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Study of Potential Impacts of Climate Change on Food Production in Bangladesh

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Study of Potential Impacts of Climate Change on Food Production in Bangladesh

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DECLARATION

I here by certify that the thesis entitled "**Study of Potential Impacts of Climate Change on Food Production in Bangladesh".** Submitted to the University of Rajshahi, Bangladesh for the degree of Masters of Philosophy is best on my research work carried under the supervisor Professor Dr. M. Sayedur Rahman and Co-supervisor Professor Dr. Md. Ripter Hossain, Department of Statistics, University of Rajshahi. To the best of my knowledge, this work has not been submitted before as candidature for any other degree.

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Dedicated

To

My Late Parents

CERTIFICATE

This is to certify that the thesis entitled ”**Study of Potential Impacts of Climate Change on Food Production in Bangladesh”** submitted by Md. Mizanur Rahman Chowdhury, Lecturer, Department of Statistics, Krisnopur College, Patnitola, Naogaon, Bangladesh in partial fulfillment for the requirements of the degree of Masters of Philosophy. It is also certified that the research work embodied in this thesis is original and carried out by him under our supervision and in this thesis is genuine and original. No part of the work has not been submitted for any others degree.

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ABSTRACT

The climate plays significant role in the agriculture of a country. The Rajshahi region is the driest part of the country in terms of rainfall. Rainfall is the most important weather parameter affecting non-irrigated crop areas. Water deficits and excess water are the greatest constraints for rainfed rice yields in this region. The daily rainfall data for 30 years during the period 1981-2010 of the station Rajshahi, Barisal and Comilla district in region are considered in this study. This study also considered weekly rainfall for 2.5mm and 5mm. The daily data were reduced in the weekly form and the drought index has been calculated using the probability of Markov chain model. Drought is temporary but complex feature of the climate system. Agriculture drought is mainly concerned with inadequacy of rainfall. Markov chain model have been used to evaluate probabilities of getting a sequence of wet-dry weeks over this region. An index best on the parameters of this model has been suggested for agriculture drought measurement in this region.

The results indicate that the drought index for rainfall 2.5mm of rain for Rajshahi district annual is Mild, pre-kharif are Mild, Occasional, and Moderate, kharif is Occasional and Rabi is Chronic.

The drought index for rainfall 5mm of rain for Rajshahi district annual is Mild, pre-kharif are Mild, Occasional and Moderate, kharif is Occasional and Rabi is Chronic.

The drought index for rainfall 2.5mm of rain for Barisal district annual is Mild, pre-kharif are Mild, Occasional and Mild, kharif is Occasional and Rabi is Chronic.

The drought index for rainfall 5mm of rain for Barisal district annual is Mild, pre-kharif is Occasional, kharif is Occasional and Rabi is Chronic.

The drought index for rainfall 2.5mm of rain for Comilla district annual is Mild, pre-kharif are Mild, Occasional, Mild and Moderate, kharif is Occasional and Rabi is Chronic.

The drought index for rainfall 5 mm of rain for Comilla district annual is Occasional, and Mild, pre-kharif are Mild, Occasional and Mild, kharif is Occasional and Rabi is Chronic. As a result, failure to rains and the occurrences of drought during any particular growing season lead to severe food shortages.

A Markov chain model is established to fit daily rainfall data for the various aspects of rainfall occurrence patterns and could be mathematically derive from the Markov Chain by maximum likelihood estimate and these were also established to fit the observed data .The distribution of the number of success is asymptotically normal. The rainfall probability was not found to very much during rabi (November-February) season. But much more variation of rainfall probabilities was observed during both kharif (June-October) and pre-kharif (March-May) seasons. Obviously, one would presume conditions variation in these probabilities also yearly, seasonally and annually. Based on these findings and using chi-square test, it could be concluded that the model fit was good.

This study investigates the methods to obtain estimates of the conditional probabilities, the probability of success and its probability distribution to describe the yearly, seasonal and annual variability. The limited data set the results are quite good and the model is doing a reasonably good job of daily rainfall. The probability can be used for both instantaneous and climate time scale retrievals. As the distribution of number of success asymptotically normal, it is playing a vital role for important decisions such as disaster prevention preparedness strategy. This study will contribute toward a better understanding of the climatology of drought in major monsoon region of the world. The findings of this study will be helpful for every researcher.

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I'm fine, I am alone responsible for the shortcoming and the errors if there be any, I am sorry for that.

The Author

Md. Mizanur Rahman Chowdhury

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α	=	the probability of a wet week following a dry week.
β	=	the probability of a dry week following a wet week.
DI	=	Drought Index.
Pr (W/D)	=	Probability of a wet week given dry on previous week.
Pr (W/W)	=	Probability of a wet week given wet on previous dry week.
P_j (W/D)	=	Probability of rainfall of wet day after dry in month j.
P_j (W/W)	=	Probability of rainfall of wet day after wet day in month j.
P	=	Probability of Success.
P_{00}	=	Probability of a dry week given dry on previous week.
P_{01}	=	Probability of a dry week given wet on previous week.
P_{10}	=	Probability of a wet week given dry on previous week.
P_{11}	=	Probability of a wet week given wet on previous week.

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CHAPTER-I

Introduction:

Bangladesh is a South Asian Country located between 20.34º to 26.38º north latitude and 88.01º to 92.42º east longitude with an area of 147570 sq. km. (BBS, 1996). It is a fact that 75 % land is covered with cultivation to feed 140 million people plus million of new comers every year. Still the country is not self sufficient in cereal and foods resulting in regular imports of A to Z food items. Geologically it is a part Bengal Basin filled by sediments washed down from the highlands on three sides of it and especially from the Himalayas, where the slopes are steeper and the rock less consolidated .It is bordered on the west ,north and east by India, on the southeast by Myanmar and on the south by the Bay of Bengal. An understanding of the physical environment of Bangladesh is essential for the appraisal of the countries land degradation and aridity problems. The climate is sub-tropical warm and humid in the summer on the other hand dry and cool in the winter. The summer is the hottest period with maximum temperature exceeding 40ºC and is characterized by Northwest thunderstorms as well as high evaporation rate. Temperature in Bangladesh varies between 7 to 40ºC. It peaks during April and minimum is recorded in January. The Northwest region in Bangladesh is the driest part where rainfall is the lowest and experiencing aridity and drought condition (UNCCD, 2000).

The Rajshahi Barind region is the driest part of the country in terms of rainfall which annually ranges from 1300 to 1400 mm on the average. The region is characterized by high fluctuating rainfall and the ratio of dry to rainy months is found to be highest in Bangladesh.

Almost the whole region has cool winter and maximum number of driess with temperature above 40^0c in summer (Rahman, 1999b).

Rainfall is the most important weather parameter affecting non-irregated crop areas; the greatest constrains to rainfed rice yields world wide are water deficits and excesses. An irrigated rainfall distribution pattern affects crop growth. The maximum cultivated area of this region depends on rainfall. Extrem drought and excess rainfall have a dramatic impact on the economy as well as living conditions of the inhabitants of the affected region. The analysis of rainfall variability patterns and trend in the Rajshahi, Barisal and Comilla region has implications for land use and water management planning in the regional perspectives (Rahman and Alam,) 1997; Sanderson and Ahmed, (1979 a,b).

A preliminary investigation of the water balance of country was done by Ahmed (1978), the variability of annual rainfall by Shamsuddin and Ahmed (1974), the spetial and temporal variability by Samad and Alam (1993)and monsoon seasonality and aspects by hydrology and agriculture by Shamsuddin and Alam (1990), Trend surface analysis of pre-monsoon rainfall in Bangladesh Sanderson and Ahmed (1979a), potential evapotranspiration and water deficit during the pre monsoon rainfall in Bangladesh by Sanderson and Ahmed (1979b).

Statistical inference is an essential tool for concluding any research. The probability theory of Markov chain has been extensively developed. Where as statistical inference concerning Markov chain model has not been comparatively developed yet (Billingsley, 1961). There is a tendency for rainy days and dry days to cluster and to form respective sequences. This reality of meteorological persistence can best be described by a Markov chain model of proper order corresponding to the order of conditional dependence of physical phenomena (Rahman, 1999a, b). The significance of rainfall analysis has been highlighted by hydrological and climatologycal studies because of its influence in all human activities such as agricultural, industrial and domestic (Rahman, 2000). Variability of rainfall is especially important because it has got effects on both hydrology and agriculture of the high Barind region (Rahman and Alam, 1997). Inference problems, such as estimation and hypothesis testing, involving Markov chains were considered by several authors (Anderson and Goodman, 1957). These problems were studied not only for their theoretical interest but also for their applications in diverse areas.

The lacks in revealing the rainfall characteristics of different spatial units in the manner required for agro-hydrological planning purposes. In such backdrop the simulation model is a preliminary investigation of the variability of rainfall in a micro regional perspective. The high Barind region has already been identified as the most drought prone (Karim and Ibrahim, 1990) and where saturation deficit is considered to be highest during dry summer months (Rashid, 1977).

Studies of the rainfall characteristics of Bangladesh are few. The significance of rainfall analysis has been highlighted of hydrological and climatological studies because of its influence in all human activities such as agricultural, industrial and domestic. Shamsuddin and Alam (1990) showed that the analysis of the rainfall amounts and associated spatio-temporal variation have useful application in agriculture and hydrology. It is essential to know the average amount and variability of rainfall for the Purpose of agriculture, hydrological planning, industrial and water management. Variability of rainfall is especially important because it affects both hydrology and agriculture of a high Barind region (Rahman and Alam, 1997).

The Rajshahi Barind Tract is a distinct agro-ecological zone, located in the northwestern part of Rajshahi district of the country, which has already been identified as the most drought prone area. The Barind is a dries area of Bangladesh and also has a highly variable rainfall (CV=25 to 28%). Evaporation exceeds in three monsoon months (Zuberi and Rahman, 1994). Temperatures are also extreme, with the lowest rabi (winter) temperatures (90-110 days <15ºC) and higher Kharif (summer) temperatures (5-15days>40ºC) in the country (FAO, 1988).

As a signatory of the convention, preparation and implementation of Nation Action Program (NAP) is an obligation of the country to address the concerned problems. Ministry of Environment and Forest had taken priority action and organized an national awareness seminar on "Combating Land Degradation and Desertification" in 1998 with assistance from UNCCD. This has created opportunity of public awareness ensuring inter-sectoral discussion at public, private and civil society level on issues and consequences of land degradation, drought, aridity and desertification. As a follow-up of this event, Government, University and NGOs came up with action research programmers. Particularly, it is worthy to mention that barind Multipurpose Development Authority (BMDA) a government agency devoted to carry out huge programmes to combat aridity and desertification in the Northwest part of Bangladesh. NEMAP follow up action toward combat desertification is another initiative toward this end. In this regard it is also significant to note that International University of Business and technology (IUBAT) submitted a proposal for UNDP-GEF funding for "Reversing Desertification in the Barind Tract of Bangladesh through Integrated Ecosystem and Resource Management" which is actively under consideration (UNCCD, 2000).

1.1. Objective of the study:

The aims and objectives of my study are as follows:

i) to estimate the conditional probabilities P_{01}, P_{11} for two state Markov chain model.

(a) for 2.5 mm and 5 mm of pre-kharif season

(b) for 2.5 mm and 5 mm of kharif season

(c) for 2.5 mm and 5 mm of Rabi season

ii) to estimate the mean and variance of number of wet weeks which follows normal distribution each season.

iii) to estimate drought index (DI) for 2.5 mm and 5 mm. of season as well as 30 periods of times

iv) to test of significance for seasonal and annual data.

CHAPTER II

2. Review of Literature:

2.1. Weather

Weather is a natural variability but seems to strive after effects of the global warming. Severe weather such as heavy rains causing flash flood is more frequently reported, while a prolonged sequence of dry cyclones (those passing without rains but with clouds)causing drought is more common than ever before (Kim, 2000).

The climate is controlled primarily by summer and winter winds and partly by pre-monsoon and post- monsoon circulation .The Southwest Monsoon originates over the Indian Ocean and carries warm, moist, and unstable air. The easterly Trade winds are also warm, but relatively drier. The Northeast Monsoon comes from the Siberian Desert, retaining most of its pristine cold and blows over the country, usually in gusts, during dry winter months (Rahman and Alam, 2003). Some of the projections for how the climate may change in response to human activities are put forward with a focus on global temperature and changes in precipitation and hydrological cycle and in particular, changes in extremes of rainfall, flooding and drought (Trenberth, 1997, 2000; Karl *et al*, 1995).

The model formulation of the weather generator is implemented by Wilks (1992). The model variables are 4 daily weather characteristics: total sun radiation (S_{rad}), maximum temperature (T_{max}), minimum temperature (T_{min})and amount of precipitation(rain).An occurrence of the precipitation is modeled by a non-stationary first- order Markov

Chain, precipitation amount is modeled by gamma distribution, GAMMA (ALPHA, BETA). The remaining quantities or more exactly, the standardized deviations from their mean annual courses are modeled by a first-order autoregressive process (Dubrovsky, 1995).

The SEMP component devoted to address the issue of dry land ecosystem under "Ecosystem Management in Barind Areas" focusing on reversing aridity and enhancement of dry land ecology with an approach of participatory ecosystem management leading to sustainable development of the concerned area. The working models of improvements in dry land ecosystems with improved water management and regeneration of indigenous flora and fauna through community participation in the vast tract of Barind Region. Along with environmental documentation and awareness components, SEMP has one component for "Sustainable Development Networking Programme (SDNP)" to disseminate the message and information to the hundreds of institution and civil society as well as public institutions involved in development work (UNCCD, 2000).

The natural disaster is defined as "Strictly speaking, a natural disaster is the catastrophic consequence of a natural phenomenon or combination of phenomena resulting injury, loss of life and property on a relatively large scale and serve disruption to human activities" (Reddy, 2004). He identified several natural disasters, namely (i) Weather disaster such as (a) tropical cyclones, hurricanes, typhoons; (b) other types of storms (extra-tropical cyclones, thunderstorms, tornadoes); (c) floods; (b) drought; and climate change, etc. and (ii) non-weather disasters such as (a) fires (ecological hazard); (b) infestations (biological hazard); (c) earthquakes (geological hazard) and (d) release of hazardous materials from industry, transport, volcanoes etc. (ecological hazsrd); etc. Except earth quake, the intensity of the other three non-weather disasters are also related to weather conditions. However, earthquakes and hazardous material may affect weather (Reddy, 2004).

The FAO water balance model, which has got this character, was chosen for the estimation of "water stress" factor. Based on the literature review, it was noted that the water stress alone can explain maximum yield variations in the tropics, where majority of the developing countries are located (crop varieties are generally chosen based on their adaptiveness to a given environment and thereby it meets the energy requirements, in general--Reddy, 1995.

The information produced were (i) general weather (rainfall, temperature), (ii) soil moisture reserve at the end of each decade along with rainfall probabilities for the next decade (serves as forecast), (iii) crop condition/crop production/drought situation, (iv)cropped area by crop, planting time, growth cycle, etc., (v) bulletins/handouts. However the information included in different types of bulletins was somewhat different with the progression of crop season. The impact of natural disasters on population could be reduced through proper scientific assessment of the past and the present weather data. However, the success of this depends on how the implementing agencies react to these suggestions (Reddy, 2004).

2.2. Rainfall:

Bangladesh has an average rainfall of about 2300 mm, ranging from 1250-5000 mm. Mean annual rainfall is lowest in the centre-west (1250 mm). It increases towards the north, east and south, reaching more than 2500 mm in the extreme north-west, near and within the northern and eastern hills, and near the coast, and exceeding 5000 mm in the extreme north- east. In all areas, about 85-90 percent of the annual total occurs between mid-April and end-September. Totals vary considerably between years. This is mainly because of the yearly variability in pre-monsoon rainfall and the irregular incidence of heavy rainfall events within the monsoon season. Winter rainfall, when it occurs may be either from local thunderstorms or from depressions crossing northern India. Pre-monsoon thunderstorms usually give rainfall of high intensity. Periods of heavy monsoon rainfall may give more than 100 mm in a day (BARC, 1991).

The heavy rainfall between May and September comes at a time when the major rivers are bringing in large volumes of water from the upper catchment areas outside Bangladesh. The high river levels block drainage of rainwater from the land. Because of this, most floodplain areas are submerged by rainwater in the monsoon season. In Bangladesh, there is a difference between flooding and flood. Flooding implies inundation of the land by water, such as floodplain inhabitants expect in 'normal' years and on which farmers base their traditional cropping patterns. On the other hand, flood implies abnormal submergence of the land, which may cause damage or loss of crops, property and lives (Rahman and Alam, 2003).

2.3. Climate

Climate is the average condition of the atmosphere near the earth`s surface over a long period of time, taking into account temperature, precipitation, humidity, wind, cloud, etc. Bangladesh is located in the tropical monsoon region its climate is characterized by high temperature, heavy rainfall, often excessive humidity, and fairly marked seasonal variations. The most striking feature of its climate is the reversal of the wind circulation between summer and winter which is an integral part of the circulation system of the South Asian subcontinent. From the climatic point of view, three distinct seasons can be recognized in Bangladesh-the cool dry season from November to February, the pre-monsoon hot season from March to May, and the rainy monsoon season which lasts from June to October. The month of March may also be considered as the spring season, and the period from mid- October through mid-November may be called the autumn season. The rainy season, which coincides with the summer monsoon, is characterized by southerly or southwesterly winds, very high humidity, heavy rainfall, and long consecutive days of rainfall, which are separated by short spells of dry days. The climate of Bangladesh is characterized high temperature, heavy rainfall, often excessive humidity, and fairly marked seasonal variations (Rahman and Alam, 2003).

The balance of scientific evidence now suggests that over the last century humans have begun to have a discernible influence on the earth's climate, causing it to warm (IPCC, 1996, 1998). Since the beginning of the industrial age, the concentration of CO2 in the atmosphere has increased from 280 to 350 pars per million (Bazzaz and Fajer, 1992). The increase of CO_2 and several other green house gases such as methane, nitrous oxide, chlorofluorocarbons (CFCs) could an increase global temperature of about 4.2°C and possibly a change in precipitation patterns and amounts in some regions (Kimball *et al*., 1983). Global warming due to increasing concentrations of green house gases poses a threat to human society by changing the living and working environment to which society has adapted over many generations (Jodha, 1989).

The lack of rainfall and high air temperature are the chief reasons for the desertification. Climate change occurs due to natural and anthropogenic disturbances in our environment. These anthropogenic factors may contribute to the observed climatic change and variations. The degree of climatic change is very important in assessing environmental impacts such as the increase of bacteria, virus and related diseases that have been reported. The global climate change is the sum of both local and regional departures in climate elements and variables (Munn, 1998).

Effect of climate variability on agriculture is very important. Several studies indicate that weather during cropping season strongly influences the crop growth. In all agricultural regions, the effects of natural climate variability will interact with human induced climate change to determine the magnitude of the impacts on agricultural production (Rahman, 2000).

2.3.1. Climate Change

Climate jump is the fact that an abrupt change of climate variables has been occurred in a certain region and then it may impact on the mean value for a while although most climate diagnosis are performed based on the assumption of continuous change . Thus climatic jump is appeared not on just one atmospheric variables but on various atmospheric variables in a large area (Wilks, 1995).

Statistically robust and accurate model-based climate prediction is necessary to help in formulation domestic and International energy policy. While there is yet much to be done, it should be emphasized that progress has been and will continue to be rapid on developing models capable of unraveling the climate puzzle. This is of vital importance to mankind so that changes, be they catastrophic or gradual, can be planned for and even ameliorated as man seeks a sensible balance with the natural world (Rahman, 2001).

The Intergovernmental Panel on Climate Change's Second Assessment Report (1996) concluded, "The balance of evidence suggests that there is a discernible human influence on global climate," `important uncertainties remain. What changes in climate can we expect? What will the impacts be on, for example, agriculture, unmanaged, ecosystems, and sea level? Which regions of the world will be most affected? Accordingly, the climate modeling community needs the capability for multiple simulations using ever more detailed and accurate coupled models. Multiple simulations will be the basis for forecasting–tens to hundreds of years in the future- the likelihood and impact of climate variability and change over regions as small as river basins (Bell *et al*., 2000).

The indirect effects on crops indicate that changes in pest scenario, soil moisture storage, irrigation water availability mineralization of nutrients and socio-economic changes may have large effects on agricultural production. The change in climate may bring about changes in population dynamics, growth and distribution of insect and pests. Regional weather changes may, therefore, influence the occurrence of particular species of aphids during the cropping season (Hundal and Prabhjyot Kaur, 2004).

Sustainable development is the first identification and preliminary analysis of a member of adaptation issues on five important sectors of the country. These are (a) agriculture, (b) coastal resources, (c) water resources, (d) bio-diversity and (e) human health. The study showed how major projects, especially the ones being undertaken by the world Bank and Asian Development responded to the needs for adaptation to climate change and how issues of adaptation could be incorporated into the long-term planning framework of sustainable development of the country. The report has highlighted key risk to climate change and possible adaptation options both in terms of physical and institutional. The vulnerable Assessment of the SAARC Coastal Region due to Sea level Rise. Bangladesh Case undertaken by the SAARC Meteorological Research Centre (SMRC) (Rahman and Alam, 2003).

The World Meteorological Organization (1975a).The distinction should be made between drought and aridity. Aridity is usually defined in terms of low-average precipitation, available water, or humidity and setting aside the possibility of climate change is a permanent climatic feature of a region.

Climate change will largely affected irrigation, tourism, physical and natural environments of the world, including India and Bangladesh by 2010, according to latest study by North, South, East and West (NSEW). The off season downpours this time in Bangladesh due to tidal surges in the Bay of Bengal is likely to hit hard in coming year. Geographers predicted that being drenched in India toxic. Surface acid, the Bengal basins might have to receive worse ever consequences, either in term of green house emission or ecology.

Recently, Bangladesh will have to experience worse ever disaster within next on decade, once a forestation fails to match with the surging flow of greenery degradation. According to latest geographical survey, worldwide climate change may take a violent mood by 2010 touching Indian basins in harmful effects. It is likely to be caused by alarming increase in the harmful emission carbon dioxide (CO_2). Due to growing generation of sulfuric acids in Indian air, the subcontinent is already at the risk position with level (CO_2) .it may be largely caused by unplanned industrialization and the decaying trend in the physical and natural environments. Foods, drought, disease, natural man-made disaster are set some part of India almost daily a global climate change research organization (NESW), Already, the people of Indian and neighbouring countries including Bangladesh are suffering heat waves and sea level rise. With this trend the people will find their health increasingly threatened by climatic change. Climatic change already touches every corner of the planet and every aspect of people's life. As the global temperature increases, its impact will be come even more extreme (NSEW) (Arnab, 2006).

Several studies have been demonstrated significant changes in local, regional and global surface air temperature and precipitation patterns measured over the past century (Jones, 1988; Hansen and Lebedeff, 1988; IPCC, 1997). Climatic system is not simple to be understood due to its non-linearity of interactions among many physical and dynamical processes under external forcing 9Oh and Lee, 2000. A number of recent atmospheric and oceanic studies pointed that there is significant low frequency variability in the climate system. The variation of climatic variables such as temperature, precipitation and sea surface temperature is closely related to ENSO (EL Nino/Southern Oscillation) (Allen *et al*., 1995; Wang 1995).

2.3.2. Impact of Climate Change

The nature of climate changes in Bangladesh and to assess the physical, economic, environmental and social Impacts of the predicted climate change. Agriculture is always vulnerable to unfavorable weather events and climate conditions. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are still key factors in agricultural productivity. Often the linkages between these key factors and production losses are obvious, but sometimes the linkages are less direct (Ahmed and Shibasaki, 2000).

To estimate the impacts, we need: a model which relates weather and/or climate characteristics with the characteristics of the system being studied climatic and/or weather data for present-climate and changed-climate conditions for given location or for a region in a resolution required by the model used in an impact study (Dubrovsky, 1997).

The impacts of climate change on agricultural food production are global concerns, and they are very important for Bangladesh. Agriculture is the single most and the largest sector of Bangladesh's economy which accounts for about 35% of the GDP and about 70%of the labor force. Agriculture in Bangladesh is already under pressure both from huge and increasing demands for food and from problems of agricultural land and water resources depletion (Ahmed and Shibasaki, 2000). Estimation of quantitative impacts of potential climate change on environment and various aspects of human being requires high-resolution surface weather data (Dubrovsky, 1997).

It is generally assumed that the increasing concentration of greenhouse gases in the atmosphere will significantly contribute to the change of climate in near future. The potential subjects of the climate change impacts include, e.g. cycle and water resource management, agriculture, forestry, tourism and human health. The rising temperature and carbon dioxide and uncertainties in rainfall associated with global climate change may have serious direct and indirect consequences on crop production and hence food security (Sinha and Sawaminathan, 1991). It is, therefore, important to have an assessment of the direct and indirect consequences of global warming on different crops contributing to our food security. The effect of changes in temperature, precipitation and CO_2 concentrations on crop productivity have been studies extensively using crop simulation model. The combined effects of climate change have been found to have implications for dry land and irrigated crop yields (Rosenzweig and Iglesias, as well as by the magnitude of warming, the direction and magnitude of precipitation change (Adams *et al*., 1998).

2.3.3. Drought Index

The American Meteorological Society (1997) suggests that the time and space processes of supply and demand are the two basic processes that should be included in an objective definition of drought and derivation of a drought index. The world Meteorological Organization defined a drought index as an index, which is related to some of the cumulative effects of a prolonged and abnormal moisture deficiency (World Meteorological Organization, 1992). Friedman (1957) identified four basic criteria that may drought index should meet :1) the timescale should be appropriate to the problem at hand; 2) the index should be a quantitative measure of large-scale, long-continuing drought conditions: 3) the index should be applicable to the problem being studiet; and 4) a long accurate past record of the index should be available or computable.

Many quantitative measures of drought have been developed based on the sector and location affected, the particular application, and the degree of understanding of the phenomena. The water balance model developed by Palmer (1965) was a turning point in the evolution of drought indices. While an improvement over simple early twentieth-century measures, the Palmer Index suffers from some inherent weaknesses (these weaknesses will be discussed later). Post-Palmer solutions include modern indices, such as the Surface Water Supply Index and the Standardized Precipitation Index, and the Drought Monitor.

Blumenstock (1942) applied probability theory to compute drought frequencies in a climate study. For his index, he used the length of the drought in days, where a drought was considered terminated by the occurrence of at least 2.54 mm (0.10 in.) of precipitation in 48 h or less.

Keetch and Byram (1968) developed an index of drought for use by fire control managers. Based on a 203- mm (8 in) soil moisture storage capacity, the Drought Index (DI) is expressed in hundredths of an inch of spoil moisture depletion, ranging from 0 (one moisture deficiency) to 800 (absolute drought). Computation of the DI is based on a daily water budgeting procedure where by the drought factor is balanced with precipitation and soil moisture. The Keetch-Byram drought Index (KBDI) has become widely used in wildfire monitoring and prediction.

2.3.4. Predicting and Planning Drought

Predicting drought depends on ability to for cast two fundamental meteorological surface parameters, precipitation and temperature. From the historical record we know that climate is inherently variable. We also know that anomalies of precipitation and temperature may last from several months to several decades.

Precipitation is the largest single determinant of drought. Temperature and other climate elements are also important. It is not uncommon for drought periods to be accompanied by higher summer temperatures. Drought planning involves preparing for not only average conditions, but also extremes. Thus, producers should know the extent of their current drought conditions and what the expectations are for the coming week, month and season (NDMC, 2006).

Drought is normal part of virtually every climate on the planet, even rainy ones. It is the most complex of all natural hazards, and it affects more people than any other hazard. The impacts of drought are greater than the impacts of any other natural hazard. The impacts of these droughts illustrate our continuing and perhaps increasing vulnerability to extended periods of water shortage (Wilhite and Glantz, 1987).

Although drought is a natural hazard, society can reduce its vulnerability and therefore lessen the risks associated with drought episodes. The impacts of drought, like those of other natural hazards, can be reduced through mitigation and preparedness. In additional to drought planning at the state and national level. Planning has also become more prevalent at the regional and local levels. The output numeric values were analyzed in two steps: for rainfed land and for irrigated land. A high numeric value within each category was assumed to be indicative of a geographic area that is likely to be vulnerable to agricultural drought (NDMC, 2006).

CHAPTER-III

3. Materials and Methods

3.1. Site selection and data Collection

The data used in this study refers to the daily rainfall data of three stations Rajshahi, Barisal and Comilla district rainfall recording stations were available for 30 years from 1981-2010 and recorded by Bangladesh Meteriological Department.

3.2 Model Building

3.2.1 Markov Chain Model

A two-state Markov chain method involves the calculation of two conditional probabilities (1) α, the probability of a wet week following a dry week and (2) β, the probability of a dry week following a wet week. The two states Markov chain for the combination conditional probabilities is:

Present State	Future State		
		Dry	Wet
	Dry	1- α	α
	Wet	β	1- β

Let us sequence s conditional probabilities which are denoted by

$$\left.\begin{aligned} P_o &= \Pr\{W/D\} \\ P_1 &= \Pr\{W/W\} \end{aligned}\right\} \qquad (1)$$

This sequence is irreducible Markov chain with two ergodic state. Its stationary probability distribution has a probability of success.

$$P = P_0 / (1-(P_1-P_0)) \qquad (2)$$

3.2.2. Method of Markov Chain Model

Several authors have found that the sequences in daily rainfall occurrences can be described by a simple Markov chain model. Additional evidence to indicate the feasibility of using a Markov chain model has been presented by Katz (1974), Anderson and Goodman (1957), Todorovic and Woolhiser (1974) and Rahman (1999 a,b).

Let X_0, X_1, $X_{2,}$........................ ,$X_{n,}$ be random variables distributed identically and taking only two values, namely o and 1, with probability one,i.e,

$$X_n=\begin{cases} 0 \;\; if\ the\ nth\ week\ is\ dry \\ 1 \;\; if\ the\ nth\ week\ is\ wet \end{cases} \tag{3}$$

Firstly we assume that,

$P(X_{n+1}= x_{n+1} \mid X_n= x_n ,X_{n-1} = x_{n-1},$ ....,$X_0=x_0) = P\ (X_{n+1} = x_{n+1} \mid X_n= x_n)$

Where X_0, X_1, ... , x_{n+1} € {o, 1}.

In other words, it is assumed that probability of wetness of any week depends only one whether the previous week was wet or dry. Given the event on previous week. the probability of wetness in assumed independent of further preceding weeks, So {Xn, n= 0, 1,2.......... } is a Markov chain (Medhi, 1981).

Consider the transition matrix.

$$\begin{bmatrix} P_{00} & P_{01} \\ P_{10} & P_{11} \end{bmatrix} \tag{4}$$

Where $p_{ij}= P(x_1=j \mid X_0=i)$ i,j=0, 1. Note $Poo+P_{01}=1$ and $P_{10}+P_{11}=1$

Let P = P(X_0=1), Here P is the absolute probability of a week being wet during the monsoon period. Clearly, P(X_0 =0)=1-p.

For a stationary distribution

$$[1\text{-}P \quad P] \begin{bmatrix} P_{00} & P_{01} \\ P_{10} & P_{11} \end{bmatrix} = [1 - P \quad P] \qquad (5)$$

Which gives

$$P = \frac{P_{01}}{1-(P_{11}-P_{01})} \qquad (6)$$

It is further assumed that p_{ij}'s remaining constant over the years. The maximum likelihood estimates of P_{o1} and P_{11} are appropriate relative functions.

Let Y be the random variable such that Y= number of wet weeks among an weeks period i.e .Y=X_0+ X_1 + ...+ X_{n-1}

For large n, Y follows normal distribution with Mean = nxp

Variance = n p (1-p) $\frac{1+P_{11}-P_{01}}{1-P_{11}+P_{01}}$

Where p is the stationary probability of a week being wet.

This is an asymptotic result indicates neither the exact distribution for small n nor the rapidity of approach to normality (Feller, 1957).

3.2.3. Index of Drought proneness

P_{11} gives the probability of a week to be wet given that previous week was w*et al*so. When P_{11} is large, the chance of wet weeks is also large. But only a small value of P_{11} may not indicate high drought proneness. In this case, large value of P_{01} implies a large number of short wet spells which can prevent occurrence of drought.

Hence an index of drought-proneness may be defined as:

$$DI = P_{11} \times P_{01} \quad (7)$$

This index of drought-proneness is bounded by zero and one. Higher the value of DI, lower will be the degree of drought-proneness. The extent of drought-proneness is given below (Banik *et al*., 2000):

Table 3.1: Index of drought-proneness

Criteria	Degree of drought-proneness
$0.000 \leq DI \leq 0.125$	Chronic
$0.125 < DI \leq 0.180$	Severe
$0.180 < DI \leq 0.235$	Moderate
$0.235 < DI \leq 0.310$	Mild
$0.310 < DI \leq 1.000$	Occasional

From equation (1), have calculated higher transition probability matrix, where $P_{ij}^{n} = P_{ij}^{n+1}$, in this condition using stable transition probability matrix finally calculated,

$$D1 = P_{11} \times P_{01}$$

3.3. Statistical Inference for Markov Chain Model

Statistical inference is an essential tool for concluding any research. The probability theory of Markov chain has been extensively developed, where as, statistical inference concerning Markov chain model has not yet been comparatively developed (Billingsley, 1961).

Drought occurs when various combinations of the physical factors of the environment produce an internal water stress in crop plants sufficient to reduce their productively. In the low rainfall areas especially in tropics, the importance of rainfall overrides that of all other climatic factors, which determine yield. So, agricultural drought is mainly concerned with inadequacy of rainfall. In purulia (West Bengal) and Giridih (Bihar) districts and dry land areas of the State of Maharashtra, the rainy season is mainly due to Southwest monsoon and it ranges from June to September. Hence the crop yield in the area depends on variation of rainfall in this season (Banik *et al*., 2000).

Different units of time period are used for rainfall analysis. For agriculture, week may be nearer to the optimum length of time. The week with rainfall greater than the threshold value a minimum amount, say 2.5) is considered to be a wet week. The expected number of wet weeks in a given period of time can decide the crop production of an area. The probability of sequences of wet weeks can indicate the adequacy of water and that of dry weeks indicate the reverse and recurrence of the risk of crop failure. Wet and dry sequences of weeks can be well represented by the Markov chain model (Banik *et al*., 2000; Richardson, 1981; 1982). The occurrence of daily precipitation at a station can seldom be properly considered as an independent random event described by Bernoullis trials. Analysis of daily precipitation time series always tends to reveal the existence of stochastic dependence.

Drought is a temporary but complex feature of the climate system of a given region with widespread significance (Olapido, 1985), which is usually caused by precipitation deficit (Gregory, 1986). Such natural disasters leave a long lasting effect on a social and economic fabric of a region where it strikes, sometimes requiring relief efforts on a global scale (Ahmed, 1995). Although we can recognize a drought when it hits a given region, there is no universal definition of this term. Various characteristics of droughts, including definitions and their meteorological, hydrological and economic aspects were discussed by Doornkamp *et al*., (1980), Giambelluca *et al*., (1988). Landsberg (1982), Dennet *et al*., (1985), Olapido (1985), Ahmed (1991) and reviewed extensively by Gregory (1986) and Nieuwolt (1986).

3.4. Test of Hypothesis

On the basis of the asymptotic distribution theory discussed in the proceeding section, we can derive certain methods of statistical inference. Here we shall assume that every p_{ij}>o. First we consider testing the hypothesis that certain transition probabilities, p_{ij} have specified values p_{ij}. We make use of the fact that under the null hypothesis the $(n_1)^{1/2}(p_{ij}-p_{ij}^{o})$ have a limiting normal distribution with means zero, and variances and covariance's depending on p_{ij}^{0} in the same way as observations for multinomial estimates. We can use standard asymptotic theory for multinomial or normal distributions to test a hypothesis about one or more p_{ij} or determine a confidence region for one more p_{ij}.

As a specific example consider testing the hypothesis that $p_{ij} = p_{ij}^{0}$, j= i, 2,............. ,m for given i. Under the null hypothesis,

$$\sum_{j=1}^{m} n_i^{*} \frac{\left(\hat{p}_{ij} - p_{ij}^{0} \right)^2}{p_{ij}^{0}} \qquad (8)$$

has an asymptotic χ^2- distribution with m- 1 degrees of freedom (according to the usual asymptotic theory of multinomial variables) . Thus the critical region of first test of this hypothesis at significance level $\propto$ consists of the set p_{ij} for which is greater than the significance point of the χ^2-distribution with m-1 degrees of freedom.

In the stationary Markov chain, p_{ij}, is the probability that an individual in state i at time t-1 moves to state j at t, A general alternative to this assumption is that the transition probability depends on t;let us say it is p_{ij} (t). We test the null hypothesis H: p_{ij} (t) =p_{ij} (t=1,2............T)

. Under the alternative hypothesis, the estimates of the transition probabilities for time t are.

$$\overline{P}_{ij}(t)=n_{ij}(t)/n_i(t-1) \qquad (9)$$

The likelihood function maximized under the null hypothesis is

$$\prod_{t=1}^{T}\prod_{i,j}\hat{P}_{ij}^{nij(t)} \qquad (10)$$

The likelihood function maximized under the alternate is

$$\prod_{i}\prod_{ij}\hat{P}_{ij}^{nij(t)} \qquad (11)$$

The ratio is the likelihood ratio criterion

$$\lambda=\prod_{i}\prod_{ij}\left[\frac{\hat{P}_{ij}}{(t)}\right]^{n_{ij}(j)} \qquad (12)$$

For a given i, the set p_{ij} (t) has the same asymptotic distribution as the estimates of multinomial probabilities $p_{ij}(t)$ for T independent samples. The asymptotic distribution of $-2\log\lambda\, is\, \chi^2\, with (m-1)(T-1)$ degrees of freedom. The preceding remarks relating to the contingency table approach dealt with a given value i, Hence, the hypothesis can be tested separately for each value of i, Similarly the test criterion based on can be written as

$$\sum_{i=1}^{m} -2\log\lambda_i = -2\log\lambda. \tag{13}$$

CHAPTER – IV

4. Results and Discussions

4.1. Drough Index calculated by using Rainfall 2.5 mm of rain for Rajshahi district.

The daily rainfall of 30 years during the period from 1981-2010 in Rajshahi district considering 52 standard weeks have been used.

Table 4.1.1. Analysis of probability of wet and dry weeks and index of drought-proneness in Rajshahi district for Annual by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 years (1981-2010)	0.51	0.53	0.52	27.04	13.39	0.27	Mild
10 years (1981-1990)	0.52	0.55	0.54	28.08	13.71	0.29	Mild
10 years (1991-2000)	0.49	0.50	0.49	25.48	13.25	0.25	Mild
10 years (2001-2010)	0.53	0.54	0.53	27.56	13.21	0.28	Mild

Table 4.1.1.The mild drought prone weeks are found in Rajshahi district which are drought index values DI= 0.27, 0.29, 0.25, 0.28.

The daily rainfall of Pre-Kharif season of 30 years (1981-2010) during the period from March to May in Rajshahi district considering 13 standard weeks have been used.

Table 4.1.2. Analysis of probability of wet and dry weeks and index of drought-proneness in Rajshahi district for Pre-Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 years (1981-2010)	0.52	0.49	0.50	6.54	3.12	0.26	Mild
10 years (1981-1990)	0.62	0.55	0.58	7.54	2.76	0.34	Occasional
10 years (1991-2000)	0.47	0.47	0.47	6.11	3.34	0.22	Moderate
10 years (2001-2010)	0.46	0.46	0.46	5.98	3.23	0.21	Moderate

Table 4.1.2. The Mild, Occasional, Moderate, Moderate drought prone weeks are found in Rajshahi district which are drought index values DI= 0.26, 0.34, 0.22, 0.21.

The daily rainfall of Kharif season of 30 years (1981-2010) during the period from June to October in Rajshahi district considering 22 standard weeks have been used.

Table 4.1.3. Analysis of probability of wet and dry weeks and index of drought-proneness in Rajshahi district for Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E (Y)	Variance	DI	Comment
30 years (1981-2010)	0.79	0.81	0.81	15.06	3.22	0.64	Occasional
10 years (1981-1990)	0.74	0.77	0.76	16.72	4.26	0.57	Occasional
10 years (1991-2000)	0.76	0.78	0.78	17.16	3.93	0.59	Occasional
10 years (2001-2010)	0.87	0.87	0.87	11.31	1.47	0.76	Occasional

Table 4.1.3. The occasionally drought prone weeks are found in Rajshahi district which are drought index values DI= 0.64, 0.57, 0.59, 0.76.

The daily rainfall of Rabi season of 30 years (1981-2010) during the period from November to February in Rajshahi district considering 17 standard weeks have been used.

Table 4.1.4. Analysis of probability of wet and dry weeks and index of drought-proneness in Rajshahi district for Rabi by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 years (1981-2010)	0.16	0.16	0.16	2.72	2.16	0.02	Chronic
10 years (1981-1990)	0.18	0.18	0.18	3.06	2.51	0.03	Chronic
10 years (1991-2000)	0.19	0.19	0.19	3.23	2.62	0.03	Chronic
10 years (2001-2010)	0.11	0.11	0.11	1.87	1.66	0.01	Chronic

Table 4.1.4.The chronic drought prone weeks are found in Rajshahi district which are drought index values DI= 0.02, 0.03, 0.03, 0.01.

Table 4.1.5. Annual Drought Index Scenario for rainfall 2.5 mm of rain for Rajshahi district.

Year	Drought Index
1981	0.37
1982	0.19
1983	0.35
1984	0.23
1985	0.34
1986	0.40
1987	0.25
1988	0.19
1989	0.32
1990	0.38
1991	0.37
1992	0.20
1993	0.33
1994	0.32
1995	0.34
1996	0.44
1997	0.34
1998	0.49
1999	0.19
2000	0.32
2001	0.19
2002	0.37
2003	0.22
2004	0.27
2005	0.31
2006	0.23
2007	0.27
2008	0.27
2009	0.25
2010	0.31

Annual variation of DI for 2.5 mm for Rajshahi district.

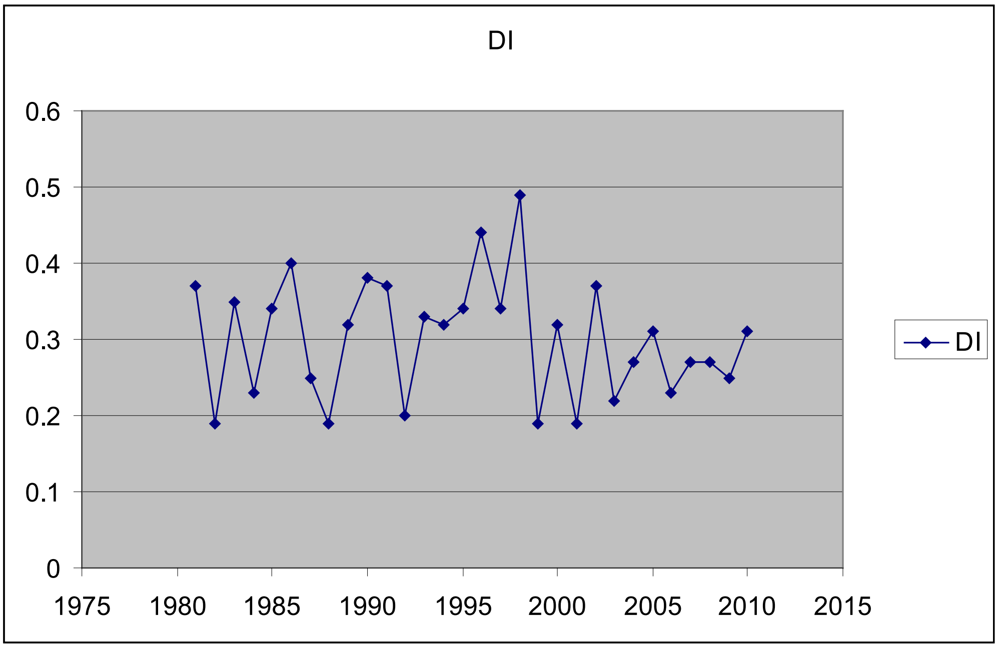

Figure-01

Discussion: We observed from the above table (4.1.5) and Figure (01) the year 1982, 1984, 1988, 1992, 1999, 2001, 2003 and 2006 are moderately drought, 1987, 2004, 2005, 2007, 2008, 2009 and 2010 are mild drought, 1981, 1983, 1985, 1986, 1989, 1990, 1991, 1993, 1994, 1995, 1996, 1997, 1998, 2000 and 2002 are occasional drought.

4.2.Test of Significance

4.2.1. Annual Scenario of Dry-Wet transition probability matrix for Rainfall 2.5 mm of rain for Rajshahi district.

The probabilities of rainfall occurrence were derived from the probability model and require two conditional probabilities P_1= Pr{wet week /previous week wet}= Pr{W/W}, Po= Pr{wet week / previous week dry}=Pr{W/D}.The fit of the Markov chain model had been tested on data of rainfall in Rajshahi district for a period of 30 years from 1981 to 2010.The conditional probabilities in a Markov chain were estimated by using maximum likelihood estimation techniques.

Table 4.2.2. The occurrence and non-occurrence rainfall in Rajshahi district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	533	201	734
Wet	195	674	869
Total	728	875	1603
Cal χ^2	404.13		
χ^2 (1 d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Rajshahi district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.2.2.). The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.2.2.) was Pr {$\chi^2 \geq 404.13$} being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.2.3. The occurrence and non-occurrence rainfall in Rajshahi district for the 10 consecutive years from 1981 to 1990. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	160	63	223
Wet	70	226	296
Total	230	289	519
Cal χ^2	119.26		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.2.3). The chi-squire value of the transition matrix (Table 4.2.3.) Was Pr ($\chi^2 \geq 119.26$} being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.2.4. The occurrence and non-occurrence rainfall in Rajshahi district for the 10 consecutive years from 1991 to 2000.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	170	65	235
Wet	57	226	283
Total	227	291	518
Cal χ^2	145.11		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.2.4.). The chi-squire value of the transition matrix (Table 4.2.4.) was Pr $\{\chi^2 \geq 145.11\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.2.5. The occurrence and on-occurrence rainfall in Rajshahi district for the 10 consecutive years from 2001 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	203	73	276
Wet	68	222	290
Total	271	295	566
Cal χ^2	140.35		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.2.5.). The chi-squire value of the transition matrix (Table 4.2.5.) was Pr $\{\chi^2 \geq 140.35\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

4.3.1. Scenario of Seasonal of Dry-Wet transition probability matrix for Rainfall 2.5 mm of rain for Rajshahi district.

Table 4.3.2. The occurrence and non-occurrence data of Pre-kharif (March-May),kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Rajshahi district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	128	69	197
Wet	67	133	200
Total	195	202	397
Cal χ^2	39.35		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	48	42	90
Wet	67	524	591
Total	115	566	681
Cal χ^2	98.21		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	323	54	377
Wet	56	18	74
Total	379	72	451
Cal χ^2	4.64		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Rajshahi district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.3.2.The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1. The chi-squire value of the transition matrix (Table 4.3.2.) were Pr$\{\chi^2 \geq 39.35\}$for Pre-kharif, Pr$\{\chi^2 \geq 98.21\}$ for Kharif, Pr$\{\chi^2 \geq 4.64\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.3.3. The occurrence and non-occurrence data of Pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Rajshahi district for the 10 consecutive years from 1981 to 1990. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	36	24	60
Wet	18	55	73
Total	54	79	133
Cal χ^2	17.25		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	16	9	25
Wet	23	170	193
Total	39	179	218
Cal χ^2	40.41		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	117	23	140
Wet	21	8	29
Total	138	31	169
Cal χ^2	1.29		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.3.3.). The chi-squire value of the transition matrix (Table 4.3.3.) were Pr$\{\chi^2 \geq 17.25\}$for Pre-kharif, Pr$\{\chi^2 \geq 40.41\}$ for Kharif, Pr$\{\chi^2 \geq 1.29\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.3.4.The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Rajshahi district for the 10 consecutive years from 1991 to 2000. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	41	18	59
Wet	24	43	67
Total	65	61	126
Cal χ^2	14.35		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	25	15	40
Wet	22	177	199
Total	47	192	239
Cal χ^2	52.74		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	83	18	101
Wet	19	5	24
Total	102	23	125
Cal χ^2	0.33		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.3.4.). The chi-squire value of the transition matrix (Table 4.3.4.) were Pr $\{\chi^2 \geq 14.35\}$ for Pre-kharif, Pr$\{\chi^2 \geq 52.74\}$ for Kharif, Pr$\{\chi^2 \geq 0.33\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.3.5. The occurrence and non-occurrence data of Pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Rajshahi district for the 10 consecutive years from 2001 to 2010.A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	51	27	78
Wet	25	35	60
Total	76	62	138
Cal χ^2	7.70		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	7	18	25
Wet	22	177	199
Total	29	195	224
Cal χ^2	5.04		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	123	13	136
Wet	16	5	21
Total	139	18	157
Cal χ^2	3.03		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.3.5.). The chi-squire value of the transition matrix (Table 4.3.5.) were Pr{ $\chi^2 \geq 7.70$}for Pre-kharif, Pr{ $\chi^2 \geq 5.04$} for Kharif, Pr{ $\chi^2 \geq 3.03$} for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

4.4.Annual Scenario of Dry-Wet transition probability matrix for Rainfall 5 mm of rain for Rajshahi district.

Table 4.4.1. Analysis of probability of wet and dry weeks and index of drought-proneness in Rajshahi district for Annual by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 years (1981-2010)	0.51	0.53	0.42	26.97	16.45	0.27	Mild
10 years (1981-1990)	0.51	0.54	0.23	27.34	22.35	0.28	Mild
10 years (1991-2000)	0.52	0.54	0.53	27.56	13.48	0.28	Mild
10years 2(001-2010)	0.49	0.51	0.50	26.00	13.53	0.25	Mild

The daily rainfall of 30 years during the period from 1981-2010 in Rajshahi district considering 52 standard weeks have been used for Table4.4.1. The mild drought prone weeks are found in Rajshahi district which are drought index values DI= 0.27, 0.28, 0.28, 0.25.

Table 4.4.2. Analysis of probability of wet and dry weeks and index of drought-proneness in Rajshahi district for Pre-Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 years (1981-2010)	0.50	0.50	0.50	6.54	3.22	0.26	Mild
10 years (1981-1990)	0.61	0.61	0.61	7.93	3.09	0.37	Occasional
10 years (1991-2000)	0.45	0.46	0.45	5.85	3.29	0.21	Moderate
10 years (2001-2010)	0.45	0.46	0.45	5.85	3.29	0.21	Moderate

The daily rainfall of Pre-Kharif season of 30 years (1981-2010) during the period from March to May in Rajshahi district considering 13 standard weeks have been used for Table 4.4.2. The Mild, occasional, Moderate, Moderate drought prone weeks are found in Rajshahi district which are drought index values DI= 0.26, 0.37, 0.21, 0.21.

Table 4.4.3. Analysis of probability of wet and dry weeks and index of drought-proneness in Rajshahi district for Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 years (1981-2010)	0.82	0.82	0.82	17.60	4.16	0.64	Occasional
10 years (1981-1990)	0.82	0.82	0.82	18.04	3.25	0.67	Occasional
10 years (1991-2000)	0.71	0.71	0.71	15.62	6.38	0.50	Occasional
10 years (2001-2010)	0.87	0.87	0.87	19.14	2.86	0.76	Occasional

The daily rainfall of Kharif season of 30 years (1981-2010) during the period from June to October in Rajshahi district considering 22 standard weeks have been used for Table 4.4.3. The occasionally drought prone weeks are found in Rajshahi district which are drought index values DI= 0.64, 0.67, 0.50, 0.76.

Table 4.4.4. Analysis of probability of wet and dry weeks and index of drought-proneness in Rajshahi district for Rabi by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.14	0.15	0.14	2.44	1.32	0.02	Chronic
10 Years (1981-1990)	0.18	0.19	0.18	3.06	0.25	0.03	Chronic
10 Years (1991-2000)	0.14	0.14	0.14	2.38	2.05	0.02	Chronic
10 Years (2001-2010)	0.11	0.11	0.11	1.87	1.66	0.01	Chronic

The daily rainfall of Rabi season of 30 years (1981-2010) during the period from November to February in Rajshahi district considering 17 standard weeks have been used for Table 4.4.4. The chronic drought prone weeks are found in Rajshahi district which are drought index values DI= 0.02, 0.03, 0.02, 0.01.

Table: 4.4.5. Annual Drought Index Scenario for rainfall 5 mm of Rajshahi district.

Year	Drought Index
1981	0.38
1982	0.27
1983	0.24
1984	0.23
1985	0.25
1986	0.27
1987	0..20
1988	0.24
1989	0.33
1990	0.42
1991	0.15
1992	0.18
1993	0.30
1994	0.28
1995	0.26
1996	0.21
1997	0.25
1998	0.41
1999	0.25
2000	0.40
2001	0.24
2002	0.37
2003	0.25
2004	0.26
2005	0.26
2006	0.18
2007	0.24
2008	0.22
2009	0.24
2010	0.39

Annual variation of DI for 5 mm of rain for Rajshahi district

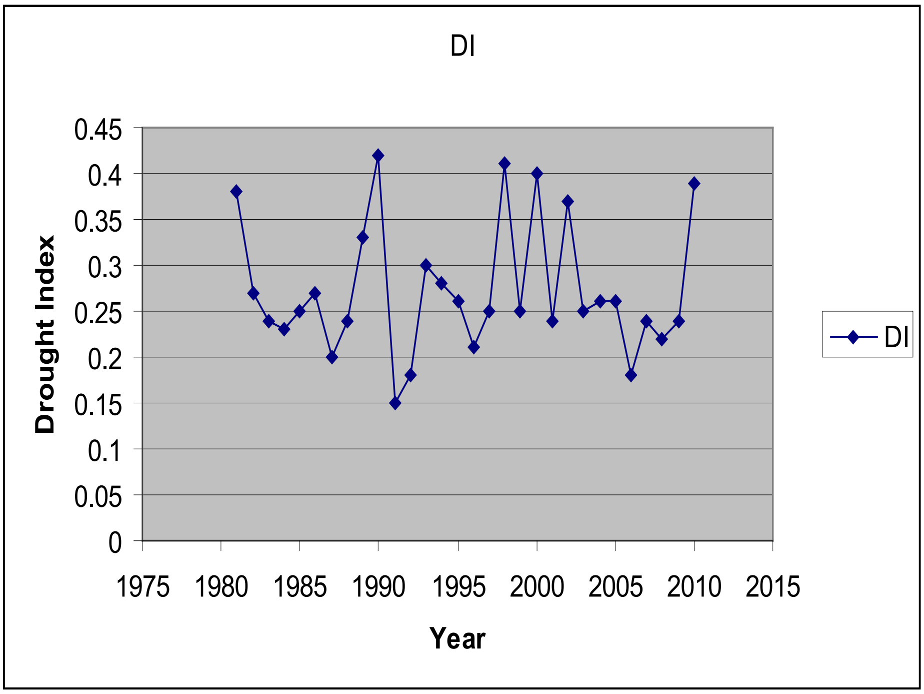

Figure No.02

Discussion: We observed from the above table (4.4.5) and Figure (02) the year 1991, 1992, 2006 are cronic drought 1984, 1986, 1987, 1996, 2008 are moderate drought 1983, 1985, 1986, 1988, 1992, 1994, 1995, 1997, 1999, 2001, 2003, 2004, 2005, 2007, 2009 are mild drought and 1981, 1989, 1990, 1998, 2000, 2002, 2010 are severe drought.

4.5 Test of Significance

4.5.1. Annual Scenario of Dry-Wet transition probability matrix for Rainfall 5 mm of rain for Rajshahi district

	Dry	Wet	Total
Dry	637	196	833
Wet	218	508	726
Total	855	704	1559
Cal χ^2	336.89		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Rajshahi district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.5.1.The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.5.1.) was Pr $\{\chi^2 \geq 336.89)$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.5.2. The occurrence and non-occurrence rainfall in Rajshahi district for the 10 consecutive years from 1981 to 1990. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	202	66	268
246Wet	74	172	246
Total	276	238	514
Cal χ^2	105.46		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.5.2.). The chi-squire value of the transition matrix (Table 4.5.2.) was Pr $\{\chi^2 \geq 105.46\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.5.3. The occurrence and non occurrence rainfall in Rajshahi district for the 10 consecutive years from 1991 to 2000. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	205	63	268
Wet	75	184	259
Total	280	247	527
Cal χ^2	120.52		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.5.3.). The chi-squire value of the transition matrix (Table 4.5.3.) was Pr $\{\chi^2 \geq 120.52\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.5.4.The occurrence and non-occurrence rainfall in Rajshahi district for the 10 consecutive years from 2001 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	230	67	297
Wet	69	152	221
Total	299	219	518
Cal χ^2	110.91		
χ^2 (1 d. f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.5.4.).The chi-squire value of the transition matrix (Table 4.5.4.) was Pr $\{\chi^2 \geq 110.91\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

4.6. Scenario of Seasonal of Dry-Wet transition probability matrix for Rainfall 5 mm of rain for Rajshahi district.

Table 4.6.1.The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Rajshahi district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	137	91	228
Wet	68	106	174
Total	205	197	402
Cal χ^2	17.41		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	57	54	111
Wet	61	447	508
Total	118	501	619
Cal χ^2	103.35		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	407	48	455
Wet	44	17	61
Total	451	65	516
Cal χ^2	14.66		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Rajshahi district for the 30 consecutive years from 1981 to 2010 were shown in Table 461he test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.6.1.) were Pr{ $\chi^2 \geq 17.41$ }for Pre-kharif, Pr{ $\chi^2 \geq$ 103.35} for Kharif, Pr{ $\chi^2 \geq 14.66$ } for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.6.2.The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Rajshahi district for the 10 consecutive years from 1981 to 1990. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	43	32	75
Wet	19	49	68
Total	62	81	143
Cal χ^2	8.26		
χ^2 (1 d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	15	15	30
Wet	19	157	176
Total	34	172	206
Cal χ^2	33.59		
χ^2 (1 d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	132	17	149
Wet	17	8	25
Total	149	25	164
Cal χ^2	7.57		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.6.2.).The chi-squire value of the transition matrix (Table 4.6.2.) were $\Pr\{\chi^2 \geq 8.26\}$for Pre-kharif, $\Pr\{\chi^2 \geq 33.59\}$ for Kharif, $\Pr\{\chi^2 \geq 7.57\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.6.3.The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Rajshahi district for the 10 consecutive years from 1991 to 2000. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	48	27	75
Wet	30	53	83
Total	78	80	158
Cal χ^2	4.87		
χ^2 (1 d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	30	20	50
Wet	24	125	149
Total	54	145	199
Cal χ^2	41.47		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	131	19	150
Wet	16	4	20
Total	147	23	170
Cal χ^2	0.80		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.6.3.).The chi-squire value of the transition matrix (Table 4.6.3.) were $\Pr\{\chi^2 \geq 4.87\}$for Pre-kharif, $\Pr\{\chi^2 \geq 41.47\}$ for Kharif, $\Pr\{\chi^2 \geq 0.80\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.6.4.The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Rajshahi district for the 10 consecutive years from 2001 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	46	32	78
Wet	26	27	53
Total	72	59	131
Cal χ^2	4.16		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	12	19	31
Wet	18	165	183
Total	30	184	214
Cal χ^2	28.31		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	144	12	156
Wet	11	5	16
Total	155	17	172
Cal χ^2	7.09		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Rajshahi district (Table 4.6.4.).The chi-squire value of the transition matrix (Table 4.6.4.) were $\Pr\{\chi^2 \geq 4.16\}$ for Pre-kharif, $\Pr\{\chi^2 \geq 28.31\}$ for Kharif, $\Pr\{\chi^2 \geq 7.09\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

4.7. Drough Index calculated by using Rainfall 2.5 mm of rain for Barishal district

The daily rainfall of 30 years during the period from 1981-2010 in Barisal district considering 52 standard weeks have been used.

Table 4.7.1. Analysis of probability of wet and dry weeks and index of drought-proneness in Barisal district for Annual by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Varian ce	DI	Comment
30Years (1981-2010)	0.56	0.58	0.57	27.06	14.18	0.29	Mild
10 Years (1981-1990)	0.54	0.61	0.56	29.04	14.72	0.30	Mild
10 Years (1991-2000)	0.46	0.58	0.47	27.08	13.79	0.28	Mild
10 Years (2001-2010)	0.59	0.56	0.59	25.06	14.02	0.29	Mild

Table 4.7.1.The mild drought prone weeks are found in Barisal district which are drought index values DI= 0.29, 0.30, 0.28, 0.29

The daily rainfall of Pre-Kharif season of 30 years (1981-2010) during the period from March to May in Barisal district considering 13 standard weeks have been used.

Table 4.7.2.Analysis of probability of wet and dry weeks and index of drought-proneness in Barisal district for Pre-Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.53	0.57	0.61	6.94	3.44	0.29	Mild
10 Years (1981-1990)	0.53	0.58	0.61	6.54	3.76	0.39	Occasional
10 Years (1991-2000)	0.54	0.59	0.65	7.31	3.34	0.27	Mild
10 Years (2001-2010)	0.52	0.54	0.58	6.98	3.23	0.23	Mild

Table 4.7.2. The Mild, occasional, Mild, Mild drought prone weeks are found in Barisal district which are drought index values DI= 0.29, 0.39, 0.27, 0.23.

The daily rainfall of Kharif season of 30 years(1981-2010) during the period from June to October in Barisal district considering 22 standard weeks have been used.

Table 4.7.3. Analysis of probability of wet and dry weeks and index of drought-proneness in Barisal district for Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.76	0.75	0.81	16.73	4.22	0.67	Occasional
10 Years (1981-1990)	0.64	0.67	0.86	16.72	5.26	0.67	Occasional
10 Years (1991-2000)	0.86	0.83	0.78	18.16	4.93	0.49	Occasional
10 Years (2001-2010)	0.77	0.75	0.79	15.31	2.47	0.86	Occasional

Table 4.7.3.The occasionally drought prone weeks are found in Barisal district which are drought index values DI= 0.67, 0.67, 0.49, 0.86.

The daily rainfall of Rabi season of 30 years (1981-2010) during the period from November to February in Barisal district considering 17 standard weeks have been used.

Table 4.7.4. Analysis of probability of wet and dry weeks and index of drought-proneness in Barisal district for Rabi Markov Chain.

Year	P01	P11	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.15	0.16	0.16	2.72	2.81	0.03	Chronic
10 Years (1981-1990)	0.18	0.19	0.18	3.06	3.51	0.05	Chronic
10 Years (1991-2000)	0.15	0.18	0.18	2.23	2.94	0.03	Chronic
10 Years (2001-2010)	0.12	0.12	0.12	2.87	1.99	0.02	Chronic

Table 4.7.4.The chronic drought prone weeks are found in Barisal district which are drought index values DI= 0.03, 0.05, 0.03, 0.02

Table 4.7.5. Annual Drought Index Scenario for rainfall 2.5 mm of rain for Barisal district.

Year	Drought Index
1981	0.57
1982	0.39
1983	0.45
1984	0.23
1985	0.14
1986	0.34
1987	0.55
1988	0.29
1989	0.12
1990	0.28
1991	0.77
1992	0.50
1993	0.43
1994	0.32
1995	0.64
1996	0.44
1997	0.54
1998	0.39
1999	0.29
2000	0.62
2001	0.49
2002	0.37
2003	0.42
2004	0.67
2005	0.41
2006	0.33
2007	0.57
2008	0.67
2009	0.45
2010	0.81

Annual variation of DI for 2.5 mm for Barisal district.

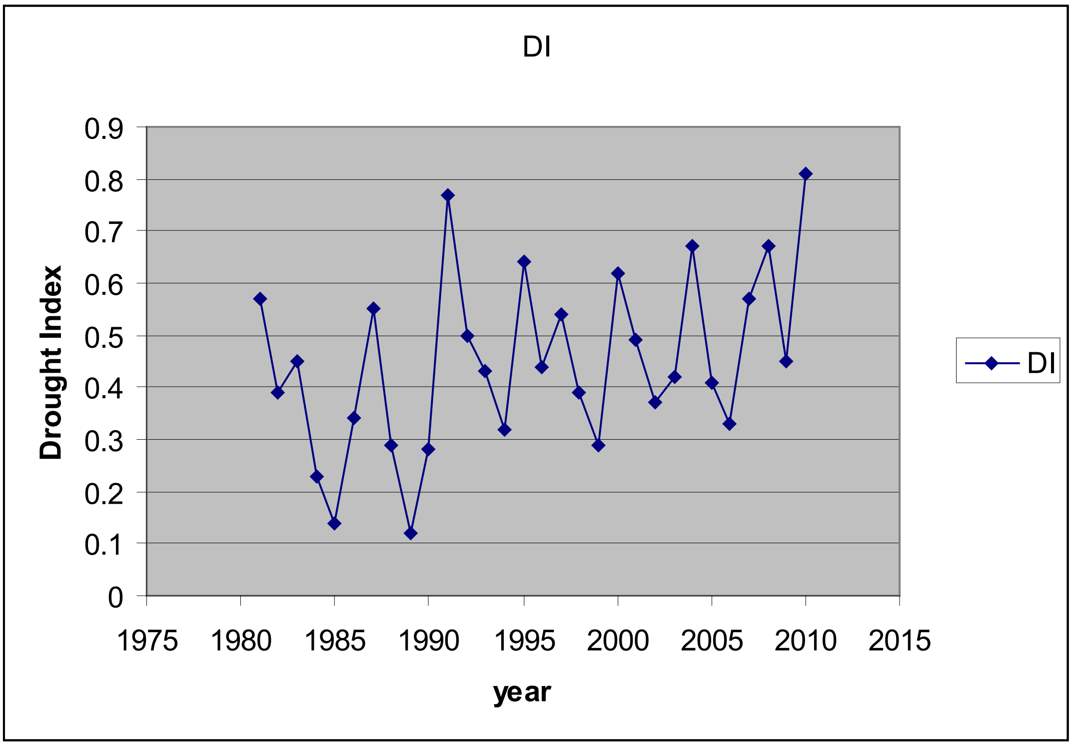

Figure no.03

Discussion: We observed from the above table (4.7.5) and Figure (03) the year 1985, 1987 are severe drought 1984 is moderate drought 1988, 1990 are mild drought 1981-1987, 1991-2010 are occasional.

Test of hypothisice

4.8. Annual Scenario of Dry-Wet transition probability matrix for Rainfall 2.5 mm of rain in Barisal district

The probabilities of rainfall occurrence were derived from the probability model and require two conditional probabilities P1=Pr{wet week / previous week wet}=Pr{w/w}, Po=Pr{wet week / previous week dry}=Pr{W/D}.The fit of the Markov chain model had been tested on data of rainfall in Barisal district for a period of 30 years from 1981 to 2010.The conditional probabilities in a Markov chain were estimated by using maximum likelihood estimation techniques.

Table 4.8.1The occurrence and non-occurrence rainfall in Barisal district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	534	208	742
Wet	194	677	871
Total	728	885	1613
Cal χ^2	407.13		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Barisal district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.8.1 The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.8.1.) was Pr { $\chi^2 \geq 407.13$} being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.8.2. The occurrence and non-occurrence rainfall in Barisal district for the 10 consecutive years from 1981 to 1990. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	164	63	227
Wet	80	229	309
Total	244	292	536
Cal χ^2	139.26		
χ^2 (1 d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.8.2). The chi-squire value of the transition matrix (Table 4.8.2) was Pr $\{\chi^2 \geq 139.26\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.8.3.The occurrence and non-occurrence rainfall in Barisal district for the 10 consecutive years from 1991 to 2000. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	170	69	239
Wet	57	216	273
Total	227	285	512
Cal χ^2	142.12		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table4.8.3.).The chi-squire value of the transition matrix (Table 4.8.3.) was Pr $\{\chi^2 \geq 142.12\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.8.4The occurrence and non-occurrence rainfall in Barisal district for the 10 consecutive years from 2001 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	209	10	219
Wet	66	23	89
Total	275	33	308
Cal χ^2	129.43		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.8.4.). The chi-squire value of the transition matrix (Table 4.8.4.) was Pr $\{\chi^2 \geq 129.43\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.8.5. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Barisal district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	125	68	193
Wet	67	137	204
Total	192	205	397
Cal χ^2	59.35		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	48	42	90
Wet	67	528	595
Total	115	570	685
Cal χ^2	99.13		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	323	54	377
Wet	56	18	74
Total	379	72	451
Cal χ^2	4.64		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Barisal district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.8.5. The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.8.5.) were Pr{$\chi^2 \geq$59.35}Pre-kharif, Pr{$\chi^2 \geq$ 99.13}Kharif, Pr{$\chi^2 \geq$4.64} Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

4.9. Seasonal Scenario of Dry-Wet transition probability matrix for Rainfall 2.5 mm of rain for Barisal district

Table 4.9.1. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Barisal district for the 10 consecutive years from 1981 to 1990. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	37	23	60
Wet	14	59	73
Total	51	82	133
Cal χ^2	17.25		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	19	10	29
Wet	23	170	193
Total	42	180	222
Cal χ^2	49.41		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	117	45	162
Wet	21	23	44
Total	138	68	206
Cal χ^2	4.29		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table4.9.1.). The chi-squire value of the transition matrix (Table 4.9.1.) were $\Pr\{\chi^2 \geq 17.25\}$ for Pre-kharif, $\Pr\{\chi^2 \geq 49.41\}$ for Kharif, $\Pr\{\chi^2 \geq 4.19\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.9.2. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Barisal district for the 10 consecutive years from 1991 to 2000. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	49	29	78
Wet	24	43	67
Total	73	73	145
Cal χ^2	17.51		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	25	15	40
Wet	33	177	210
Total	58	192	250
Cal χ^2	59.64		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	87	2	89
Wet	19	5	24
Total	106	7	113
Cal χ^2	0.39		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.9.2.). The chi-squire value of the transition matrix (Table 4.9.2.) were Pr $\{\chi^2 \geq 17.51\}$ for Pre-kharif, Pr$\{\chi^2 \geq 59.64\}$ for Kharif, Pr$\{\chi^2 \geq 0.39\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.9.3. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Barisal district for the 10 consecutive years from 2001 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	59	36	95
Wet	22	35	57
Total	81	71	152
Cal χ^2	8.70		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	9	22	31
Wet	22	177	199
Total	31	199	230
Cal χ^2	6.40		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	135	25	160
Wet	16	5	21
Total	151	30	181
Cal χ^2	5.64		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.9.3.)The chi-squire value of the transition matrix (Table 4.9.3.) were Pr{ $\chi^2 \geq 8.70$}for Pre-kharif, Pr{ $\chi^2 \geq 6{,}40$} for Kharif, Pr{ $\chi^2 \geq 5.64$} for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

4.10. Drought Index Calculated by using Rainfall 5 mm of rain for Barisal district

The daily rainfall of 30 years during the period from 1981-2010 in Barisal district considering 52 standard weeks have been used for

Table 4.10.1.Analysis of probability of wet and dry weeks and index of drought-proneness in Barisal district for Annual by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.57	0.57	0.53	27.06	14.84	0.30	Mild
10 Years (1981-1990)	0.54	0.61	0.56	2804	15.72	0.30	Mild
10 Years (1991-2000)	0.47	0.54	0.56	27.08	13.79	0.28	Mild
10 Years (2001-2010)	0.59	0.55	0.48	2606	15.02	0.29	Mild

Table 4.10.1.The mild drought prone weeks are found in Barisal district which are drought index values DI= 0.30, 0.30, 0.29, 0.28.

The daily rainfall of Pre-Kharif season of 30 years (1981-2010) during the period from March to May in Barisal district considering 13 standard weeks have been used.

Table 4.10.2. Analysis of probability of wet and dry weeks and index of drought-proneness in Barisal district for Pre-Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.55	0.57	0.64	6.94	3.49	0.39	Occasional
10 Years (1981-1990)	0.55	0.58	0.68	6.54	3.76	0.39	Occasional
10 Years (1991-2000)	0.54	0.59	0.66	7.31	2.98	0.37	Occasional
10 Years (2001-2010)	0.56	0.54	0.58	6.98	3.75	0.42	Occasional

Table.4.10.2. The occasional drought prone weeks are found in Barisal district which are drought index values DI= 0.39, 0.39, 0.37, 0.42

The daily rainfall of Kharif season of 30 years (1981-2010) during the period from June to October in Barisal district considering 22 standard weeks have been used.

Table 4.10.3. Analysis of probability of wet and dry weeks and index of drought-proneness in Barisal district for Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.76	0.75	0.81	15.39	3.57	0.84	Occasional
10 Years (1981-1990)	0.64	0.57	0.86	14.72	4.28	0.87	Occasional
10 Years (1991-2000)	0.79	0.88	0.78	16.16	3.96	0.79	Occasional
10 Years (2001-2010)	0.86	0.79	0.79	15.31	2.47	0.86	Occasional

Table 4.10.3. The occasionally drought prone weeks are found in Barisal district which are drought index values DI= 0.84, 0.87, 0.79, 0.86.

The daily rainfall of Rabi season of 30 years (1981-2010) during the period from November to February in Barisal district considering 17 standard weeks have been used.

Table 4.10.4. Analysis of probability of wet and dry weeks and index of drought proneness in Barisal district for Rabi by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.15	0.18	0.18	2.98	2.89	0.06	Chronic
10 Years (1981-1990)	0.18	0.19	0.18	3.06	2.76	0.05	Chronic
10 Years (1991-2000)	0.13	0.19	0.18	3.23	2.94	0.08	Chronic
10 Years (2001-2010)	0.14	0.15	0.17	2.11	2.99	0.04	Chronic

Table 4.10.4. The chronic drought prone weeks are found in Barisal district which are drought index values DI= 0.06, 0.05, 0.08, 0.04

Table 4.10.5. Annual Drought Index Scenario for rainfall 5 mm of rain for Barisal district.

Year	Drought Index
1981	0.57
1982	0.43
1983	0.54
1984	0.23
1985	0.24
1986	0.34
1987	0.76
1988	0.32
1989	0.21
1990	0.33
1991	0.77
1992	0.59
1993	0.43
1994	0.37
1995	0.64
1996	0.57
1997	0.44
1998	0.22
1999	0.43
2000	0.46
2001	0.49
2002	0.89
2003	0.53
2004	0.67
2005	0.43
2006	0.39
2007	0.56
2008	0.67
2009	0.76
2010	0.81

Annual variation of DI for 5mm of rain for Barisal district

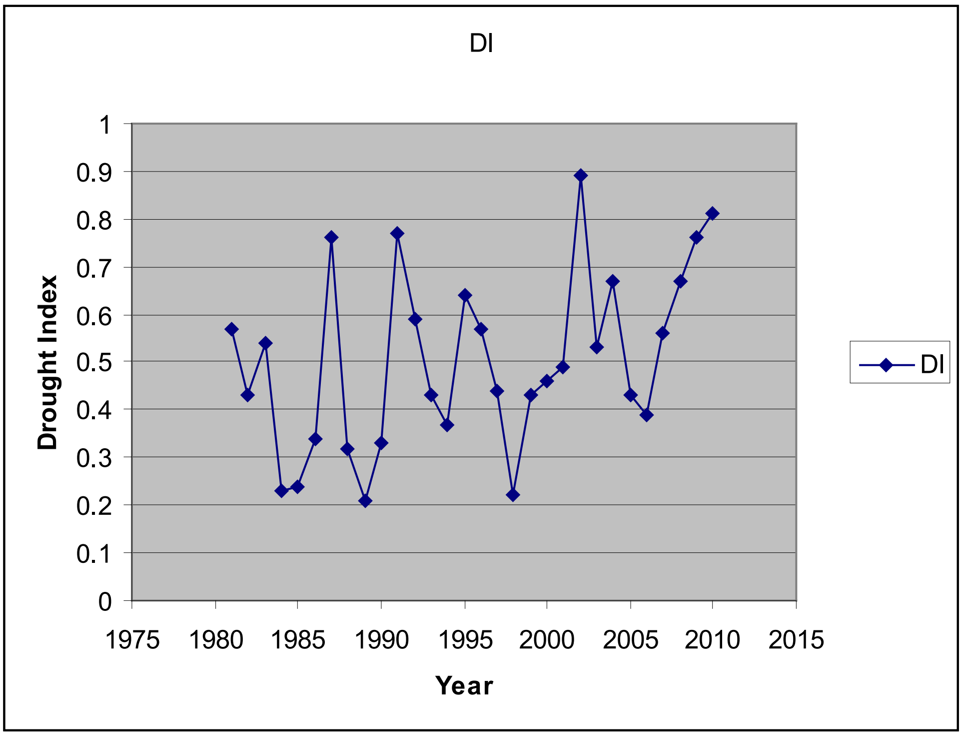

Figure No.04

Discussion: We observed from the above table (4.10.5) and Figure (04) the year 1984, 1989, 1998 are severe drought, 1985 is moderate drought and 1981-1988, 1990-1999, 2000-2010 are occasion drought.

4.10.6 Annual Scenario of Dry-Wet transition probability matrix for Rainfall 5 mm of rain for Barisal district.

Table 4.10.7.The occurrence and non-occurrence rainfall in Barisal district for the 30 consecutive years from 1981 to 2010.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	639	198	837
Wet	228	608	836
Total	867	806	1673
Cal χ^2	343.89		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Barisal district for the 30 consecutive years from 1981 to 2010 were shown in (Table 4.10.7.)The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.10.7.) was Pr $\{\chi^2 \geq 343.89\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.10.8. The occurrence and non-occurrence rainfall in Barisal district for the 10 consecutive years from 1981 to 1990. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	208	56	264
Wet	55	177	232
Total	263	233	496
Cal χ^2	109.77		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.10.8.). The chi-squire value of the transition matrix (Table 4.10.8.) was Pr $\{\chi^2 \geq 109.77\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.10.9. The occurrence and non-occurrence rainfall in Barisal district for the 10 consecutive years from 1991 to 2000.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	205	86	291
Wet	78	178	216
Total	283	264	507
Cal χ^2	119.43		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.10.9.).The chi-squire value of the transition matrix (Table 4.10.9.) was Pr $\{\chi^2 \geq 119.43\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.10.10.The occurrence and non-occurrence rainfall in Barisal district for the 10 consecutive years from 2001 to 2010.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	280	64	344
Wet	69	152	221
Total	349	216	565
Cal χ^2	113.89		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.10.10.). The chi-squire value of the transition matrix (Table 4.10.10.) was Pr $\{\chi^2 \geq 113.89\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

4.10.11. Seasonal Scenario of Dry-Wet transition probability matrix for Rainfall 2.5 mm of rain for Barisal district

Table 4.10.12.The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Barisal district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	155	89	244
Wet	88	109	197
Total			
Cal χ^2	19.43		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	72	57	129
Wet	34	456	490
Total	106	513	619
Cal χ^2	103.35		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	407	48	455
Wet	22	39	61
Total	429	87	516
Cal χ^2	14.66		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Barisal district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.10.12. The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.10.12.) were Pr{$\chi^2 \geq 19.43$}for Pre-kharif, Pr{$\chi^2 \geq$ 103.35} for Kharif, Pr{$\chi^2 \geq 14.66$} for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.10.13. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Barisal district for the 10 consecutive years from 1981 to 1990.A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	45	28	73
Wet	29	37	66
Total	74	65	133
Cal χ^2	7.22		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	11	20	31
Wet	191	57	248
Total	202	77	279
Cal χ^2	36.55		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	102	24	126
Wet	17	8	25
Total	119	106	151
Cal χ^2	7.64		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.10.13.).The chi-squire value of the transition matrix (Table 4.10.13.) were $\Pr\{\chi^2 \geq 7.22\}$ for Pre-kharif, $\Pr\{\chi^2 \geq 36.55\}$ for Kharif, $\Pr\{\chi^2 \geq 7.64\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.10.14. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Barisal district for the 10 consecutive years from 1991 to 2000. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	37	38	75
Wet	33	50	83
Total	70	88	158
Cal χ^2	4.99		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	28	33	61
Wet	20	98	118
Total	48	131	178
Cal χ^2	39.66		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	120	36	156
Wet	19	10	29
Total	139	46	185
Cal χ^2	0,85		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.10.14.). The chi-squire value of the transition matrix (Table 4.10.14.) were $\Pr\{\chi^2 \geq 4.99\}$ for Pre-kharif, $\Pr\{\chi^2 \geq 39.66\}$ for Kharif, $\Pr\{\chi^2 \geq o.85\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.10.15.The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Barisal district for the 10 consecutive years from 2001 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	56	22	78
Wet	33	11	44
Total	89	33	122
Cal χ^2	4.02		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	18	11	29
Wet	32	155	187
Total	50	166	216
Cal χ^2	28.31		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	120	55	156
Wet	8	13	21
Total	128	68	177
Cal χ^2	7.22		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Barisal district (Table 4.10.15.).The chi-squire value of the transition matrix (Table 4.10.15.) were Pr{ $\chi^2 \geq 4.02$}for Pre-kharif, Pr{ $\chi^2 \geq 28.31$ } for Kharif, Pr{ $\chi^2 \geq 7.22$} for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

4.11.Drough Index calculated by using Rainfall 2.5 mm of rain for Comilla district.

The daily rainfall of 30 years during the period from 1981-2010 in Comilla district considering 52 standard weeks have been used..

Table 4.11.1. Analysis of probability of wet and dry weeks and index of drought-proneness in Comilla district for Annual by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Varian ce	DI	Comment
30 Years (1981-2010)	0.52	0.55	0.54	27.99	14.07	0.27	Mild
10 Years (1981-1990)	0.54	0.56	0.54	26.07	14.07	0.26	Mild
10 Years (1991-2000)	0.49	0.58	0.51	29.27	13.95	0.28	Mild
10 Years (2001-2010)	0.51	0.51	0.57	28.63	14.03	0.27	Mild

Table 4.11.1. The mild drought prone weeks are found in Comilla district which are drought index values DI= 0.27, 0.26, 0.28, 0.27.

The daily rainfall of Pre-Kharif season of 30 years (1981-2010) during the period from March to May in Comilla district considering 13 standard weeks have been used.

Table 4.11.2. Analysis of probability of wet and dry weeks and index of drought-proneness in Comilla district for Pre-Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Varian ce	DI	Comment
30 Years (1981-2010)	0.51	0.53	0.56	7.31	3.34	0.28	Mild
10 Years (1981-1990)	0.58	0.56	0.59	8.09	2.95	0.38	Occasional
10 Years (1991-2000)	0.49	0.49	0.56	7.85	3.08	0.26	Mild
10 Years (2001-2010)	0.47	0.55	0.53	5.98	3.98	0.21	Moderate

The daily rainfall of Pre-Kharif season of 30 years (1981-2010) during the period from March to May in Comilla district considering 13 standard weeks have been used for Table 4.11.2. The Mild, occasional**,** Mild, Moderate drought prone weeks are found in Comilla district which are drought index values DI= 0.28, 0.38, 0.26 , 0.21

The daily rainfall of Kharif season of 30 years (1981-2010) during the period from June to October in Comilla district considering 22 standard weeks have been used

Table 4.11.3. Analysis of probability of wet and dry weeks and index of drought-proneness in Comilla district for Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Varian ce	DI	Comment
30 Years (1981-2010)	0.64	0.64	0.65	15.71	2.97	0.62	Occasional
10 Years (1981-1990)	0.56	0.58	0.57	14.07	3.98	0.63	Occasional
10 Years (1991-2000)	0.65	0.63	0.64	15.98	3.08	0.54	Occasional
10 Years (2001-2010)	0.72	0.72	0.72	17.08	1.87	0.68	Occasional

Table 4.11.3. The occasionally drought prone weeks are found in Comilla district which are drought index values 0.62, 0.63, 0.54, 0.68.

The daily rainfall of Rabi season of 30 years (1981-2010) during the period from November to February in Comilla district considering 17 standard weeks have been used.

Table 4.11.4. Analysis of probability of wet and dry weeks and index of drought-proneness in Comilla district for Rabi Markov Chain.

Year	P01	P11	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.16	0.15	0.15	2.72	1.87	0.05	Chronic
10 Years (1981-1990)	0.15	0.19	0.19	3.07	2.08	0.04	Chronic
10 Years (1991-2000)	0.16	0.17	0.17	2.98	2.45	0.03	Chronic
10 Years (2001-2010)	0.18	0.10	0.10	2..08	1.09	0.07	Chronic

Table 4.11.4. The chronic drought prone weeks are found in Comilla district which are drought index values 0.05, 0.04 ,0.03, 0.07.

4.11.5. Annual Drought Index Scenario for rainfall 2.5 mm of rain for Comilla district.

Year	Drought Index
1981	0.32
1982	0.17
1983	0.31
1984	0.25
1985	0.43
1986	0.31
1987	0.27
1988	0.18
1989	0.34
1990	0.45
1991	0.38
1992	0.22
1993	0.37
1994	0.28
1995	0.38
1996	0.45
1997	0.32
1998	0.48
1999	0.23
2000	0.34
2001	0.19
2002	0.34
2003	0.21
2004	0.29
2005	0.31
2006	0.21
2007	0.28
2008	0.25
2009	0.24
2010	0.32

Annual variation of DI for 2.5 mm of rain for Cumilla district

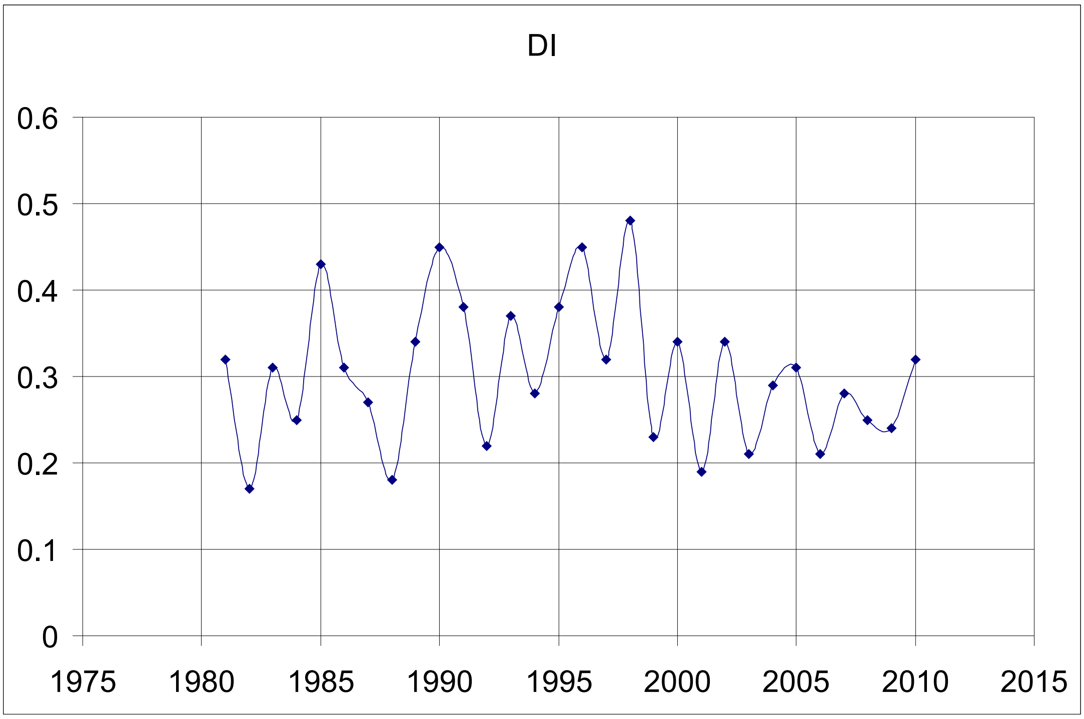

Figure No.05

Discussion: We observed from the above table (4.11.5) and Figure (05) the year 1982, 1988 are severe drought, 1983, 1982, 1998, 2001, 2003, 2006 are moderate drought 1984, 1986, 1987, 1994, 2004, 2005, 2007, 2008 and 2009 are mild drought 1981, 1985, 1989, 1990, 1991, 1993, 1995, 1996, 1997, 1998, 2000, 2002, 2010 are occasional drought.

Test of Significance

4.11.6. Annual Scenario of Dry-Wet transition probability matrix for Rainfall 2.5 mm of rain for Comilla district

The probabilities of rainfall occurrence were derived from the probability model and require two conditional probabilities P1=Pr{wet week /previous week wet} = Pr{w/w}, Po=Pr{wet week/previous week dry}=Pr{W/D}. The fit of the Markov chain model had been tested on data of rainfall in Comilla district for a period of 30 years from 1981 to 2010.The conditional probabilities in a Markov chain were estimated by using maximum likelihood estimation techniques.

Table 4.11.7. The occurrence and non-occurrence rainfall in Comilla district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	522	212	734
Wet	183	686	869
Total	705	898	1603
Cal χ^2	399.16		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Comilla district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.11.7. The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.11.7.) was Pr {$\chi^2 \geq 399.16$} being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.11.8. The occurrence and non-occurrence rainfall in Comilla district for the 10 consecutive years from 1981 to 1990.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	155	69	224
Wet	78	219	297
Total	233	288	521
Cal χ^2	121.12		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.11.8.). The chi-squire value of the transition matrix (Table 4.11.8.) was Pr $\{\chi^2 \geq 121.12\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.11.9. The occurrence and non-occurrence rainfall in Comilla district for the 10 consecutive years from 1991 to 2000. A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	180	49	229
Wet	72	210	282
Total	252	259	511
Cal χ^2	144.12		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.11.9.). The chi-squire value of the transition matrix (Table 4.11.9.) was Pr $\{\chi^2 \geq 144.12\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.11.10. The occurrence and non-occurrence rainfall in Comilla district for the 10 consecutive years from 2001 to 2010.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	199	86	285
Wet	65	227	292
Total	264	313	577
Cal χ^2	139.43		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.11.10.). The chi-squire value of the transition matrix (Table 4.11.10.) was Pr $\{\chi^2 \geq 139.43\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

4.12. Seasonal Scenario of Dry-Wet transition probability matrix for Rainfall 2.5 mm of rain for Comilla district

Table 4.12.1. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Comilla district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	126	74	200
Wet	55	145	200
Total	181	219	400
Cal χ^2	38.65		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	56	34	90
Wet	48	535	583
Total	104	569	673
Cal χ^2	97.99		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	302	75	377
Wet	51	24	75
Total	353	99	452
Cal χ^2	4.52		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Comilla district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.12.1. The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.12.1) were $\Pr\{\chi^2 \geq 38.65\}$ for Pre-kharif, $\Pr\{\chi^2 \geq 97.99\}$ for Kharif, $\Pr\{\chi^2 \geq 4.52\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.12.2. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Comilla district for the 10 consecutive years from 1981 to 1990. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	45	17	62
Wet	22	33	55
Total	67	50	117
Cal χ^2	14.98		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	18	11	29
Wet	25	168	193
Total	43	179	222
Cal χ^2	41.09		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	123	19	142
Wet	25	8	33
Total	148	27	175
Cal χ^2	1.86		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.12.2.). The chi-squire value of the transition matrix (Table 4.12.2.) were $\Pr\{\chi^2 \geq 14.98\}$ for Pre-kharif, $\Pr\{\chi^2 \geq 41.09\}$ for Kharif, $\Pr\{\chi^2 \geq 1.86\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.12.3. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Comilla district for the 10 consecutive years from 1991 to 2000. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	41	18	59
Wet	24	43	67
Total	65	61	126
Cal χ^2	14.35		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	25	15	40
Wet	22	177	199
Total	47	192	239
Cal χ^2	52.74		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	83	18	101
Wet	19	5	24
Total	102	23	125
Cal χ^2	0.33		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.12.3.). The chi-squire value of the transition matrix (Table 4.12.3.) were Pr $\{\chi^2 \geq 14.35\}$ for Pre-kharif, Pr$\{\chi^2 \geq 52.74\}$ for Kharif, Pr$\{\chi^2 \geq 0.33\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.12.4. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Comilla district for the 10 consecutive years from 2001 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	55	23	78
Wet	19	43	62
Total	74	66	140
Cal χ^2	7.32		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	9	17	26
Wet	28	173	201
Total	37	190	227
Cal χ^2	5.01		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	132	11	143
Wet	11	7	18
Total	143	18	161
Cal χ^2	2.99		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.12.4.). The chi-squire value of the transition matrix (Table 4.12.4.) were $\Pr\{\chi^2 \geq 7.32\}$for Pre-kharif, $\Pr\{\chi^2 \geq 5.01\}$for Kharif, $\Pr\{\chi^2 \geq 2.99\}$for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

4.12.5. Drought Index Calculated by using Rainfall 5 mm of rain for Comilla district

The daily rainfall of 30 years during the period from 1981-2010 in Comilla district considering 52 standard weeks have been used for

Table 4.12.6. Analysis of probability of wet and dry weeks and index of drought-proneness in Comilla district for Annual by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30Years (1981-2010)	0.66	0.66	0.27	28.26	19.35	0.31	Occasional
10 Years (1981-1990)	0.64	0.68	0.27	29.78	24.08	0.38	Occasional
10 Years (1991-2000)	0.68	0.69	0.29	26.98	17,08	0.26	Mild
10 Years (2001-2010)	0.67	0.62	0.26	28.01	16.88	0.29	Mild

Table 4.12.6. The Occasional, occasional, mild, mild drought prone weeks are found in Comilla district which are drought index values 0.31, 0.38, 0.26, 0.29.

The daily rainfall of Pre-Kharif season of 30 years (1981-2010) during the period from March to May in Comilla district considering 13 standard weeks have been used.

Table 4.12.7. Analysis of probability of wet and dry weeks and index of drought-proneness in Comilla district for Pre-Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30Years 1981-2010)	0.54	0.55	0.64	6.65	4.29	0.29	Mild
10 Years (1981-1990)	0.65	0.59	0.65	6.99	4.01	0.39	Occasional
10 Years (1991-2000)	0.49	0.54	0.63	6.88	4.77	0.26	Mild
10 Years (2001-2010)	0.48	0.52	0.64	6.08	4.09	0.23	Mild

Table 4.12.7. The Mild, Occasional, Mild, Mild drought prone weeks are found in Comilla district which are drought index values 0.29, 0.39, 0.26, 0.23

The daily rainfall of Kharif season of 30 years (1981-2010) during the period from June to October in Comilla district considering 22 standard weeks have been used.

Table 4.12.8. Analysis of probability of wet and dry weeks and index of drought-proneness in Comilla District for Kharif by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.86	0.86	0.85	20.07	4.93	0.74	Occasional
10 Years (1981-1990)	0.84	0.85	0.85	17.99	4.77	0.98	Occasional
10 Years (1991-2000)	0.85	0.85	0.85	19.06	7.02	0.54	Occasional
10 Years (2001-2010)	0.89	0.89	0.86	23.12	2.99	0.69	Occasional

Table 4.12.8. The occasionally drought prone weeks are found in Comilla district which are drought index values 0.74, 0.98, 0.54, 0.69

The daily rainfall of Rabi season of 30 years (1981-2010) during the period from November to February in Comilla district considering 17 standard weeks have been used.

Table 4.12.9. Analysis of probability of wet and dry weeks and index of drought-proneness in Comilla district for Rabi by Markov Chain.

Year	P_{01}	P_{11}	P	Mean E(Y)	Variance	DI	Comment
30 Years (1981-2010)	0.16	0.15	0.16	2.68	1.39	0.04	Chronic
10 Years (1981-1990)	0.19	0.18	0.19	3.12	0.32	0.02	Chronic
10 Years (1991-2000)	0.17	0.14	0.17	2.91	1.98	0.04	Chronic
10 Years (2001-2010)	0.12	0.12	0.12	2.01	1.87	0.07	Chronic

Table 4.12.9. The chronic drought prone weeks are found in Comilla district which are drought index values 0.04, 0.02, 0.04, 0.07

Table 4.12.10. Annual Drought Index Scenario for rainfall 5 mm of rain for Comilla district.

Year	Drought Index
1981	0.54
1982	0.32
1983	0.33
1984	0.37
1985	0.55
1986	0.33
1987	0.38
1988	0.29
1989	0.43
1990	0.38
1991	0.53
1992	0.74
1993	0.57
1994	0.71
1995	0.54
1996	0.75
1997	0.64
1998	0.51
1999	0.85
2000	0.87
2001	0.78
2002	0.42
2003	0.52
2004	0.44
2005	0.64
2006	0.33
2007	0.42
2008	0.33
2009	0.64
2010	0.75

Annual variation of DI for 5 mm of rain for Comilla district

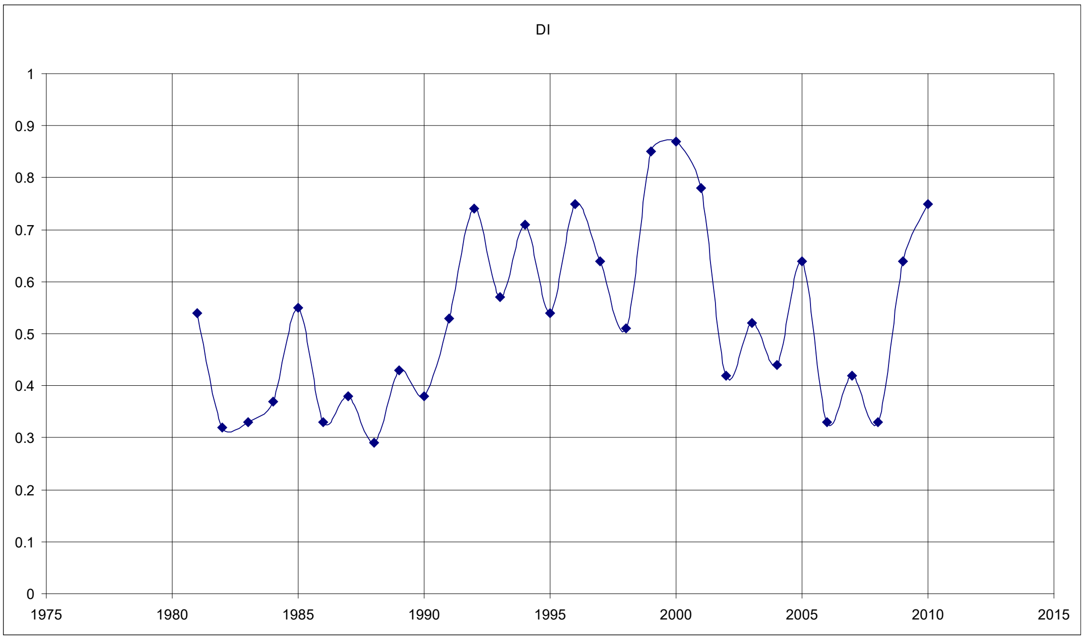

Figure No. 06

Discussion: We observed from the above table (4.12.10) and Figure (01) all years are occasional except 1988 are mild.

Test of Significance

4.13. Annual Scenario of Dry-Wet transition probability matrix for Rainfall 5 mm of rain for Comilla district.

Table 4.13.1. The occurrence and non-occurrence rainfall in Comilla district for the 30 consecutive years from 1981 to 2010.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	625	212	837
Wet	196	528	724
Total	821	740	1561
Cal χ^2	339.03		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Comilla district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.13.1.The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.13.1.) was Pr{ $\chi^2 \geq 339.03$}being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.13.2. The occurrence and non-occurrence rainfall in Comilla district for the 10 consecutive years from 1981 to 1990.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	199	76	275
Wet	87	155	242
Total	286	231	517
Cal χ^2	104.99		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.13.2.). The chi-squire value of the transition matrix (Table 4.13.2.) was Pr { $\chi^2 \geq 104.99$} being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.13.3. The occurrence and non-occurrence rainfall in Comilla district for the 10 consecutive years from 1991 to 2000.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	187	97	284
Wet	87	175	262
Total	254	272	546
Cal χ^2	122.78		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.13.3.). The chi-squire value of the transition matrix (Table 4.13.3.) was Pr $\{\chi^2 \geq 122.78\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.13.4. The occurrence and non-occurrence rainfall in Comilla district for the 10 consecutive years from 2001 to 2010.A dry week is denoted by state 0 and a wet week is denoted by state 1.

	Dry	Wet	Total
Dry	228	73	301
Wet	72	149	221
Total	300	222	522
Cal χ^2	111.21		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.13.4.). The chi-squire value of the transition matrix (Table 4.13.4.) was Pr $\{\chi^2 \geq 111.21\}$ being very small indicating the null hypothesis that chain of order 0 is rejected.

4.13.5. Seasonal Scenario of Dry-Wet transition probability matrix for Rainfall 5 mm of rain in Comilla district.

Table 4.13.6. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Comilla district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	136	92	228
Wet	56	112	168
Total	192	204	396
Cal χ^2	16.98		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	62	53	115
Wet	59	449	508
Total	121	502	623
Cal χ^2	104.06		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	412	33	445
Wet	49	15	64
Total	461	48	509
Cal χ^2	13.95		
χ^2 (1d.f. at 5% level)	3.841		

The occurrence and non-occurrence rainfall in Comilla district for the 30 consecutive years from 1981 to 2010 were shown in Table 4.13.6. . The test of null hypothesis that the chain is of order 0 against the alternative hypothesis that is of order 1.The chi-squire value of the transition matrix (Table 4.13.6.) were Pr{$\chi^2 \geq 16.98$}for Pre-kharif, Pr{$\chi^2 \geq$ 104.06} for Kharif, Pr{$\chi^2 \geq 13.95$} for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.13.7. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Comilla district for the 10 consecutive years from 1981 to 1990. A dry week is in Comilla district for the 30 consecutive years from 1981 to 2010. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	39	36	75
Wet	23	45	68
Total	62	81	143
Cal χ^2	8.26		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	17	13	30
Wet	16	160	176
Total	33	173	206
Cal χ^2	33.59		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	132	17	149
Wet	17	8	25
Total	149	25	164
Cal χ^2	7.57		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.13.7.). The chi-squire value of the transition matrix (Table 4.13.7.) were $\Pr\{\chi^2 \geq 8.26\}$ for Pre-kharif, $\Pr\{\chi^2 \geq 33.59\}$ for Kharif, $\Pr\{\chi^2 \geq 7.57\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.13.8. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Comilla district for the 10 consecutive years from 1991 to 2000. A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	47	28	75
Wet	35	49	84
Total	82	77	159
Cal χ^2	4.76		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	33	15	48
Wet	34	127	161
Total	67	142	209
Cal χ^2	42.01		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	127	22	149
Wet	11	5	16
Total	138	27	165
Cal χ^2	0.79		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.13.8.). The chi-squire value of the transition matrix (Table 4.13.8.) were $\Pr\{\chi^2 \geq 4.76\}$ for Pre-kharif, $\Pr\{\chi^2 \geq 42.02\}$ for Kharif, $\Pr\{\chi^2 \geq 0.79\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

Table 4.13.9. The occurrence and non-occurrence data of pre-kharif (March-May), kharif (June-Oct) and Rabi (Nov-Feb) seasons of rainfall in Comilla district for the 10 consecutive years from 2001 to 2010.A dry week is denoted by state 0 and a wet week is denoted by state 1.

Pre-Kharif	Dry	Wet	Total
Dry	39	42	81
Wet	34	18	52
Total	73	60	133
Cal χ^2	4.11		
χ^2 (1d.f. at 5% level)	3.841		
Kharif	Dry	Wet	Total
Dry	16	17	33
Wet	22	157	179
Total	38	174	212
Cal χ^2	28.11		
χ^2 (1d.f. at 5% level)	3.841		
Rabi	Dry	Wet	Total
Dry	134	23	157
Wet	13	4	17
Total	147	27	164
Cal χ^2	6.99		
χ^2 (1d.f. at 5% level)	3.841		

The results were found of the Comilla district (Table 4.13.9.). The chi-squire value of the transition matrix (Table 4.13.9.) were Pr $\{\chi^2 \geq 4.11\}$ for Pre-kharif, Pr$\{\chi^2 \geq 28.11\}$ for Kharif, Pr$\{\chi^2 \geq 6.99\}$ for Rabi seasons being very small indicating the null hypothesis that chain of order 0 is rejected.

CHAPTER -V

5. Concluding Remarks

5.1. Conclusion

Weather modify is a provisional but compound feature of the weather system. Rainfall is the most important weather parameters affecting non-irrigated crop areas. The harvest yield in the area will depend on difference of rainfall in monsoon. Markov chain model have been used to estimate probabilities of getting a sequence of wet-dry weeks over for Rajshahi, Barisal and Collilla district in Bangladesh. The study equipment will be helpful for every agriculture research. The result indicate that the drought index for rainfall 2.5 mm of rain for Rajshahi district annual is Mild, pre-kharif are Mild, Occasional, and Moderate, kharif is Occasional and Rabi is Chronic. The drought index for rainfall 5 mm of rain for Rajshahi district annualy is Mild, pre-kharif are Mild, Occasional and Moderate, kharif is Occasional and Rabi is Chronic. The drought index for rainfall 2.5 mm of rain for Barisal district annual is Mild, pre-kharif are Mild, Occasional and Mild, kharif is Occasional and Rabi is Chronic. The drought index for rainfall 5 mm of rain for Barisal district annual is Mild, pre-kharif is occasional, kharif is Occasional and Rabi is Chronic. The drought index for rainfall 2.5 mm of rain for Comilla district annual is Mild, pre-kharif are Mild, Occasional, Mild and Moderate, kharif is Occasional and Rabi is Chronic. The drought index for rainfall 5 mm of rain for Comilla district annual is Occasional and Mild, pre-kharif are Mild, Occasional and Mild, kharif is Occasional and Rabi is Chronic.

The study could be helpful for farmers for the management of irrigation and this information can be disseminated through Upazila

Agriculture Extension Office. Ground water recharge for any specific year depends on the annual rainfall of the previous year. Rainfall distribution is the major contributors in the susceptibility of the country. Surface water availability is insufficient in the dry season, while ground water availability in the most of the study areas remains at a satisfactory level with respect to the present crop water demand. If all the potential irrigation areas are taken under intensive irrigation practices, the available ground water may not act as a sustainable resource in the most of the places. The scenarios of the study could be prepared by showing the net irrigation requirement of different crops in different seasons and developing agencies for adopting drought management practices. The study will contribute to policy formulation and strategic planning in the areas such as, agricultural practices and crop diversification, investments in irrigation development works and allocation of water to different uses.

Disaster Management Bureau (DMB) of the Government of Bangladesh monitors drought and other hazardous events. Bangladesh Meteorological Department (BMD), BARC also collaborate with BMD by providing necessary information on weather, water and suggesting appropriate action for mitigating the effects of desertification.

Extreme rainfall is the main cause of flood and if no rainfall will be drought. When the flood over than the crops are of production will be bellow. Similarly the drought will be high crops are production will be bellow. In the sense we can say the above cases the production of food is also depend.

The results of this study have provided self-confidence in the use of modeling techniques for land use Rajshahi, Barisal and Comilla district. The use of the results is necessary for the development of an operational style that could be used in land use planning. The practical agricultural research is vital to agricultural growth in Bangladesh. Public venture in agricultural research and advance is needed to build capacity to go faster technical progress. The importance needs to be located on site and seasonal-specific technologies and addition messages in combination with glory and marketing services.

The effect of the probability of frequency of rainfall is of essential importance in competent planning and completing of water programs for agricultural growth and environmental strategies in Bangladesh. This type of in order is very cooperative in determining water needs for supplemental irrigation for agriculture and also for urban areas. These necessities could be translated in terms of worth for supplementary reservoir storage if there is storage of water or suitable drainage system if there is extreme rainfall.

The results of this study would be helpful for every agricultural researcher, policy planners and researchers in order to identify the areas where agricultural growth should be paying concentration as a long-term environmental approach for Bangladesh. Water is a expensive commodity through the dry period. This is still true in areas where agriculture is accomplished in climatologically insignificant areas. Water resource could be measured and the labor fee and power utilization could be decrease in order to settle on the water obligation of a yield.

5.2. Suggestions and Recommendation

The production of crops (food), especially aman yield is greatly damaged every year due to insufficient earth humidity system established in drought affected areas.

We have to study three districts in Bangladesh. In the result we can take the decision of this three district, if the weather is very drought, we need to supply water by any system. This system may be Shalo Pump, Dib-tubewell and others scientific process.

When agricultural production of any crops very costly and dangerous, frequently it is not possible for the farmers to grow crops beneficially at the personal level due to the deficiency of necessary water. If the idea of this studies are appropriately utilized in cultivating crops it will be the pouring force for growing production of food crops, particularly rice and white. In severe and extremely severe drought affected areas, government pronouncement for intensification complementary irrigation during the transplanted aman season will continue. The result of the studies will help in correct execution of agricultural strategy to raise in common agricultural production in Bangladesh, which is predictable to carry about important positive adjust in the economic of the country.

The results would also help the government and relevant organizations to individuality methods for dropping poverty and achieving sustainable development in agriculture and land use. The Ministry of Food (MOF), Ministry of Agriculture and Forest (MOAF), Nation Environment Management Action Plan (NEMAP), Department of Agriculture Extension (DAE), Soil Resources Development Institute (SRDI) and Barind Multipurpose Development Authority (BMDA) could use these results in analyzing land use implications of different policy scenarios. The studies are particularly impotent for national, regional and local assessments of the effect of erosion on food production.

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