foundation with technical back up of IIT Guwahati can be explored in some places.

7.2.8 Scope of making tea garden self sufficient in energy sector can also be investigated as a separate project.

7.2.9 From the climate change study of Golaghat district it is seen that rainfall intensity (mm/day) will increase in future causing more erosion and flood. At the same time number of dry day will also increase, as such this will lead to drought situation. So, planning of water management needs to be done more conservatively for both flood and drought situations. An increase of 20% in rainfall intensity is recommended for the design and irrigation planning. Similarly, water supply planning need to be done considering the fact that number of dry day will increase in future. While it is difficult to say the length of continuous dry spell, it is expected that with the increase of dry day length of dry spell will also increase.

7.3 SCOPE FOR FUTURE WORK:

7.3.1 The long historical data series of better spatial resolution collected under this project will help for calibration of model parameters and will enable the researchers to predict climate change with high reliability in different places of the NE region. Method used in this study for downscaling can be replicated and other method can also be tried.

7.3.2 Sustainability of Tea Industry, Agriculture and small hydro projects are very important for economic development of this region. Collaborative project in these lines can be taken up with various relevant agencies for assuring sustainable economic development of this region.

7.3.3 Based on the economic analysis of the water harvesting project taken up by some of the gardens, these can be replicated in other potential area with technical support of IIT Guwahati.

7.4 Procedure to share the information

7.4.1 Arrangement will be made to get these data certified by IMD so that these can be used as an authentic data for any official use and then the data will be shared with any relevant organization.

7.4.2 Future climate change scenario developed by analyzing these data will be provided to Tea Industry and other organization for their use. Arrangement will be made to share such information by following formal procedure to be set by IIT Guwahati.

References

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2) Sarma D. (2010), *Analysis of Extreme Streamflow Condition in Brahmaputra Rive*, Masters Dissertation submitted under Prof. A.K.Sarma to IIT Guwahati for partial fulfilment of M.Tech Degree.
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4) Deka S. and A.K.Sarma (2011), *Impact of climate change on precipitation characteristics of Brahmaputra Basin,* Report submitted to climate change directorate ministry of water resources, July 2011
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ANNEXURE: I

INFORMATION OF THE TEA ESTATE AT A GLANCE

Name of the Estate…………………………………………………………………………

Name of the Company……………………………………………………………………..

Year of Establishment……………………………………………………………………

Address……………………………………. Vill……………………………………………..

Rev. Circle……………………………………….

Sub Division……………………………………..

District…………………………………………..

Phone No………………………………………..

E-mail Id………………………………………...

Geographical Position Longitude…………………………. ^{o} E

Latitude……………………………. ^{o} N

Altitude…………………………… M above MSL

Area of the Estate ………………………………. Ha

Area under Tea …………………………………... Ha

Soil Type - Structure…………………………………….

Organic matter content………………………

Soil Profile- Report submitted by deep tube well contractors.

Source of water:-

River:-

Name of the River…………………………………………………..

Distance from the Estate……………………………………….. KM

Pond:-

Size of the Pond……………………………………………….……….

Well:-

Shallow Tube well……………………………………….… M Deep

Deep tube well…………………………………………… M Deep

Ring well………………………………………………… M Deep

Any other information related to water that the estate like to contribute

a)

b)

c)

Note:- If any information is not available then it may be marked as NA (Not available)

Annexure II

…………………………………………………………………………… Tea Estate

MATEOROLOGICAL DATA

RAINFALL in mm: YEAR……………………….

Month/Date	January	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
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No of Raining days												

Annexure III

……………………………………………………………………………… Tea Estate

MATEOROLOGICAL DATA

Temperature in (degree C): YEAR………………………..

Month/Date	January		Feb		March		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
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Annexure IV

………………………………………………………………………… Tea Estate

MATEOROLOGICAL DATA

RELATIVE HUMIDITY %

Month/Date	January		Feb		March		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A
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Annexure V

……………………………………….. Estate

Meterological Data

Year………………….

Month	Sunshine (Hrs)	Wind Speed	Soil Temp.	Evaporation rate
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				