CHAPTER I
INTRODUCTION

1.1 Background of the study

The increasing pace of climate change and its effect on agriculture has been a very important issue of discussion and debate in recent years.

Climate variability denotes the inherent characteristic of climate which manifests itself in changes of climate with time. The degree of climate variability can be described by the differences between long-term statistics of meteorological elements calculated for different periods. In this sense the measure of climate variability is the same as the measure of climate change. Climate variability is often used to denote deviations of climate statistics over the given period of time such as a specific month, (season or year) from the long-term climate statistics relating to the corresponding calendar period. In the sense, climate variability is measured by those deviations which are usually termed anomalies.

Agriculture is very much sensitive to climate variability. Climate variability causes the extreme impacts on agricultural production. Variability of climate not only causes slashing of crop yield but also forces farmers to adapt the new agricultural practices. Decrease in water availability, shortening of growing periods due to climatic variability reduces the potential yield. In the country like Nepal, where about 80% of the people still engaged in agricultural sector, the immediate impact of climate on agriculture has profound effect. Agricultural sector alone contributes about 42% of the total GDP of the country. Thus, Nepalese economy depends heavily on agriculture.

Rice, maize and wheat are the main agricultural production in Nepal. Paddy is the most important crop in Nepal as its production and yield both are highest than other crops and have highest consumption too. Terai belt produces the highest amount of rice in Nepal. About 82% of the total cultivated area in the Terai comes under the paddy production. In this context, the study of climate on agriculture is strongly needed for the country. Thus, an attempt has been made to investigate the effect of climate variability on the paddy yield in transplant, maturity and harvest periods along the hilly belt of Nepal.

Climate change is a phenomenon due to emissions of greenhouse gases from fuel combustion, deforestation, urbanization and industrialization (Upreti, 1999) resulting variations in solar energy, temperature and precipitation. It is a real threat to the lives in the world that largely affects water resources, agriculture, coastal regions, freshwater habitats, vegetation and forests, snow cover and melting and geological processes such as landslide, desertification and floods, and has long-term effects on food security as well as in human health.

1.2 Statement of the problems

The majority of Nepal's present population depends on agriculture for their subsistence but still about 63% of the agricultural lands are deprived of modern irrigation facilities (FAO 2004). All the crop water requirements of the non-irrigated lands are met solely by rainfall. The increased precipitation variability may create difficulties in cultivating these lands and could result in probable food insecurity for the population. Moreover, the agricultural land currently having irrigation facilities may not have sufficient water during dry seasons in the future due to climate change. That may result in water stress in the agricultural sector of Nepal. Changing climatic conditions causing soil moisture reduction, thermal and water stress, flood and drought etc are putting the whole agricultural sector at serious risk (AFDB 2002). In some cases, due to rugged topography and lack of roads, people cannot access food even when they could afford to buy it. Currently, about 31% of Nepal's total pupation is below the poverty line and 95% of them live in rural areas (MOF 2005). The poor people are more vulnerable to climatic extremes as well as gradual changes in climate than the rich because they have less protection, less reserves, fewer alternatives and a lower adaptive capacity and because they are more reliant on primary production (IPCC 2001, AFDB 2003).Climate change may alter rainfall and snowfall patterns. The incidence of extreme weather events such as droughts, storms, floods and avalanches is expected to increase. This can lead to loss of lives and severely reduce agricultural production (IPCC 1998). Traditional wisdom and knowledge to cope with such natural hazards that once ensured food security may no longer prove effective (Jenny and Egal 2002). Climate induced natural hazards have very serious human implications because they affect the livelihood security of the majority of the population (Swaminathan 2002). About 29% of the total annual deaths of people and 43% of the total loss of properties from all different disasters in Nepal are caused by water-induced disasters like floods, landslides and avalanches (Khanal 2005).

Therefore, it is very important to quantify such impacts in order to identify the problem and adaptation options and thereby minimize the potential damage magnitude of climate change in the production of major cereal crops on a local and regional scale.

1.3 Research Questions

The research question of the study are mentioned below

- What is the relationship between rainfall and yield?
- What is the relationship between temperature and yield?
- What is the trend of rainfall and temperature in Nuwakot district over 20 year's period (1990-2009)?

1.4. Objectives of the Study

The main purpose of the present work is to analyze the climate impact on agriculture with preference to paddy considering maximum temperature, minimum temperature, rainfall and the rice yield. Furthermore, the study focuses on the variability of rainfall and temperature in Nepal in various cropping periods of paddy. The main objectives are elaborated as follows.

- To study the maximum and minimum temperature variation and their trend over Nuwakot
- To study the rainfall variation and its trend over Nuwakot
- To study correlation between rainfall and major crops yield
- To study correlation between the temperature and major crops yield

1.5 Rationale of the study

Vulnerability projection under A_2 emission scenario in 2050 places, Nepal is under significant vulnerability category for static adaptation capacity (Gary et al, 2006). The districts of central hilly and mountain ecological zones are relatively more vulnerable compared to the other districts. Nuwakot falls under the central hilly ecological zone. Climate change vulnerability mapping for Nepal with respect to overall climate change trend shows that Nuwakot lies in the vulnerability range of 0.270-0.441 which is a moderate value (NAPA, 2010). But from the landslide risk/exposure point of view the district falls in highly vulnerable category (0.358-0.566). Most of the rural communities of Nuwakot are dependent upon agricultural production for food security and livelihoods. Agriculture in both irrigated and rain fed areas are dependent upon favorable climatic conditions. The changes in temperatures and rainfall are leading to increased crop failure, pasture short ages and possibly increased incidence of pests, diseases and parasites. Information on climate change and its effect on agriculture in Nepal is generally lacking (Shrestha et all 2007).Regarding all this fact, this study can play significant role to generate data for the validity of debate

1.6 Overview of contents

The whole research work has been systematically described in total six chapters. Chapter I includes the introductory part that covers Background, problem statement and objectives of the study. Chapter II describes about literature review, various literature especially impact of climate change on agricultural food production have been reviewed. Chapter III includes methodology adopted to undertake the research work. It consists of research design, and methods of data collection. Chapter IV consists of brief description of study area. Chapter V contains the discussions of the results obtained so far. Chapter VI includes the conclusion and recommendations regarding the study.

CHAPTER II

LITERATURE REVIEW

Exponential growth of CO_2 and other greenhouse gasses in the atmosphere is causing climate change. It affects agriculture, forestry, human health, biodiversity, snow cover and aquatic to mountain ecosystems. Changes in climatic factors like temperature, solar radiation and precipitation have potentials to influence crop production. Despite many efforts possible on combating impacts of climate change, there are still difficulties in Nepalese agriculture. With an average of 0.06^{0}C/year, a rise in temperature from 1975 to 2006 by 1.8^{0}C has been recorded in the country. Problem of frequent drought, severe floods, landslides and mixed type of effects in agricultural crops have been experienced in Nepal because of climate change. Study done on CO_2 enrichment technology at Khumaltar revealed that the yield of rice and wheat increased by 26.6% and 18.4% due to double CO_2, 17.1% and 8.6% due to increase in temperature respectively. A crop simulation model (DSSAT) to study the effects ofCO_2, temperature and rain in NARC showed positive effect in yield of rice and wheat in all regions, but negative effect in maize especially in Terai. In Nepalese agriculture, the time has come for the authorities to find out adaptive measures to mitigate the effects to reduce untold natural calamities and miseries due to recent erratic weather pattern. Increased amount of anthropogenic emissions of greenhouse gases has made the climate change a major and costly challenge to climate vulnerable people and communities. The impacts of climate change are more pronounced in landlocked and mountainous country like Nepal.

Nepal is highly vulnerable to climate change. It suggest that more than 1.9 million people are highly climatic vulnerable and 10 million are increasingly at risk, with climate change likely to increase this number significantly in the future (MOE/NAPA Project, 2010). In terms of agriculture and food security local communities have identified changes in climate as being largely responsible for declining crop and livestock production. Decline in rainfall from November to April adversely affects the winter and spring crops (DFID, 2009). Rice yields are particularly sensitive to climatic conditions and these may fall in the western region where a larger population of the poor live and this could threaten overall food security. Food insecurity is also due to loss of some local land races crops (Regmi and Adhikary, 2007). Excessive rainfall longer drought periods, landslides and floods affect agriculture in that extent that it directly affects the agriculture based industry (Shrestha et al, 1999) in a study based on an analysis of temperature trend from 49 stations for the period 1977 to 1994 indicate an annual rate of growth of temperature at 0.06 degree centigrade. Similarly a study conducted by Practical Action (2009) using data from 45 weather stations for the period of 1976-2005 indicate a consistent and continuous warming in maximum temperature at an annual rate of 0.04 degree centigrade.

Weather is considered to be a key factor in agricultural production. Short or long term fluctuations in the weather patterns such as climatic variability and climate change has the extreme impacts on agricultural production, slashing crop yields and also force the farmers to adapt the new agricultural practices. Climate change over long term particularly global warming could affect the agriculture in a number of ways such as:

- Climate and agro-ecological zones may shift, forcing farmers to adopt and threatens natural vegetation and fauna as well.
- The sea level may rise which threatens the valuable coastal agricultural and specially the low lying small islands.
- The climatic extremes might become more frequent.
- Affect the productivity in terms of both quality and quantity of crops.

According to Passioura (1979) “Our understanding of a biological phenomenon is incomplete unless we can relate it to (or translate it into) phenomenon in the adjoining levels of the organizational scale.” Hence, CO_2 and H_2O fluxes above vegetated surfaces must be related to plant parameters (photosynthetic rates, respiration, stomatal conductance) and soil processes (soil evaporation, soil surface CO_2 flux) – one organizational scale smaller, as well as to transport events in the planetary boundary layer – one organizational scale larger (Arkebauer, 1994).

Temperature records for the past century indicate that there have been periods of both warming and cooling superimposed on these intervals is an apparent overall warming (ones et al., 1986). This warming trend coupled with the expectation for further warming due to increased concentration of carbon dioxide and other “greenhouse gases" in the atmosphere has provided speculation there may be a warmer atmosphere in the twenty first century (Decker, 1994).

It is general perception that evapotranspiration process has a significant effect on the crop microclimate and on the mesoclimate in irrigated areas, in regions subject to desertification and in urban environment. To the contrary, no such importance has been attached to carbon dioxide assimilation by vegetation, since it represents a minor fraction of incident radiation energy and since the modification of the CO_2 level of the ambient air in or above a canopy is measured in an few ppmv or less than 1% of the ambient value (Bavel, 1994).

2.1. Impact of climate variation on agriculture

The effects of climate variations on agricultural production are very complex. This complexity results from both positive and negative impacts from increases in atmospheric CO_2 on plant growth and crop production. Climate change has both direct and indirect effects on crop production. For example, Carbon dioxide can affect the crop growth directly. It is well known that the occurrence of less than 300ppm of atmospheric CO_2 limits crop growth under optimal growth conditions. Therefore, increases in atmospheric CO_2 above the pre-industrial revolution background should increases crop growth and yield. One of the best known direct effects of CO_2 on plants is the induced partial closure of stomata at increased atmospheric CO_2 concentrations, which can result in lowering transpiration. This can produce increased water use efficiency in biomass production (Newman, 1994). Crop water use efficiency should increase by approximately 5% to 10% under atmospheric CO_2 doubling (Enoch and Hurd, 1979). The natural variability of climatic elements such as rainfall, temperature is considered to be the main factor behind the variability in agricultural production (FAO). The decrease in potential yield might cause because of shortening of the growing period, decrease in water availability and poor vulneralization. However technological advances such as improved varieties, genetically modified organisms and irrigation systems are also considered important.

Similarly, CO_2 also has the indirect effects on crop production. There are latitudinal variations in estimated mean annual precipitation resulting from atmospheric CO_2 doubling. These estimates are based largely on Flohn's scenario of a future climate in and ice-free Arctic (Flohn, 1979). Water balance, or the difference between precipitation and evaporation (P-E), is an important consideration in crop production and agriculture in general (Newman, 1994).

Furthermore, climate change has the impacts on the agricultural seasons also. Changes in seasonal temperature and precipitation could affect agricultural growing season in subtropical latitudes. These winter maximum precipitation regions are sensitive to seasonal changes in both precipitation and temperature, particularly in the absence of irrigation. Seasonal temperature change is the main concern in the middle and higher latitudes where crop growing seasons are determined by the length of the frost-free period each year (Newman, 1994).

It is clearly established that ozone can cause a range of effects on crops and there is enough knowledge to suggest that ozone injury can occur all over the world where industrialization has started (Sharby, 2000). In the U.S., the NCLAN (National Crop Loss Assessment Network) has shown that ambient concentrations of ozone over large areas of the country are high enough to cause yield reduction of field grown crops (Heck et al., 1998). In Europe, a similar network has shown the same results (Sharby et. al., 1998).Wheat is considered to be one of the most ozone sensitive crop species (Heagle et al., 1979, Fuhrer et al., 1995) and this seems to be true also for wheat varieties used in Pakistan (Wahid et al., 1995).

2.2. Climatic Parameters

The major climatic parameters which strongly influence the growth and the yield of paddy, wheat and maize are discussed below.

2.2.1 Rainfall

Rainfall is considered to be the most variable and least predictable agro climatic element. The amount and the distribution of the rainfall determines the paddy cropping season and the rainfall during the crop growing season is considered to be more beneficial than off season rainfall. Paddy is very much sensitive to water stress so the rainfall distribution is considered to be more important than the season total. The basic agricultural water requirement includes water for soil preparation to start the crop and for its transpiration thereafter (Baradas, 1994). Agricultural drought occurs when rainfall amounts and distribution, soil water reserves and evaporation losses combine to cause crop or livestock yields to diminish markedly (WMO, 1998). According to WMO's (1985) classification, a given geographical area, represented by the selected rainfall station is said to have severe rainfall deficiency if its total rainfall for at least 3 consecutive months is within the lowest 5 percent of the historical rainfall record. It has serious deficiency if the rainfall is between 5 and 10 percent.

Table 2.1: Amount of water requirement of crops (after PCARRD/USDA, 1986)

Crop	Water/rainfall Requirements	Average Growing Period	Moisture Sensitive Period	Remarks
Rice	1240mm	100-180 Days	Booting to flowering	Can be grown under dry land conditions, moderately submerged and in 150-500 cm water. Cultivation only in areas with more than 1000 mm rain during growing period.
Wheat	300-1130mm	116-175days	Booting to grain filling	116 days for Terai and 165-175 days for hills.
Maize	6-10mm/crop 6-8mm/day during slinking and soft dough stage	70-75 day (green) 95-100 days (grain corn	Tasseling slinking and grain filling	Water logging for 36 hr. will injure plants.

2.2.2 Temperature

The actual air temperature is a result of the interaction of many variables, but at any specific location its temporal pattern will exhibit two basic rhythms, diurnal and annual, both driven by the solar radiation cycles. In case of a specific surface, such as soil, a leaf, or a tree trunk, the temperature is mainly a result of the interaction of radiation, airflow and evaporation and condensation processes (Griffths, 1994). Crops vary widely in the minimum temperature required for germination and growth of first shoots. Crops such as wheat, rye and barley and peas can tolerate very low soil temperatures being able to germinate when the temperature rises just above freezing (Mills and Shaykewich, 1994). It may be noted that the higher temperature in the ripening period causes the crop to ripen faster, as a result the carbohydrate in the plant stem and leaves can not traslocate properly, thus grain size becomes smaller and the yield becomes less (SMRC-NO.18). In row crops, moreover, the water content and the temperature (Ham, et al.1991), which can affect both photosynthesis and the efficiency of conversion of photosynthesis into plant biomass (McCree and Amthor, 1982). For the case of paddy each development stage and each growth processes respond in a different manner to the same temperature and each variety has its own characteristics responses. Soil temperature usually affects the nutrition of the rice plant and water temperature during the germination and seedling stage.

Table 2.2: Temperature Requirements of rice (after PCARRD/USDA, 1986)

Crop	Temperature Requirements(^{0}C)	Remarks
Rice	18-40	18-40 (germination); 25-30 (seedling emergence and establishment); 25-31 (tillering); 30-33 (anthesis); and 20-29 (ripening).
Wheat	14-25	20-25(germination); 14-15(ripening stage).
Maize	18-24 32-25(max)	Essentially warm season crop. Temperature of 38^{o}c plus water stress at tasseling and silking prevent seed set. Temperature of 13.6^o and lower greatly retards flowering and maturity.

2.2.3 Evaporation, Transpiration and Evapotranspiration

Evaporation and transpiration are the important factors in the estimation of crop water requirements. Evaporation refers to the change of water from liquid to vapor state. It depends upon the water vapour pressure gradient between the evaporating surface and the atmosphere and an energy source.

Transpiration refers to the process in which water leaves the living plant body and enters to the atmosphere. Climate factors such as sunlight intensity, atmospheric pressure, temperature and wind, soil factors such as soil moisture, soil permeability, water table and plant factors such as extent of root system, stomatal behaviors influence the transpiration.

In estimating the water which is used by crops, evaporation and transpiration are combined into one term called evapotranspiration because it is difficult to separate the two losses which occurs from the crop field. Solar radiation is considered to be the main source of energy for evapotranspiration although sensible heat from the air is also important during rainless periods. Evapotranspiration is also influenced by soil and canopy temperature, air temperature, dry air and wind. Evapotranspiration is generally estimated from climate data. Penman method, Blaney and Criddles method can be used to estimate Potential evapotranspiration. PET or Actual Evapotranspiration (AET) can be measured accurately by lysimeters.

2.2.4 Solar Radiation

It is very primary source of energy for crop growth and affects temperature and evapotranspiration as well. It is one of the most influencing parameter in crop production.

Table 2.3: Radiation wavebands and their significant for plant life (from Ross, 1975)

Type of Radiation	Spectral Region (μm)	Percent of Solar radiant Energy	Thermal	Photosynthesis	Photomorpho-Genetic
Ultraviolet	0.29-0.38	0-4	Insignificant	insignificant	Moderate
Photo synthetically active radiation (PAR)	0.38-0.71	21-46	significant	significant	Significant
Near infrared radiation (NR)	0.71-4.0	50-79	significant	insignificant	Significant
Long-wave radiation	3.0-100	--	Significant	insignificant	Insignificant

Table 2.4: Light and day length requirements of crops according to (after PCARRD/USDA, 1986)

Crop	Light Requirement	Day length Requirements
Rice	Requires direct sun mostly. Optimum light intensity is 32.3-86.1 flux	Short-day plant with critical day length of 12-14 hours. Nearly all varieties mature in a shorter time under short photoperiod (about 10 hours) than under long (14 hours), but degree of sensitivity varies with varieties. Optimum photoperiod for sensitive varieties is 10 hours.
Wheat	Long day plant Long day for flowering	Most traditional varieties are photo period sensitive but most of modern varieties are photoperiod insensitive.
Maize	Requires abundant sunshine especially important during blooming period. Optimum light intensity is 32.3-86.1flux	Response not so pronounced but times of flowering and ripening modified day length. Period from emergence to flowering reduced by short days and increased by long days.

Table 2.5: Light and day length requirements of rice according to (after PCARRD/USDA, 1986).

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Maize	Requires abundant sunshine especially important during blooming period. Optimum light intensity is 32.3-86.1flux	Response not so pronounced but times of flowering and ripening modified day length. Period from emergence to flowering reduced by short days and increased by long days.

Similarly Wind movements, water table, Humidity have the profound effect on the crops.

It is a general perception that evapotranspiration process has a significant effect on the crop microclimate and on the mesoclimate in irrigated areas, in regions subject to desertification, and in urban environment. To the contrary, no such importance has been attached to carbon dioxide assimilation by vegetation, since it represents a minor fraction of incident radiation energy.

Climate change has both direct and indirect effects on crop production. For example Carbon dioxide can affect the crop growth directly. It is well known that the occurrence of less than 300 ppm of atmospheric CO_2 limits crop growth under optimal growth conditions.

Therefore, increase in atmospheric CO_2 above the preindustrial revolution background should increase crop growth and yield. One of the best known direct effects of CO_2 on plants is the induced partial closure of stomata's at increased atmospheric CO_2

concentrations, which can result\in lowering transpiration. This can produce increased water use efficiency in biomass production (Newman, 1994).

This clearly establishes that ozone can cause a range effects on crops and there is enough knowledge to suggest that ozone injury can occur all over the world where industrialization has started (Sharby, 2000). In the US, the NCLAN (National crop loss Assessment Network) has shown that ambient concentrations of zone over large area of the country are high enough to cause yield reduction of fields grown crops (Heck et al., 1983). In Europe, a similar network has shown the same results (Sharby et al., 1998). Wheat is considered to be one of the most ozone sensitive crop species (Heagle et al., 1979, Fuhrer et al., 1989) and this seems to be true also for wheat varieties used in Pakistan (Wahid et al., 1995).

CHAPTER III

RESEARCH METHODOLOGY

This chapter includes the description of study area, different tools and technique of research process such as methods and selection of data collection and analysis.

3.1 Research Design

The research procedure adopted for the study is presented below (figure 3.1).

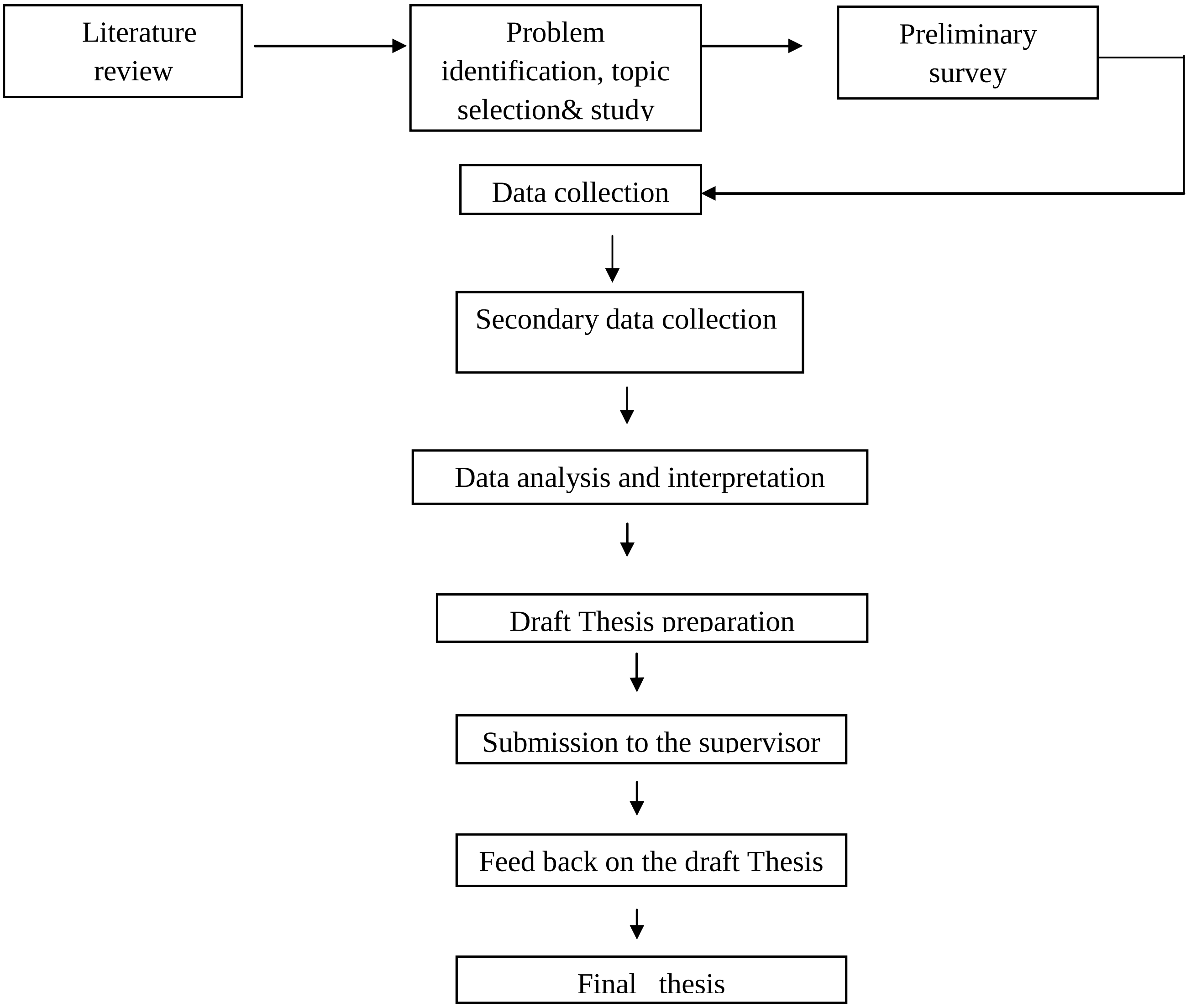


Figure 3.1: Flow Diagram of Research Design

3.2Basic Data Collection

The basic climatic elements are rainfall and surface air temperature. The hydrological and meteorological data were obtained from Department of Hydrology and Meteorology (DHM), Government of Nepal. In the present study climate variables of Nuwakot district is taken for the study purpose. The climate variables such as temperature, rainfall are utilized to explore the relation of climate to the Paddy; Maize and wheat yields based on 20 years records. In the present study the data of temperature and rainfall from the 1990-2009 of the same stations are used. For this purpose monthly data of rainfall minimum and maximum temperature of the respective periods is used. The data of cereal yields of Nuwakot District from 1990-2009 are used and is taken from Ministry of Agriculture (MOA) yearly yield is taken for the study purpose. Relevant study reports, publications and maps were also collected from various governmental and nongovernmental organizations.

3.3 Statistical Methods

3.3.1 Arithmetic Average Method

- The average monthly data of certain years were missing. The data are fulfilled by Arithmetic Average Method and linear trend method. In this method the simple arithmetic mean of the monthly data is obtained and the mean value is used as the missing data. If x_1, x_2………………$x_n$represents the series of values then the arithmetic mean of the series is given by

X= Mean of the variable = ∑Xi/N

Where, N is the total number of values in the series.

3.3.2 Mean, Standard deviation and Coefficient of Variation

Mean rainfall and mean temperature is computed to find out the mean characteristics and the variability of the data. The computation is done over both the spatial and temporal domains. If $X_{1.}X_{2……}$ Xn represents the series of values then the arithmetic mean of the series is given by

X=Mean of the Variable = ∑Xi/N

Where, N is the total number of values in the series; X1 is the individual values in the series.

The standard deviation measures the scattering of the variant in a given series and is usually denoted by σ and is defined as

$\sigma^2 = 1/N\sum(X_1 - X)^2$

Where X_1 is the individual values in the series.

The coefficient of variation {(CV) in %} is defined as:

$CV = \sigma/X*100$

For the study purpose Mean, Standard deviation and coefficient of variation are computed for rainfall analysis whereas only Mean and standard deviation are computed for temperature analysis.

3.3.3 Correlation Coefficient

According to Simpson and Kafka, "Correlation analysis deals with the association between two or more variables." The Correlation Coefficient measure the degree of relationship between the series of two variables. The value of Coefficient of Correlation lies between -1 toand1. If x and y is two given variables then their correlation Coefficient is obtained by the following relation:

$r(x, y) = CV(x, y)/\sigma_x, \sigma_y$

Where if (x_i, xj); i=1, 2, 3…..n is the bivariate distribution, then

$CV(x, y) = 1/N \sum x_i, yj - \bar{x}\,\bar{y}$

W here $\bar{x}$ and $\bar{y}$ are the sample mean of x and y respectively.

3.3.4 Regression Analysis

According to Morris Hamburg "The term Regression Analysis refers to the methods by which estimates are made of the values of a variable from knowledge of the values of one or more other variables and to the measurement of the errors involved in this estimation process." Actually regression is a fundamental relationship between a dependent random variable and one or more independent random variables (s). The general form of the regression function is

$Y = b_0 + b_1X_1 + b_2X_2 + \ldots\ldots\ldots\ldots\ldots. + b_kX_k + c$

Where (b_0, b1, b2……b_k) are the regression coefficient, X and Y are two variables and c is a constant.

3.3.5 Background Difference Filter

This method is widely used to detrend the non-stationary time series. This method consists of taking the difference $\Delta z(y) = z(y)-z(y-1)$ between the value in one year and the value in the previous year, which reduces piece wise linear trends to small constant terms. This method has the advantage over Fourier filtering or removal of the linear fits in that it is local in time (Stephenson et.al.2000)

CHAPTER IV

STUDY AREA

4.1 Background of the Nuwakot District

The study area is situated in central development region, Nuwakot is the district of Bagmati zone located towards the north-west direction of Kathmandu valley. The district boundary neither touches any zone of kingdom nor any countries. According to the geographical division the district is situated in the hilly region. The higher Himalaya plateau, smooth basins and hills are the geographical features of this district. Nuwakot district contains 71% hill, 18% Lekali area and 11% Tar, Besi and smooth surface land. There are many famous places like Belkot, Malakot, Bhaikamkot, Dhuwakot, Kalikakot, Salyankot, Simalkot, Dhaibungkot and Pyasot. The name Nuwakot is named after the union of nine kots as “NaukotkoSangam” i.e. Nuwakot.

Administratively it can be divided into three constituency regions, 13 sub-regions and 61 VDC’s and 1 metropolitan city. It is divided into 560 wards. The district provides the residence for more than 1200 settlement areas. The district headquarter which used to be in Nuwakot Durbar has been transferred to Bidur from 2027/28 B.S.

Geographically in the map of Nepal, Nuwakot is extended from 27º54’ to 28º20’ northern latitude and from 85º 0’ to 85º 45’ in eastern longitude situated 475m above sea level. This district has the total area of 1129 sq.km.

4.2 Topography

Lekali Pradesh

The high hilly region above 2500m from the sea level is characterized as Lekali Pradesh. Snow fall often occurs during the winter and the natural resources and the culture resembles with mountainous region. Ghangfedi, Gaunkharka, Vakche, Fikuri, Salronekitamb, Basunchet etc. are the main places of this region.

Pahadi Pradesh

The region below 2500m from sea level can be categorized in the region. This region occupies the maximum part of the district and it is very rich in natural and cultural resources.

Besi/Samathar Pradesh

All the low lands and basins between the height of 457m and 2500m fall under this category. Though, it occupies less part of the district from the angle of population density and productivity. This region keeps greater importance.

4.3 Climate

Due to the diversity in topography, the diversity in climate can be easily remarked. The climate can be categorized as cold, sub temperate and temperate. In higher Himalaya, the temperature is quite low and snowfall occurs in winter. In low hilly region, the temperature is moderate and where as in basins and tars the climatic condition resembles the summer average temperature 19.74 and during winter 10.02. Temperature rise can be clearly seen on April and May whereas it falls from September to October. Maximum rainfall in monsoon is 691.6mm and average annual rainfall is 186.64mm.

4.4 Socio-economic aspect

Analyzing the indexes of development, the development of this district is average. According to the socio-economic and infrastructural development index it stands in 32th position and according to the women empowerment index it lies in 38th position. Out of total population only 63.59% are economically active population. Out of that active population 57.45% are employed. In economic status and from the view point of employment the male percentage is higher. Especially, the populations of age group 40-44 are highly active. 69% are engaged in agriculture rest in non agricultural activity. Abundant agricultural area, forest, water resources and some sort of minerals are the major natural resources of this region which contribute to its economy. Out of total agricultural land 38% is irrigated (District Development Profile, 2011)

4.5 Population

According to the census of 2001, the total population of the district is 288,478 and the projected population of 2011 is 338,073. The figure of male population is 142,731and that of male is 145,747. The population density per square kilometer is 257. Total household number is 53,169.out of total population7.35%live in urban areas whereas 92.75%stay in rural area. The literacy rate is 51.15%. Average life expectancy is 63.57%.the child dependency ratio is 75%and aged dependency ratio is 15.56% the population doubling time is 43.3 years (CBS, 2011)

CHAPTER V

RESULTS

The present study attempts to determine the impact of climate variability on agriculture with taking the paddy, wheat and maize for the analysis purpose. The study also includes rainfall analysis, temperature analysis. Moreover, correlation analysis between temperature and rice, wheat and maize yield; rainfall and rice, wheat and maize yield is done. In this regard, an attempt has been made to investigate the effect of climate variability on the paddy, wheat and maize yield in plantation, maturity and harvest periods along the Nuwakot district.

5.1 Analysis of Temperature

Temperature records from 1990-2009 shows an increasing trend in Nuwakot district. Over the last 20 years the mean temperature increased by 0.051^0C per year. The mean maximum temperature increased by 0.06^0C per year whereas the mean minimum temperature increased at the rate of 0.006° C per year. Similarly, the highest and lowest values of maximum temperature were 29.19^0C in 2009 and 27.51^0Cin 1997, respectively in Nuwakot district. However, the highest and lowest values of minimum temperature were observed as 17.75^0 C in 1999 and 15.21^0 C in 1997.

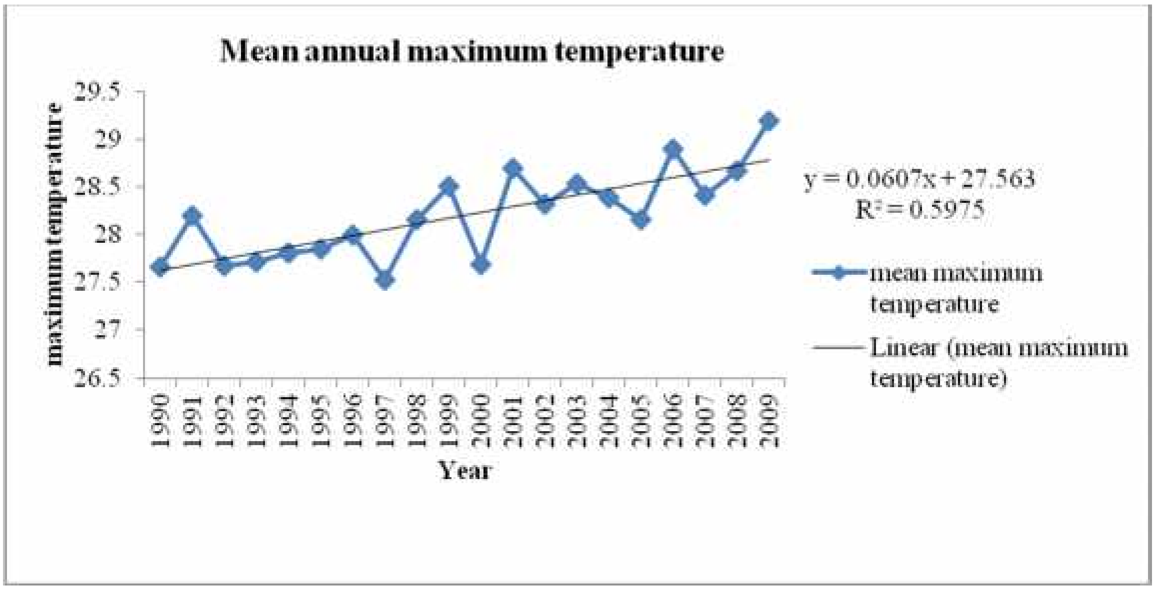


Figure 5.1: Mean Annual maximum temperature of Nuwakot (1990-2009)

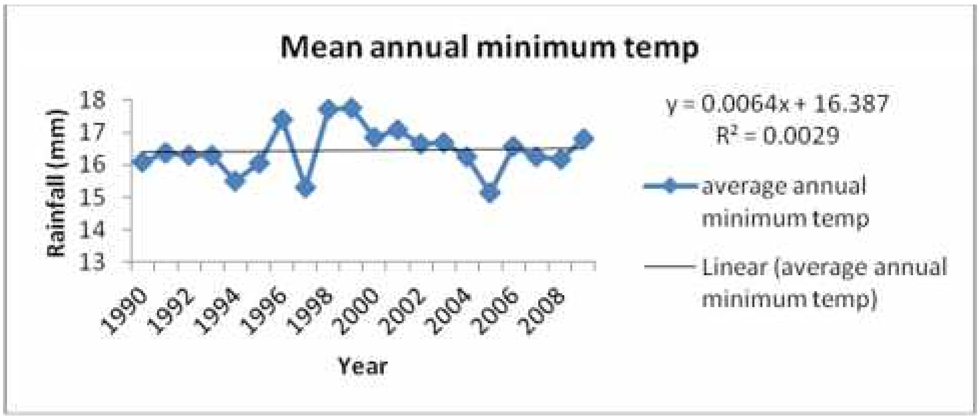


Figure 5.2: Mean Annual minimum temperature-Nuwakot (1990-2009)

5.1.1 Analysis of Temperature for Rice Yield

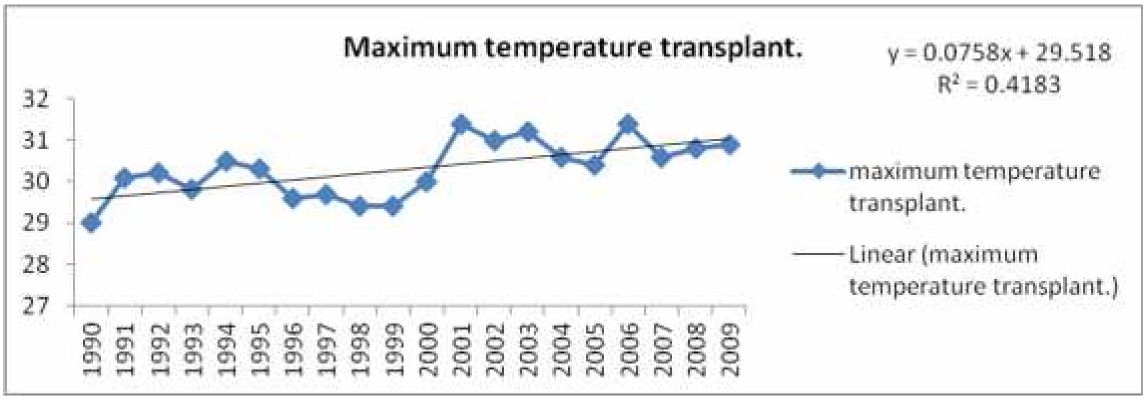
The general statistical features of temperature for three cropping periods are given in the Table 5.1.In case of paddy the S.D of maximum temperature is highest during maturity period. Likewise, the S.D of minimum temperature is highest during maturity period too. On the other hand, S.D of maximum temperature is lowest during harvesting period and S.D of minimum temperature is lowest during plantation. Regarding the information given by trend line of temperature in transplant period and maturity period it shows the increase in temperature and in case of harvest period it shows the decreasing trend.

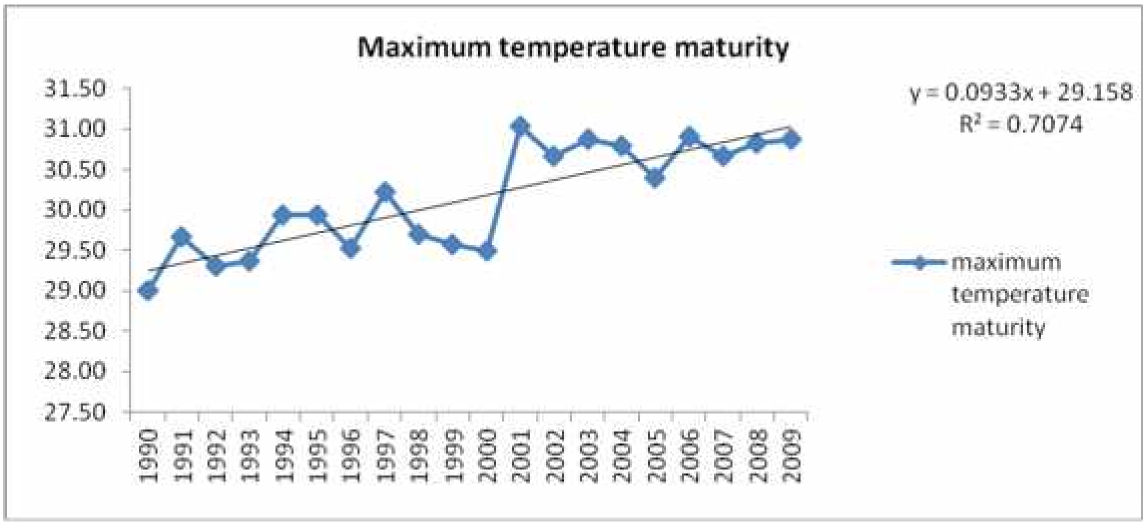
5.1.2. Analysis of Temperature for wheat Yield

The general statistical features of temperature for three cropping periods are given in the Table 5.2. The maximum temperature shows the increased trend in all three cropping period of wheat over the 20 years of time period from 1990 to 2009.In case of wheat the S.D of maximum temperature is highest during maturity period. Moreover, the S.D of minimum temperature is highest during harvesting period. On the other hand, S.D of maximum temperature is lowest during plantation period and S.D of minimum temperature is lowest during plantation too

5.1.3. Analysis of Temperature for maize Yield

The general statistical features of temperature for three cropping periods are given in the Table 5.3.In case of maize the S.D of maximum temperature is highest during plantation period. Likewise, the S.D of minimum temperature is highest during maturity period too. On the other hand, S.D of maximum temperature is lowest during maturity period and S.D of minimum temperature is lowest during harvesting period.





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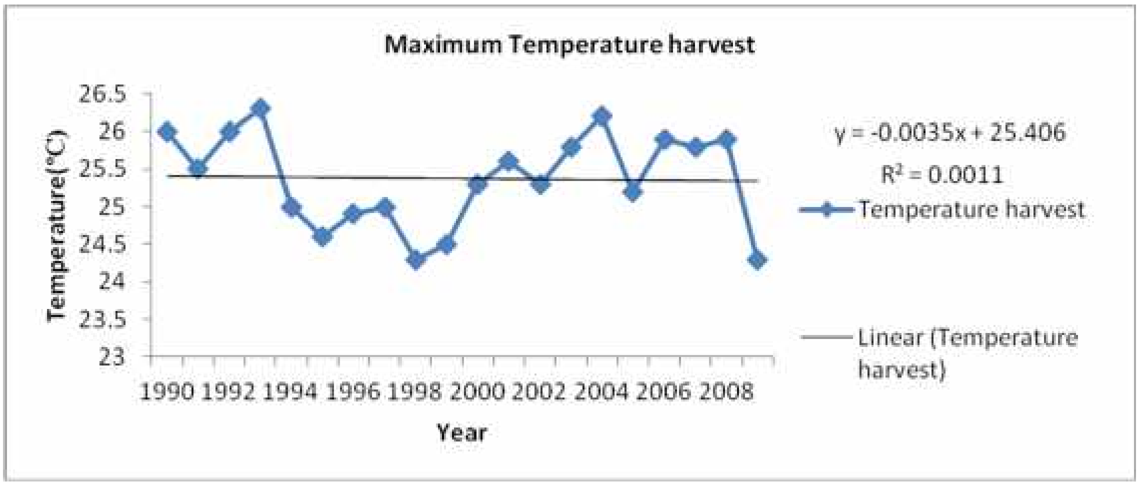
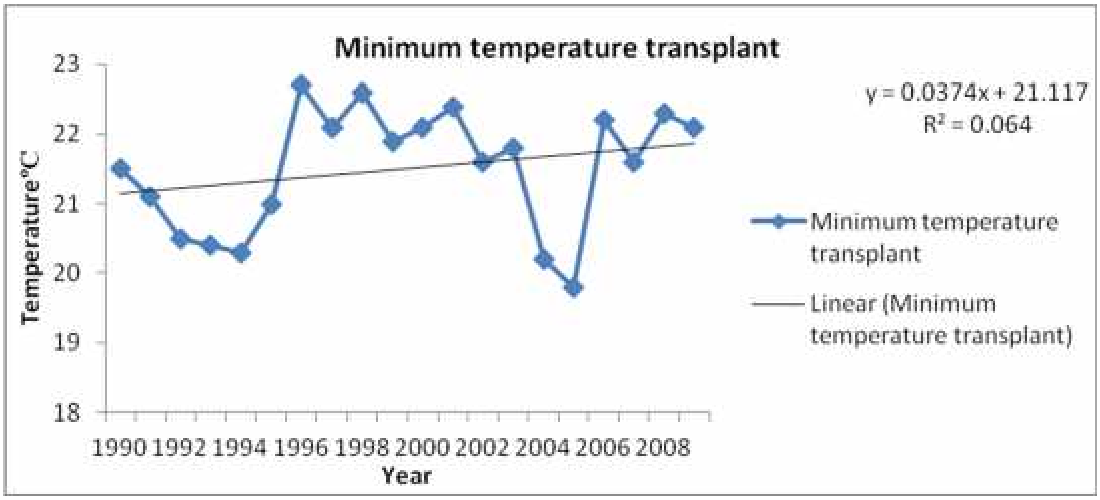
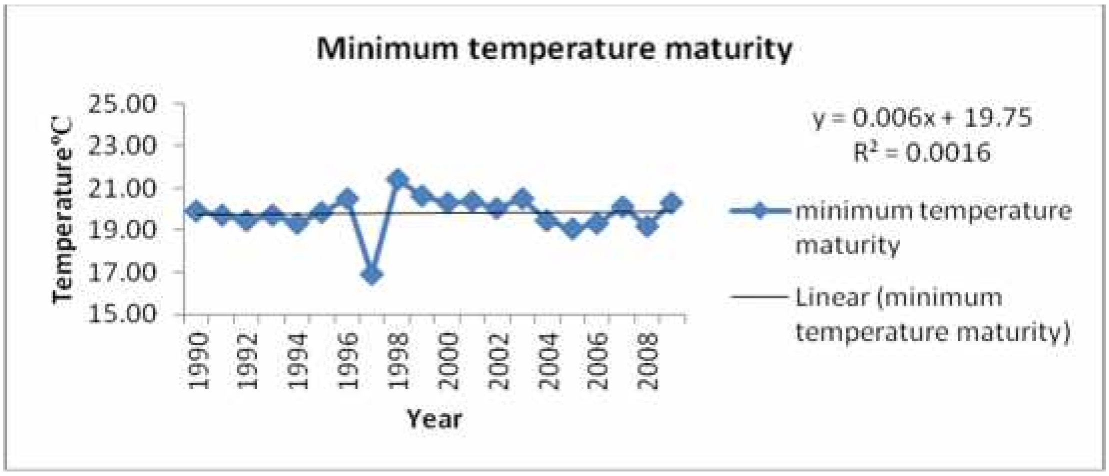


Figure5.3: The variability and trends of the maximum temperature during the cropping period of paddy





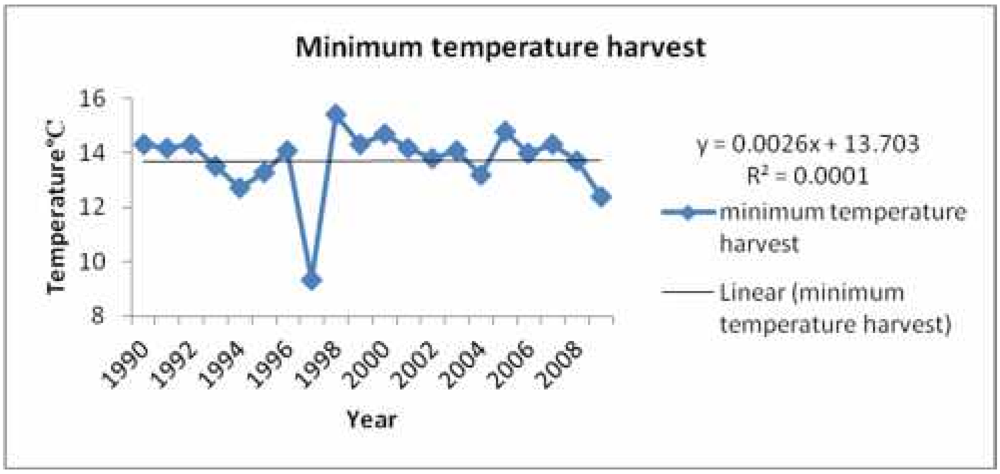
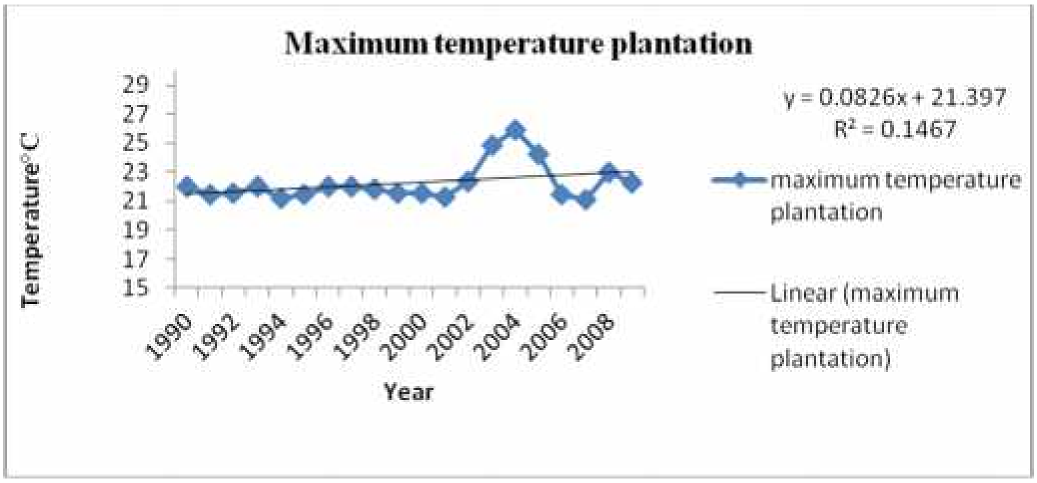
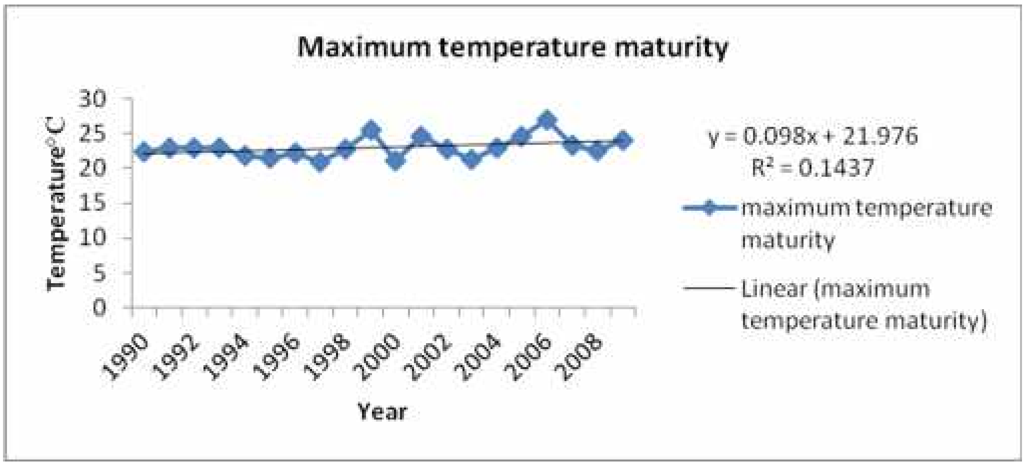


Figure5.4: The variability and trends of the minimum temperature during the cropping period of paddy.





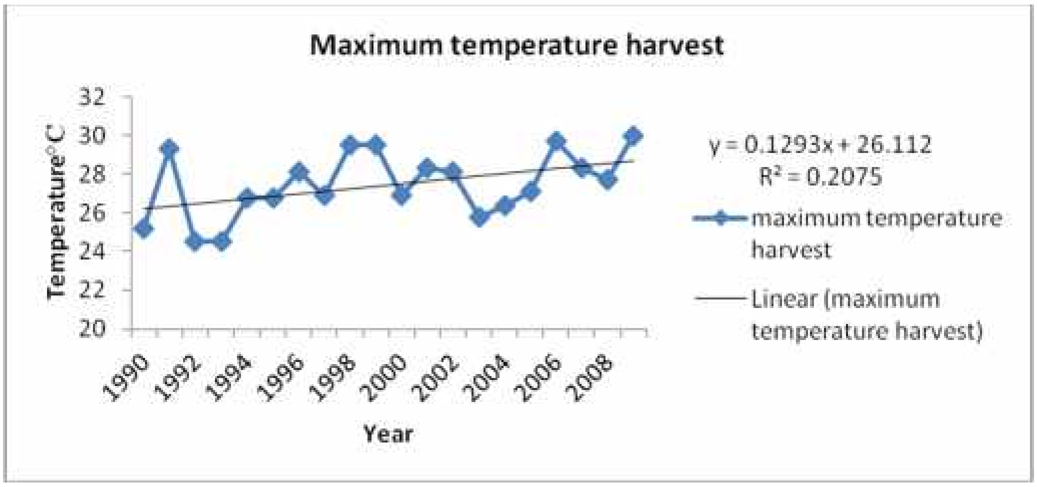
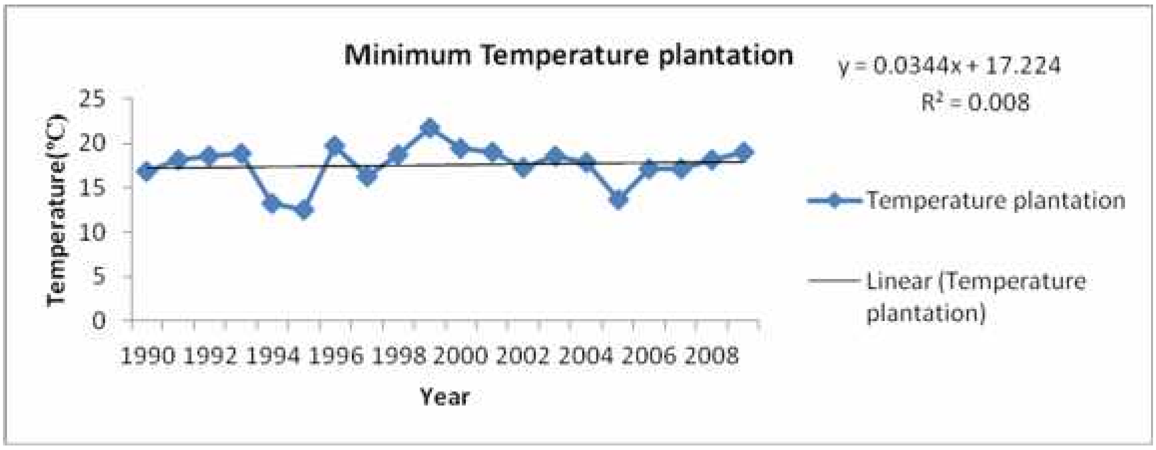
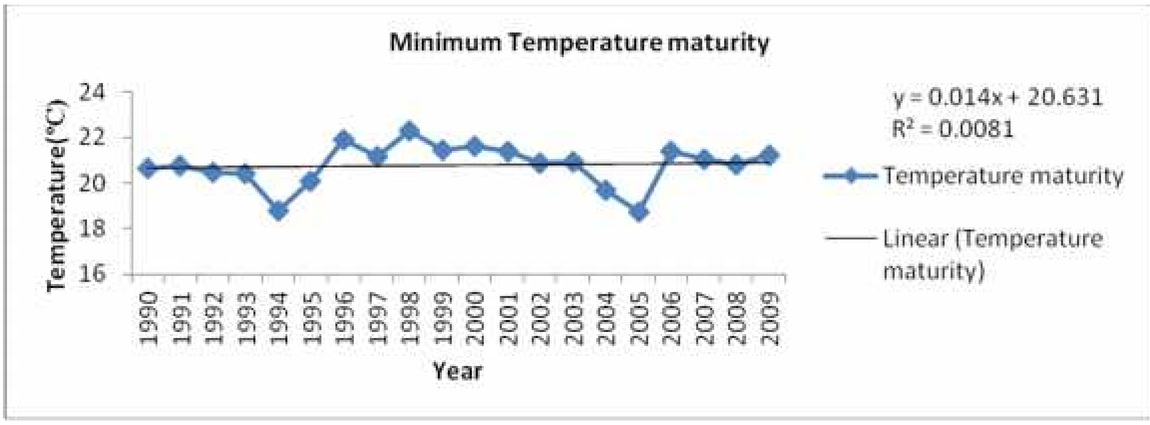


Figure 5.5: The variability and trends of the maximum temperature during the cropping period of wheat





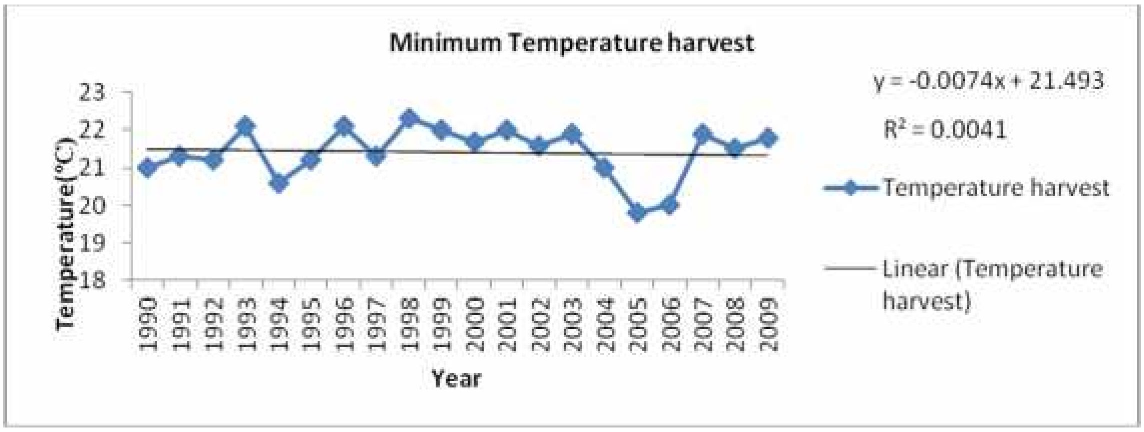


Figure 5.6: The variability and trends of the minimum temperature during the cropping period of wheat.

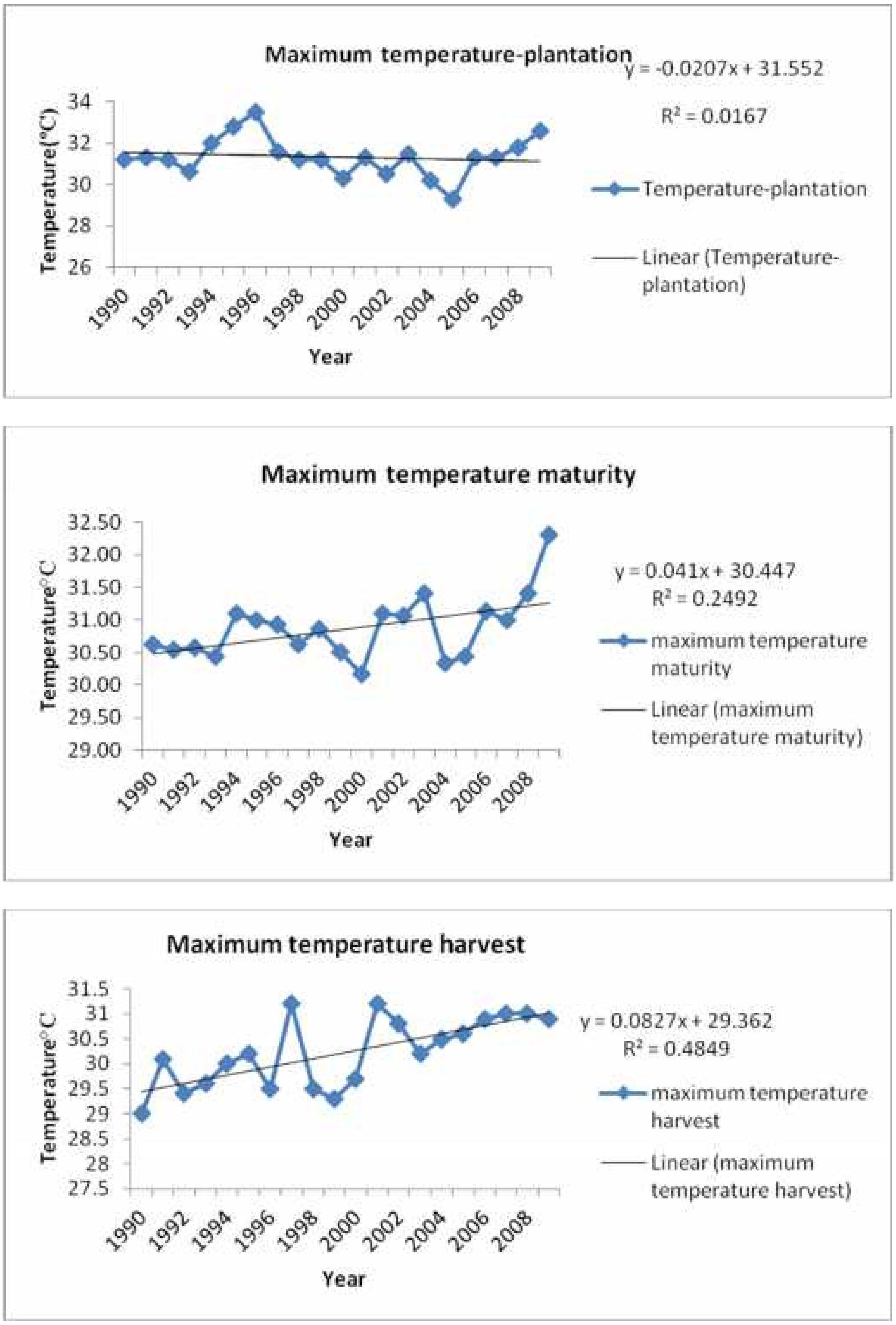


Figure5.7: The variability and trends of the maximum temperature during the cropping period of maize.

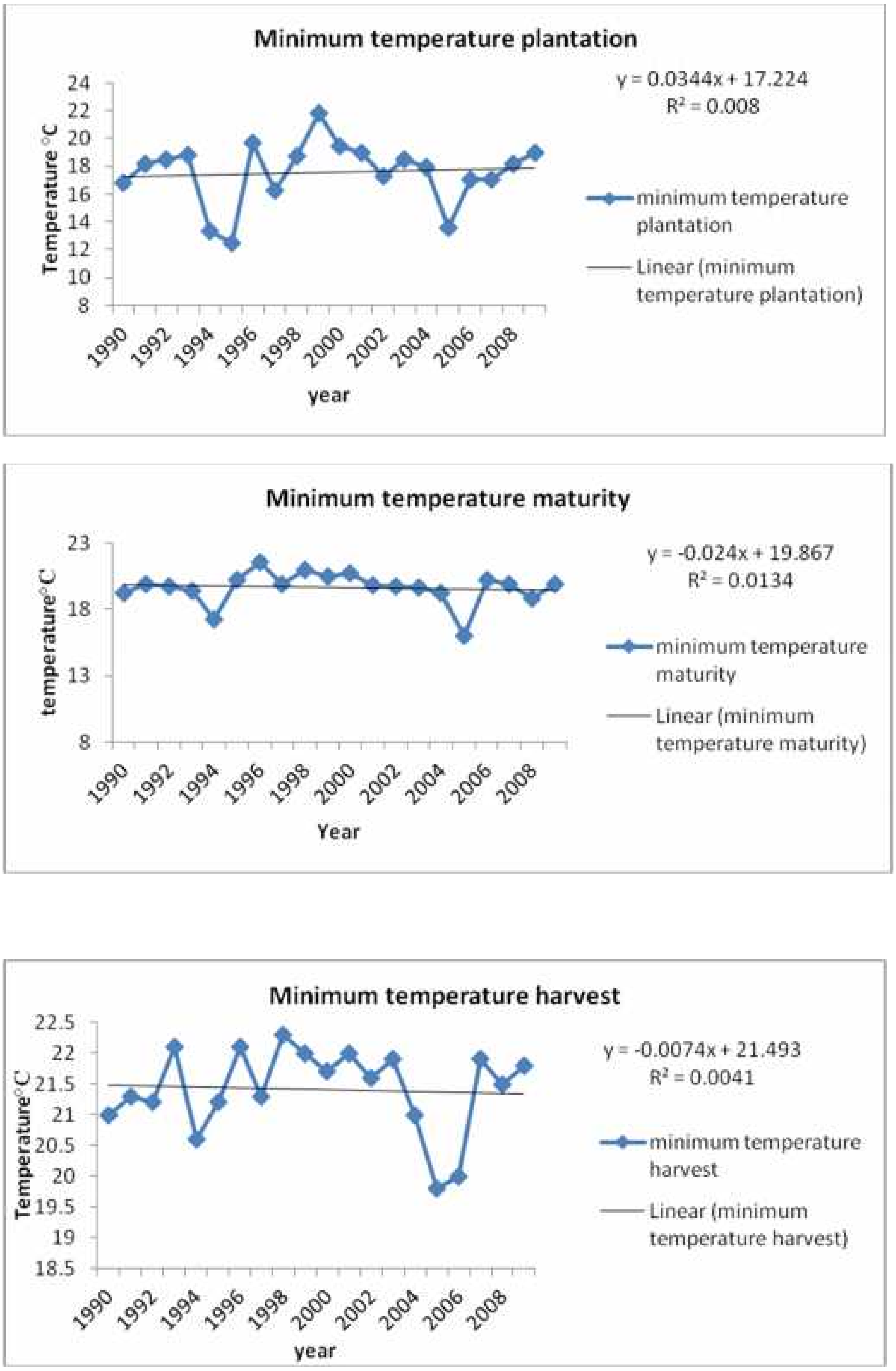


Figure5.8: The variability and trends of the minimum temperature during the cropping period of maize

5.2. Analysis of Rainfall

The mean annual precipitation in Nuwakot district is 155.72 mm and total annual rainfall was 1922.71 mm with coefficient of variation 9.85% of the mean. The year 2002 was the wettest period with total annual rainfall of 2285.6 mm. similarly the year 2006 the was the driest period with total annual rainfall of 1254.4 mm. The year 2006 could be announced as the drought year of the study period

The analysis of seasonal distribution of rainfall shows that the most of precipitation falls on monsoon season which contributes about 79.9% of the total annual rainfall while winter season shows driest period with least precipitation of 2.40%. Pre-monsoon accounts 14.40% and post-monsoon accounts 3% of the normal precipitation. The mean Rainfall during winter, pre-monsoon, monsoon and post-monsoon are 283.33 mm, 1696.83 mm, 7027.23 mm and 543.8 mm respectively. The annual increase in precipitation is o.361% the pattern of increment has no significant trend and the rainfall is erratic.

. The trend of rainfall over the 20 years from 1990-2009 is shown in figure 5.10and the seasonal distribution of rainfall is shown in figure 5.9.Similarly, the trend of rainfall for paddy, wheat and maize in different cropping period is shown in figure 5.10, 5.12 and 5.13respectively.

In case of paddy, the trend line of rainfall in different cropping period shows the positive trend in maturity period and negative trend in both transplant and harvesting period. Similarly in case of wheat the trend is positive in plantation period and shows negative trend in maturity and harvest period .Mean while, rainfall trend analysis in cropping period of maize exhibits negative trend in maturity period and slight positive and strongly positive trend in plantation and harvest period respectively.

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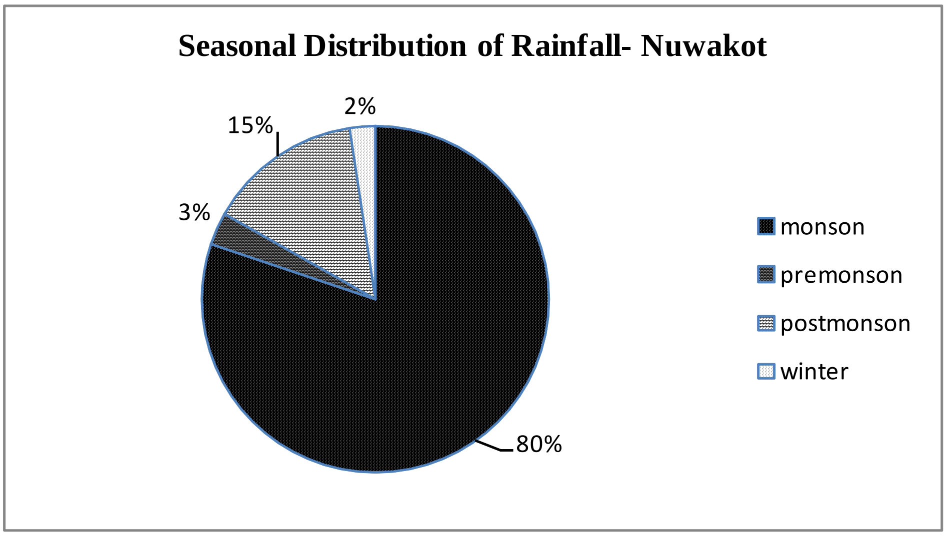


Figure5.9: Seasonal distribution of rainfall-Nuwakot.

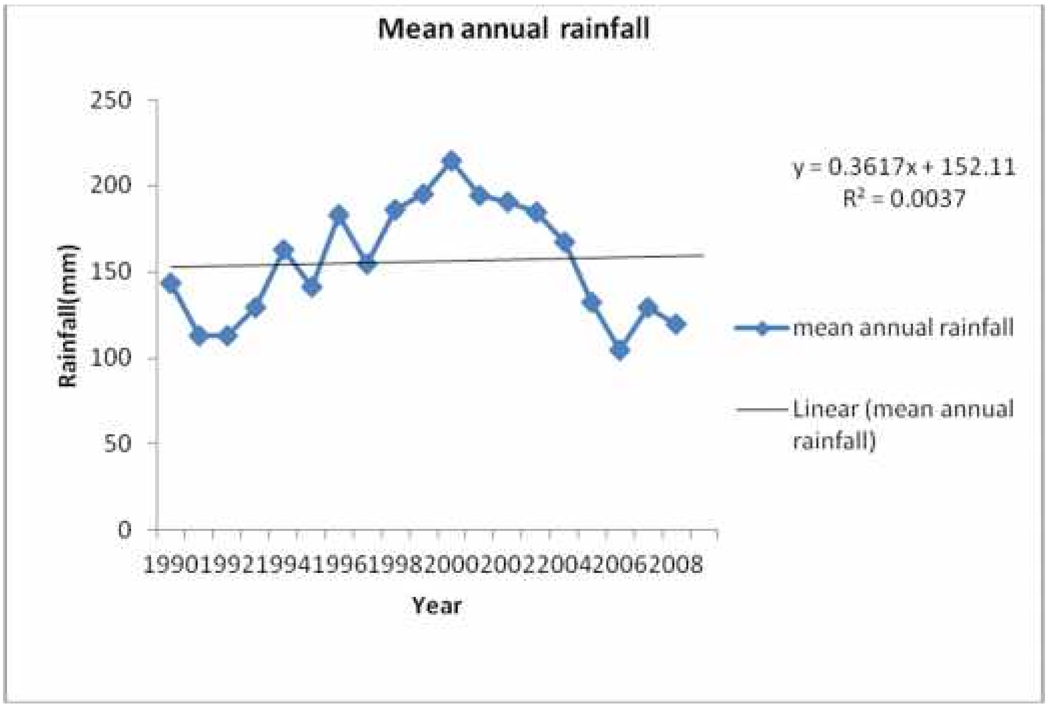


Figure 5.10: Mean annual rainfall

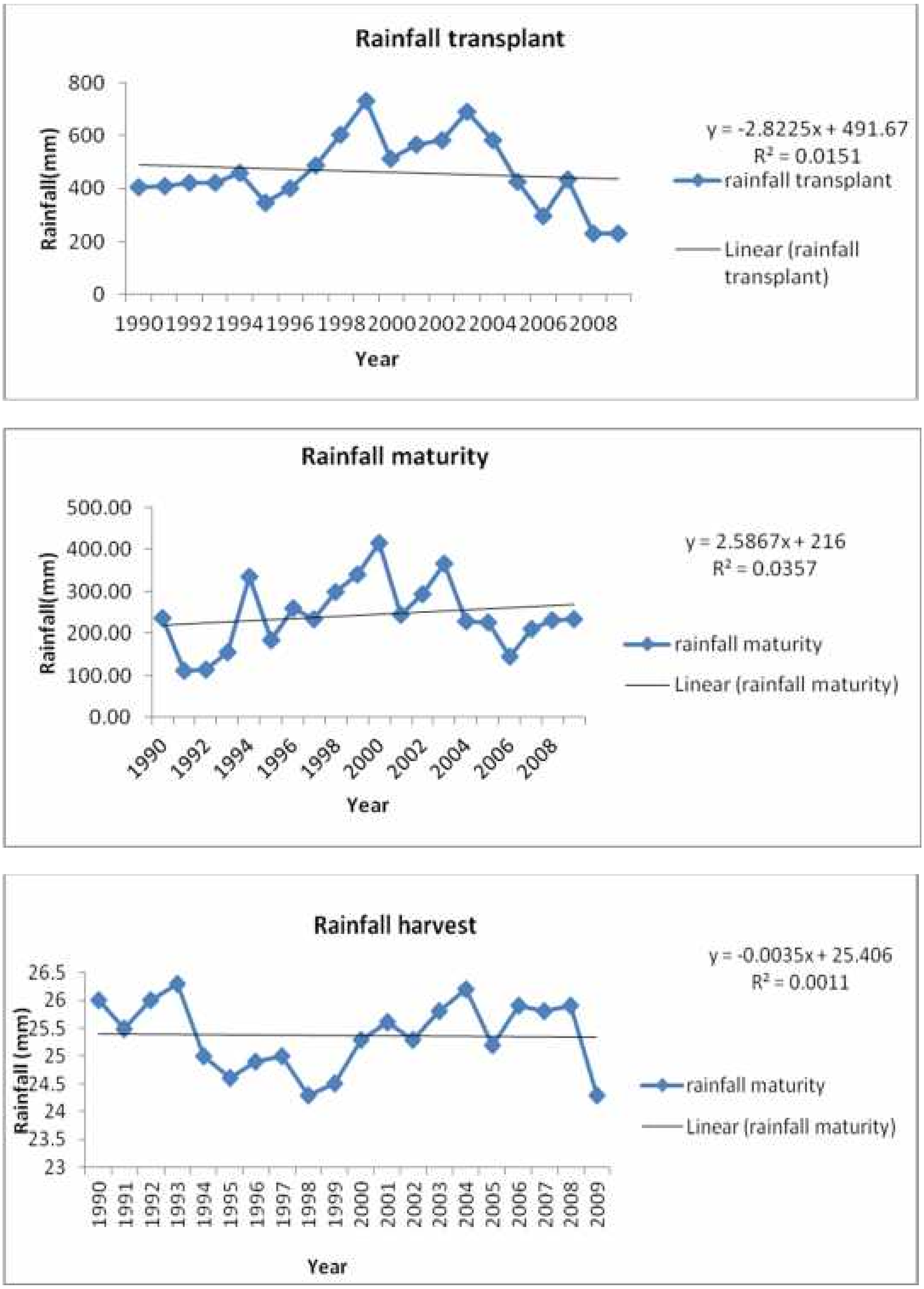
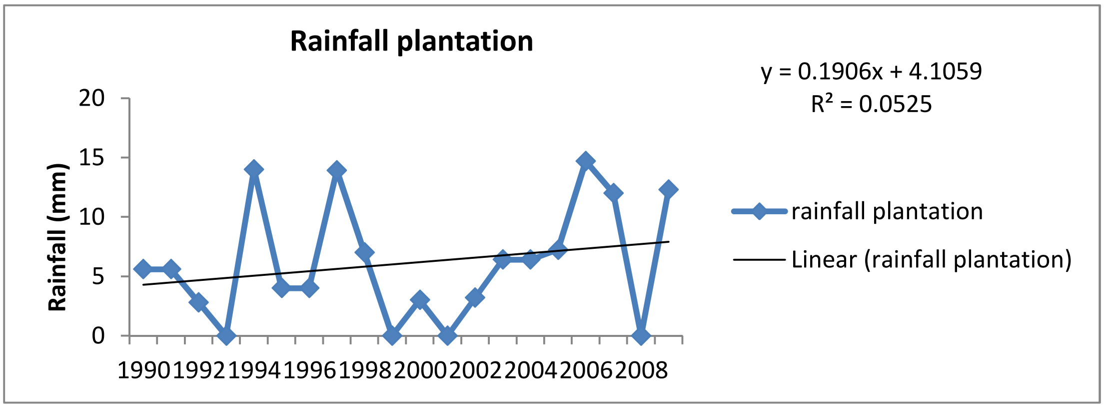
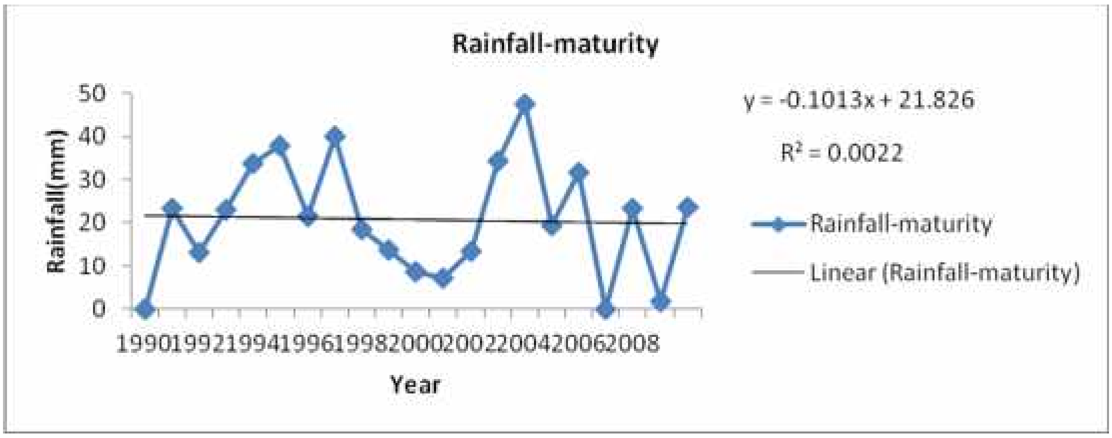


Figure 5.11: The variability and trends of the rainfall during the cropping period of paddy.





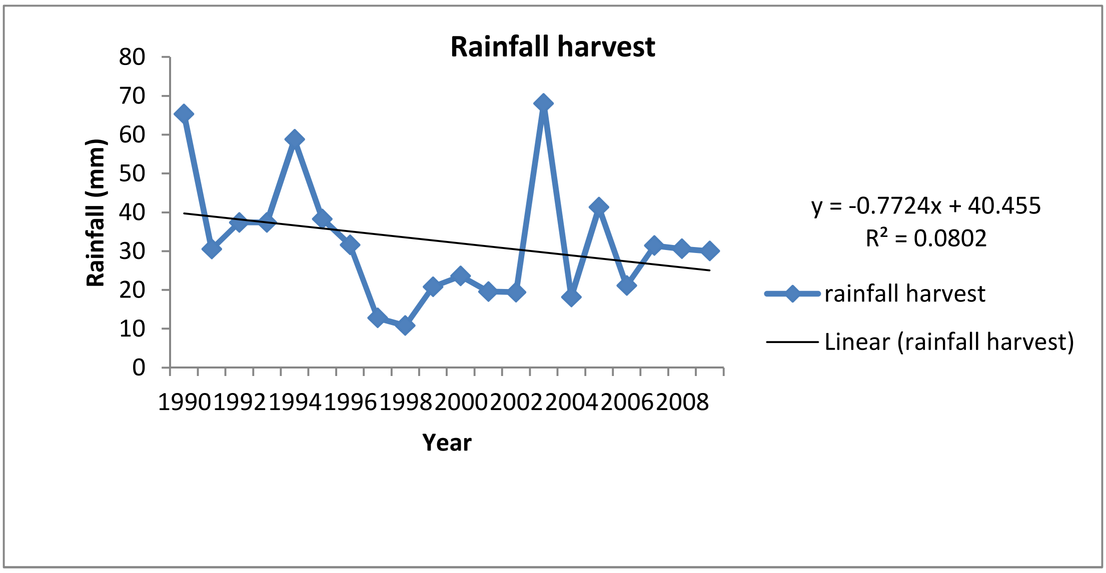


Figure5.12: The variability and trends of the rainfall during the cropping period of wheat.

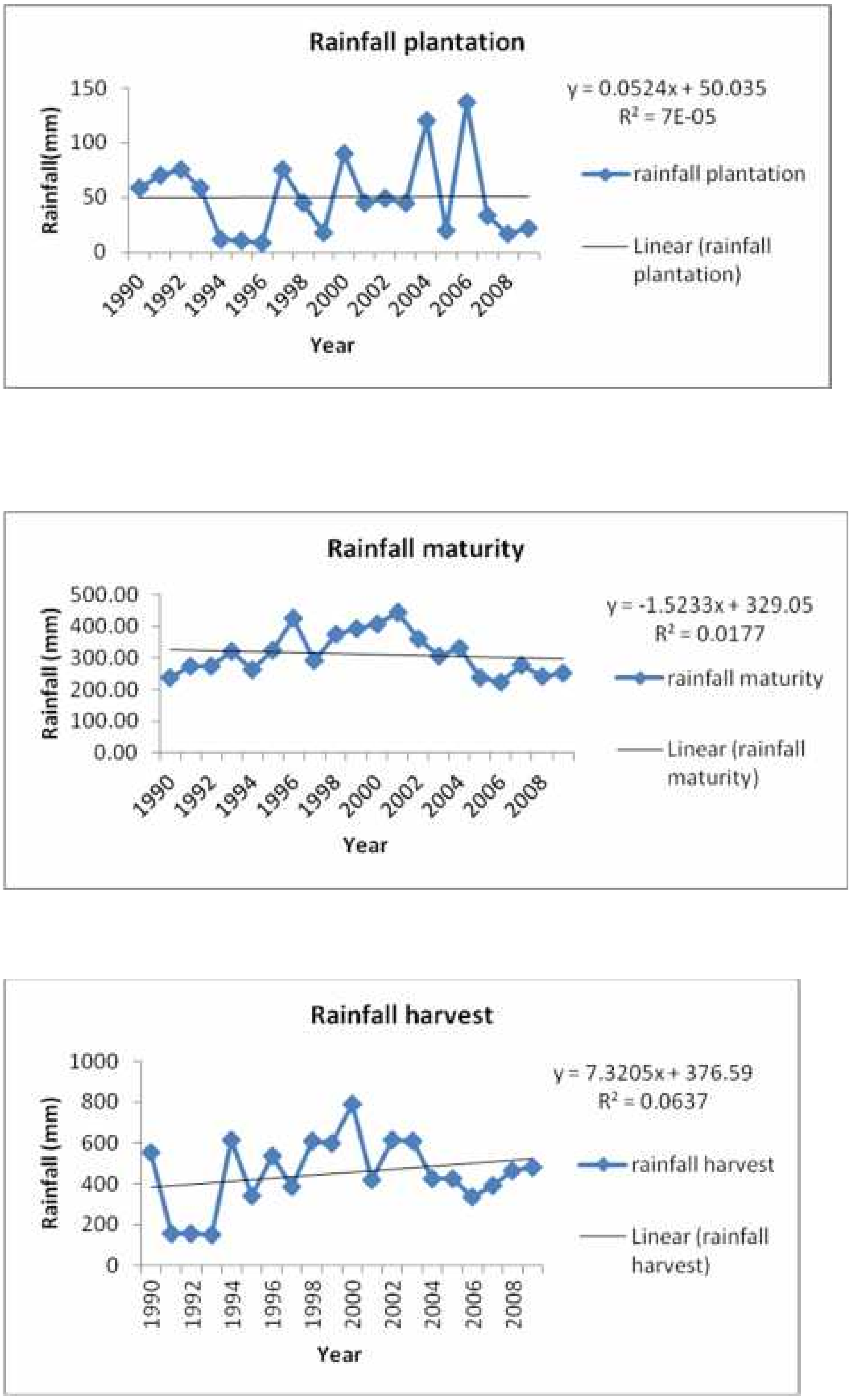


Figure 5.13: The variability and trends of the rainfall during the cropping period of maize

5.3 Impact of Climatic Variability on Agriculture

The present study attempts to determine the impacts of climate variability on agriculture taking paddy, wheat and maize as an example. The study focuses the correlation analysis of paddy, wheat and maize with temperature and rainfall. Further analysis is made to investigate the effect of climate variability on the plantation, maturity and harvesting period of selected three crops and an attempt is made to correlate it with yield.

5.3.1 Variability in Temperature

The relationships between maximum and minimum temperatures and agricultural yields (paddy, wheat and maize) of Nuwakot district are analyzed. There is always a threshold limit (upper as well as lower) of temperature requirement for a particular crop for its optimum growth. Temperature could be detrimental if it exceeds these limits. Photosynthesis slows down as the thermometer rises, which also slows the plant's growth and capacity to reproduce.

A relationship between paddy, wheat and maize yield and temperature (both maximum and minimum) are shown in figures 5.14 and 5.15 and 5.16 respectively. It is well noticed that the effect of rice yield is more dependent in maximum temperature than the minimum temperature. Unlike to paddy wheat yield is more dependent on maximum temperature of harvest period. Similarly maize yield is comparatively more dependent on minimum temperature of plantation and maturity period.

5.3.2 Variability in Rainfall

The relationship between rainfall and rice, wheat and maize yield are analyze as shown in figures 5.14, 5.15and 5.16 respectively. There is always a threshold limit (upper as well as lower) of water requirement for a particular crop. Particularly in rainy season, rain can be even detrimental if it exceeds the upper limit. In Nuwakot district, an insignificant relationship between wheat and maize yield with rainfall is obtained during plantation to harvesting period. But in case of paddy the relationship is significant during maturity period which is again insignificant during transplant and maturity period. The poor relationship between yield and rainfall can be, either the rainfall is inadequate to meet the crop demand or the meteorological station is too far from the agriculture land for the same district and therefore might not represent the plantation-harvesting period for the whole region

5.3.3 Relation with Variability of Temperature

The correlation analysis is analyzed between maximum and minimum temperature with paddy, wheat and maize yield of Nuwakot district. The analysis is carried out for all the plantation, maturity and harvesting period. The results are presented in table 5.1, 5.2 and 5.3. The analysis of paddy during transplant stage shows the negative correlation but in maturity and harvest period it shows positive correlation with maximum temperature whereas in case of minimum temperature it exhibits the positive correlation with yield in all three cropping periods. The information is also demonstrated in figure table 5.1.

In case of wheat, maximum temperature shows positive correlation for plantation however for both maturity and harvest maximum temperature shows negative correlation. The correlation is positive with minimum temperature in all the three periods .It depicts wheat is more sensitive to the variation of maximum temperature. The information is also demonstrated in figure table 5.2.

For the maize yield, plantation and harvest period shows positive correlation with maximum temperature and negative correlation with maturity period. However, harvest period shows positive correlation and plantation and maturity shows negative correlation to the variation of the minimum temperature. The information is also demonstrated in table 5.3.

5.3.4 Relation with the Variability of Rainfall

The analysis is carried out between rainfall and paddy, wheat and maize yield. The analysis of paddy during transplant, maturity and harvest period shows positive correlation. It can be said that paddy yield extremely depends upon the rainfall throughout the all periods .The information is also demonstrated in figure table 5.1

The analysis of wheat yield shows positive correlation with rainfall during plantation and shows negative correlation with rainfall during maturity and harvest period. It can be said that wheat yield extremely depends upon the rainfall during plantation. The information is demonstrated in table 5.2.

In case maize of yield, rainfall shows positive relation with maturity and harvest whereas negative correlation with plantation .It can be said that maize yield is sensitive to rainfall during plantation. The information is demonstrated in table 5.3.

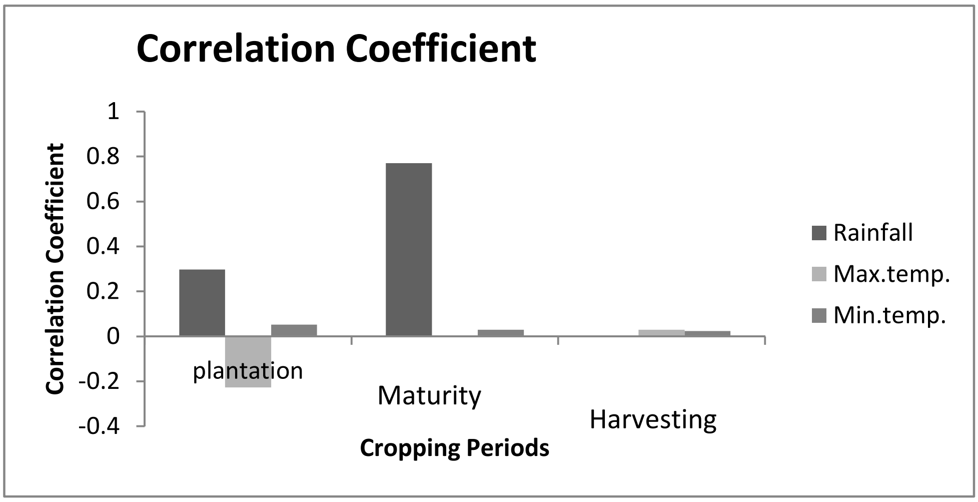


Figure 5.14: The correlation between paddy yield-temperature and paddy yield-rainfall

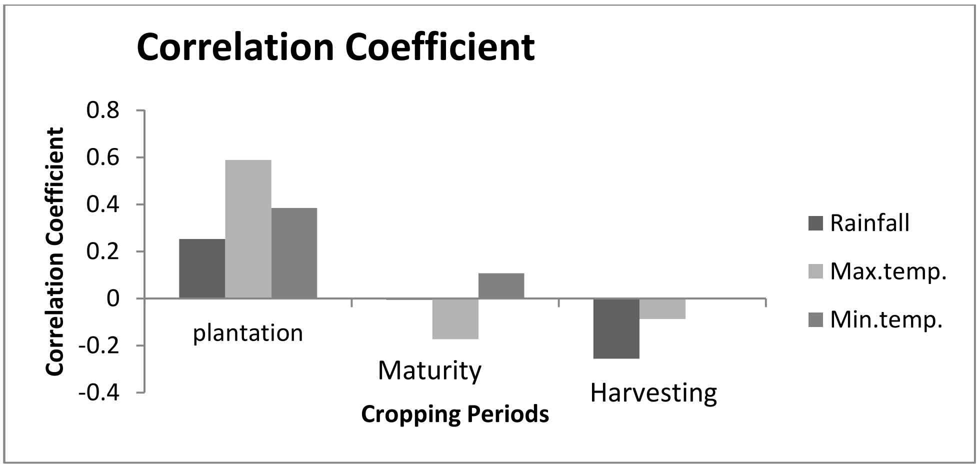


Figure 5.15:The correlation between wheat yield-temperature and wheat yield-rainfall

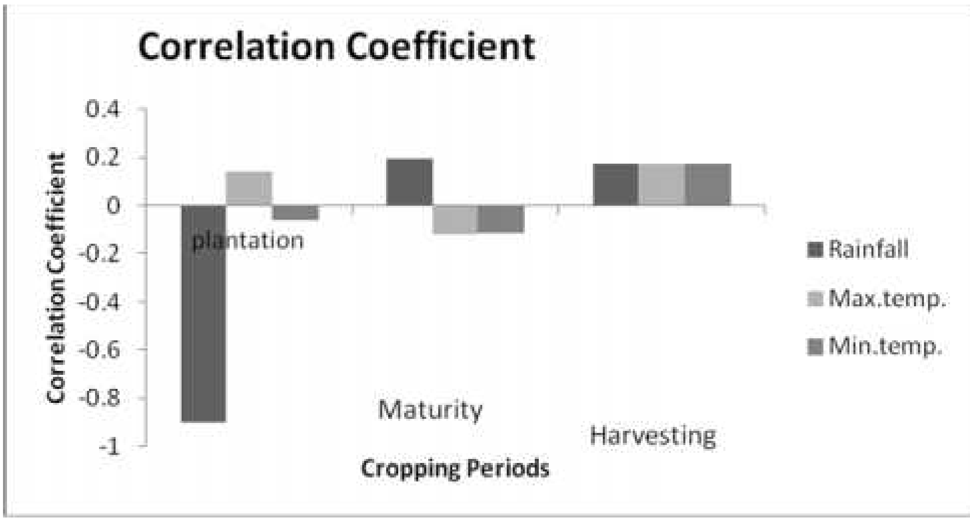


Figure 5.16: The correlation between maize yield-temperature and maize yield-rainfall

Table 5.1 Correlation between temperature and rainfall and rice yield

S.N	Parameters	Transplant	Maturity	Harvest
1	Mean maximum temperature	30.300	28.820	25.370
2	S.D maximum temperature	0.675	0.844	0.612
3	Mean minimum temperature	21.510	19.480	13.730
4	S.D minimum temperature	0.875	1.050	1.255
5	Mean rainfall	37.260	152.290	25.370
6	CV of rainfall	29.990	70.850	61.2
7	Temp max corr. With paddy yield	-0.227	0.045	0.029
8	Temp min corr. With paddy yield	0.052	0.030	0.024
9	Rainfall corr.with paddy yield	0.297	0.770	0.132

Table 5.2 Correlation between temperature and rainfall and wheat yield

S.N	Parameters	Plantation-	Maturity	Harvest
1	Mean maximum temperature	22.260	23.040	27.400
2	S.D maximum temperature	1.296	1.510	1.580
3	Mean minimum temperature	9.910	10.700	14.800
4	S.D minimum temperature	0.639	0.882	1.390
5	Mean rainfall	14.690	25.340	43.050
6	CV of rainfall (%)	32.570	19.890	43.340
7	Temp max corr. With wheat yield	0.590	-0.172	-0.087
8	Temp min corr. With wheat yield	0.386	0.108	0.313
9	Rainfall corr.with wheat yield	0.254	-0.005	-0.255

Table 5.3 Correlation between temperature and rainfall and maize yield

S.N	Parameters	Plantation	Maturity	Harvest
1	Mean maximum temperature	31.050	30.900	30.310
2	S.D maximum temperature	1.460	0.737	0.684
3	Mean minimum temperature	17.580	20.770	21.410
4	S.D minimum temperature	2.260	0.846	0.660
5	Mean rainfall	50.580	239.250	451.900
6	CV of rainfall (%)	71.5	95.940	58.900
7	Temp max corr. With maize yield	0.140	-0.121	0.173
8	Temp min corr. With maize yield	-0.060	-0.117	0.022
9	Rainfall corr.with maize yield	-0.902	0.193	0.173

CHAPTER VI
DISCUSSION

6.1 Climate change and present scenario

An attempt has been made through this study to overview the climate change pattern in Nuwakot district and its effect on agriculture. The study has considered the temperature and precipitation as the major climatic parameters and paddy wheat and maize as major food crops. Through out the 20 years of study periods from 1990 to 2009 the mean temperature increased by 0.051^0C per year. There has been 0.06^0C per annum increase in maximum temperature and 0.006^0C per annum increase in minimum temperature district noticed the year 2009 as the warmest year over the study period. Nepal has noticed the year 2006 as the warmest year, the same year shows the second warmest year record in Nuwakot district. Data released by National Oceanic and Atmospheric Administration reveals the year 2009 as the fifth warmest year on record of the world.

According to International Centre for integrated Mountain Development, warming in Nepal is in average 0.6 degree centigrade per decade which is higher than the global average the country has experienced an average maximum annual temperature increment of 0.06^0C. This rate of increase is higher in the mountains than in other regions. Despite having only 0.4 percent of the total global population and being responsible for only 0.025 percent of total GHG emissions in the world, Nepal will be affected disproportionately, especially from increasing atmospheric temperature. Rain fed agriculture, fragile ecosystem and the dramatic topography makes country prone to climate change. Increase in mean maximum temperature is likely to shorten growing season in Terai region and lengthen growing seasons in higher altitudes (Dahal, 2009).

Rainfall of Nuwakot shows the slight increased trend with the value of 0.361% per annum with coefficient of variance 9.58 of the mean but the increasing trend is erratic and irregular. The total mean annual rainfall was 1922.71 mm and the mean annual rainfall was 155.72 mm. The year 2002 was the wettest year with total annual rainfall of 2285.6 mm and the year 2006 was the driest year with total annual rainfall of 1254.4 mm. So the year 2006 could be announced as the drought year over the study period in Nuwakot. In context of Nepal the year 2003 was the wettest year and the year 1992 was the driest year. As observed through the study of rainfall of Nuwakot, the pattern resembles with the rainfall pattern of Nepal. In case of Nepal also no significant trend in rainfall is noticed and oscillatory characteristics have been observed roughly in the time interval of 2 to 5 years.(Dahal, 2009). In Nepal changes in the annual rainfall cycle, intense rainfall and longer droughts have been observed. The number of days with 100mm of heavy rainfall is increasing. The timing and duration of rainfall is changing. The adverse impacts of climate change have been noticed in agriculture and food security, water resources, forests and biodiversity, health, tourism and infrastructures. Climate induced disasters and other effects have caused damages and losses to life, property, and livelihoods (Climate change policy, 2011)

Evidence of climate change in Nepal and its impact in agriculture

• Twelve warmest years since 1975 to 2007 (e.g. 2006 was the warmest year)

• Late or pre-monsoon, unusual precipitation, decreased rainy days and intense rain fall events caused more runoff and low groundwater recharge.

• Extreme fog conditions have recently been observed in the terai regions.

• Traditional rainfalls of (mid July) have been shifted to late July and early august in Kathmandu. It has affected negatively in the paddy production. It has resulted in the decline of paddy production of Kritipur.(Malla, 2008)

The present study reveals that mean annual temperature that is both annual maximum temperature and annual minimum temperature is increasing in the Nuwakot district. . The study on climatic variability and its impact on agriculture over Terai region (Subedi, 2008) conclude that decrease in temperature and increase in rainfall are considered for better yield. The present study for wheat, maize and rice also supports this fact. However, for rice yield, the increase in temperature and increase in rainfall both are diagnosed to be favourable during transplant period. The contrary in transplant period of rice might be due to the reason that Nuwakot is a mountainous district where increase in temperature during transplant could be favourable.

The rising temperature and emission of CO_2 to some extent is helpful in production of major crops. For example, increase in agricultural production by enhancing photo synthetic processes, water use efficiency, shortening physiological period and soil microbial activities (Pathak et al.,2003a).The present study supports this statement in case of paddy and the complex and mixed relationship were seen in maize and wheat. Geophysical Fluid Dynamics Laboratory R-30 model (GFD3) model projects increase in precipitation for the whole Nepal with gradient from South West to North East in magnitude of 150-1050 mm at double increase in CO2 level (MOPE 2004). This study completely supports the projection.

The paddy, maize and wheat are the three major crops of the district. Intensification of the crops varieties is seen in the recent days. Nowadays, some people have started to cultivate wheat, buckwheat and barley in high altitudes. The plantation of rice in lower altitude is increasing in the district. People have started poly-cropping technique, planting millet in the field of maize. Farmers use different hybrid varieties of maize and improved varieties of potato as promoted by various institutions and government agencies. Local land races of paddy have been replaced mainly by the improved varieties. Also the trend of growing cash crops and fruits has been increasing in the area.

There have been numerous studies of the relationship between climate and crop yield in the world. But the studies in the context of Nepal, is quite scarce. So, to compare and discuss on the result obtained has become a tough task. Of the study made on three crops yield with rainfall and temperature shows the relationship that is statistically significant (at the 5%level). The outcomes of the study support the conclusion of the study of the various researchers as mentioned above. Some of the contradiction might be due to the fact that 38% of the study area has irrigation facility through Trisuli River and its tributaries. In addition to temperature and rainfall, there are other climatic factors that determine the crop yield. Biological factors like seed quality and physical factor like availability of fertilizers also have prominent effect on crop yield. Possible mechanism for some newly established relationship remains a mystery that requires further investigation.

CHAPTER VII
CONCLUSION AND RECOMMENDATION

7.1 Conclusion

The analysis of paddy during transplant stage shows the negative correlation but in maturity and harvest period it shows positive correlation with maximum temperature whereas in case of minimum temperature it exhibits the positive correlation with yield in all three cropping periods. Similarly the paddy yield shows positive correlation with rainfall.

In case of wheat, maximum temperature shows positive correlation for plantation however for both maturity and harvest maximum temperature shows negative correlation. The correlation is positive with minimum temperature in all the three periods. The analysis of wheat yield shows positive correlation with rainfall during plantation and shows negative correlation with rainfall during maturity and harvest period. It can be said that wheat yield extremely depends upon the rainfall during plantation.

For the maize yield, plantation and harvest period shows positive correlation with maximum temperature and negative correlation with maturity period. However, harvest period shows positive correlation and plantation and maturity shows negative correlation to the variation of the minimum temperature.

In case of maize yield, rainfall shows positive relation with maturity and harvest whereas negative correlation with plantation .It can be said that maize yield is sensitive to rainfall during plantation.

7.2 Recommendations

- The complex relationship between crop and climate should be studied in detail taking into account of the multiple relations between various meteorological variables
- The importance of non-climatic factors such as those associated with technological changes must be identified.
- Increased carbon dioxide concentrations may enhance the photosynthesis so the detail study of carbon dioxide must be carried out

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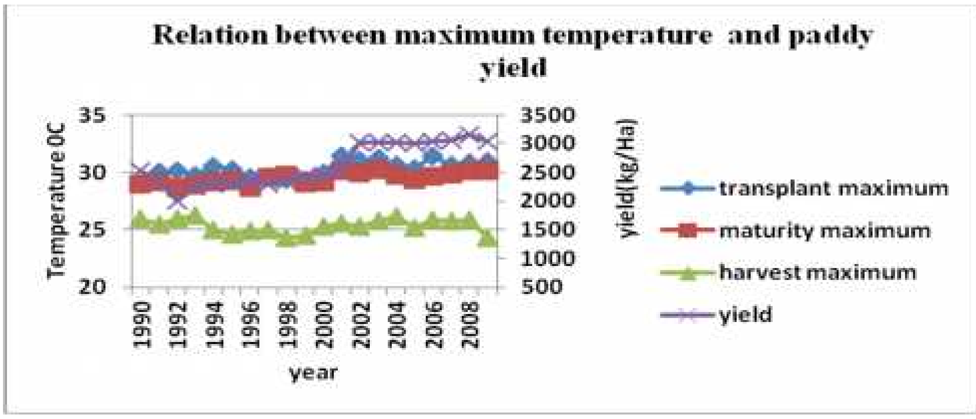
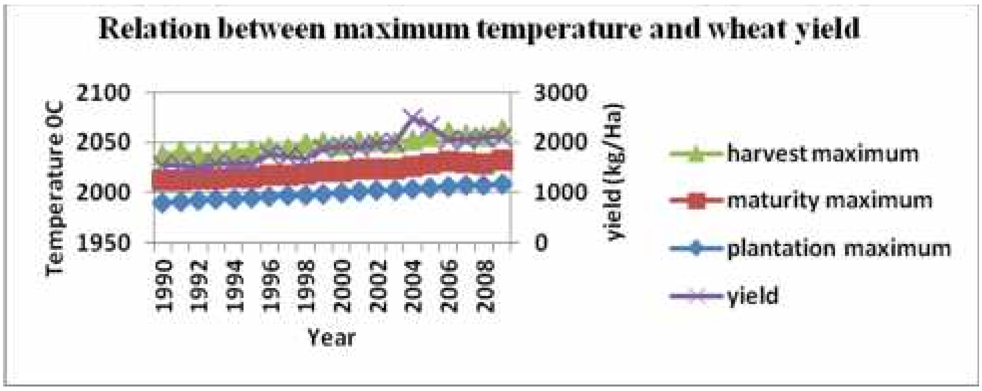
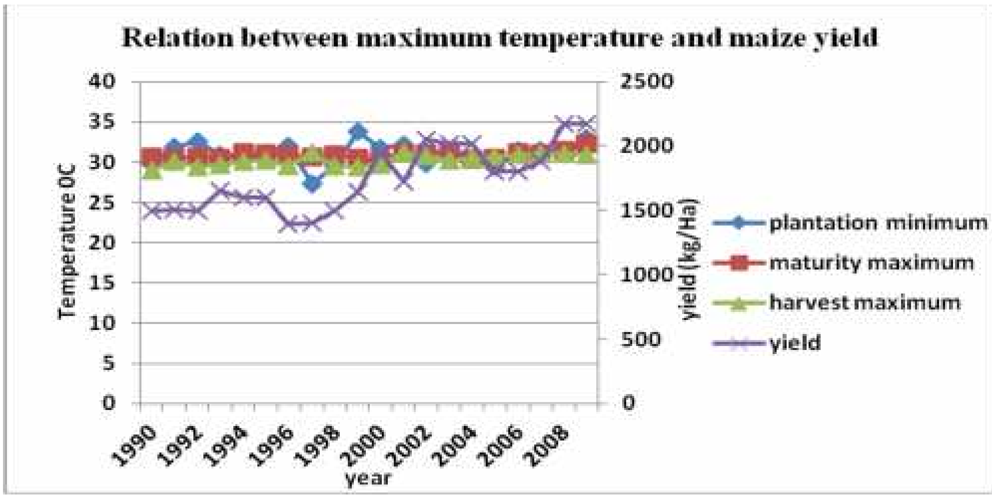
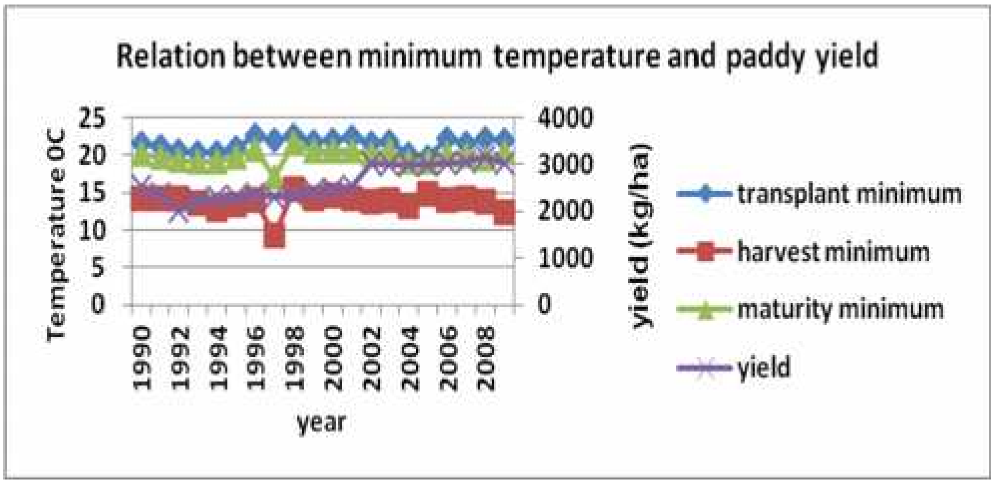
ANNEX-I

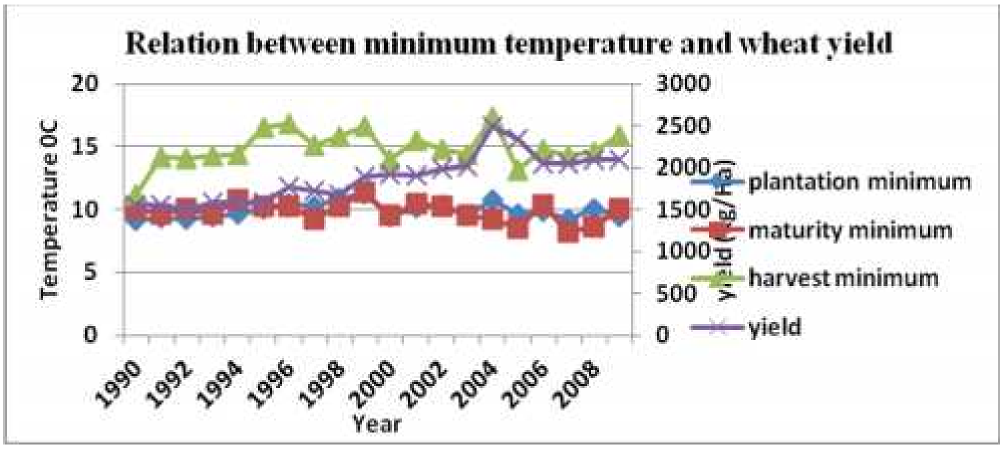

Relation between maximum temperature and paddy yield
Temperature 0C
yield(kg/Ha)
year
transplant maximum
maturity maximum
harvest maximum
yield

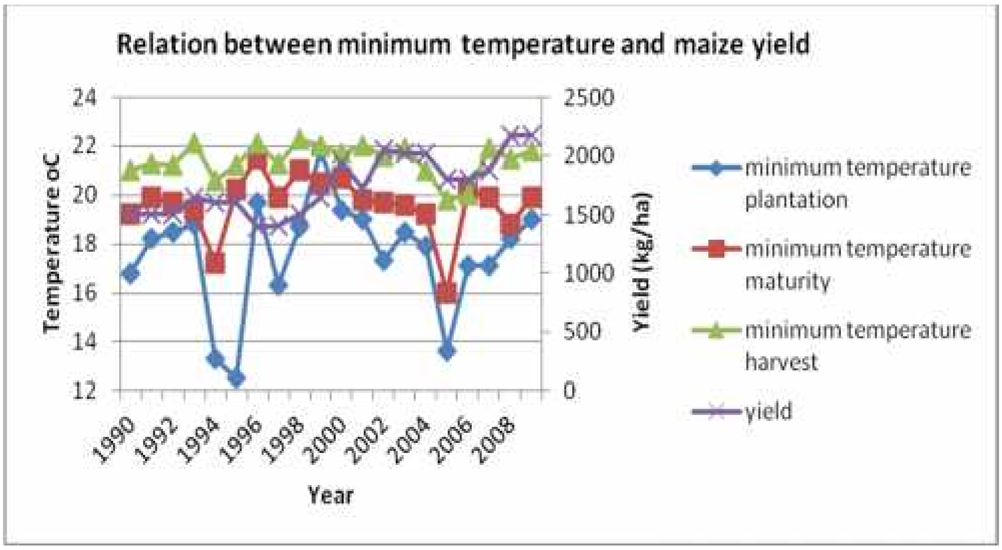

Relation between maximum temperature and wheat yield
Temperature 0C
yield (kg/Ha)
Year
harvest maximum
maturity maximum
plantation maximum
yield


Relation between maximum temperature and maize yield
Temperature 0C
yield (kg/Ha)
year
plantation minimum
maturity maximum
harvest maximum
yield

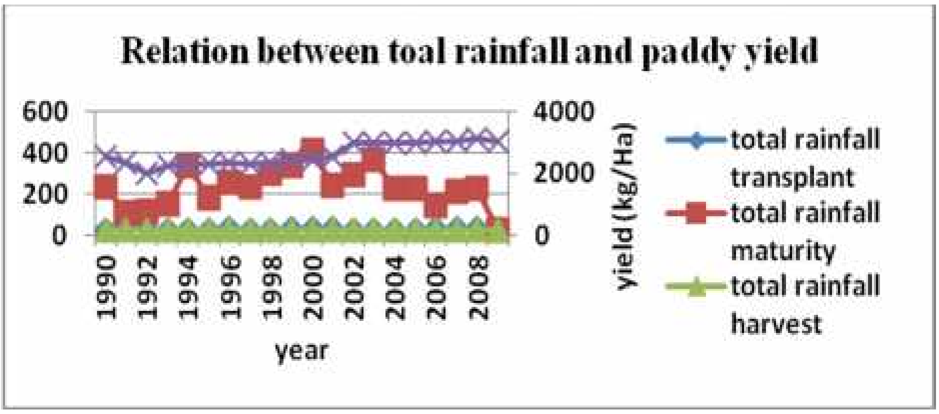
ANNEX-II


Relation between minimum temperature and paddy yield
Temperature 0C
yield (kg/ha)
year
transplant minimum
harvest minimum
maturity minimum
yield

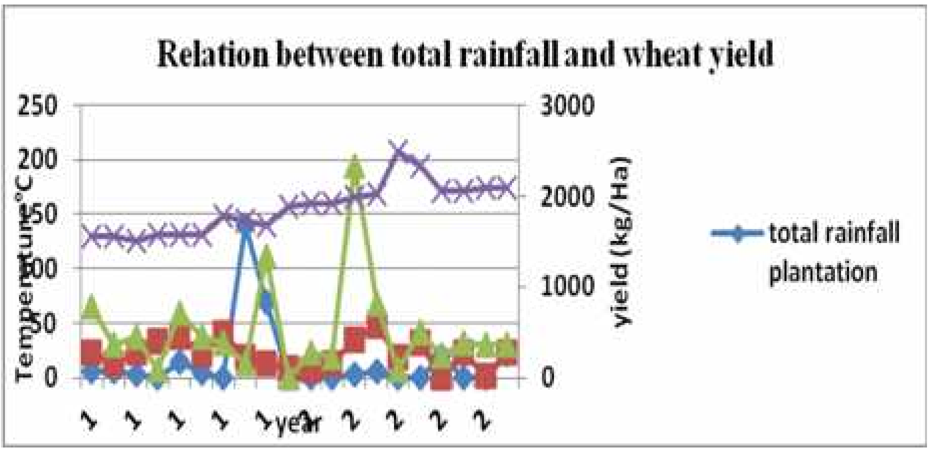

Relation between minimum temperature and wheat yield
Temperature 0C
yield (kg/ha)
Year
plantation minimum
maturity minimum
harvest minimum
yield


Relation between minimum temperature and maize yield
Temperature oC
Yield (kg/ha)
Year
minimum temperature plantation
minimum temperature maturity
minimum temperature harvest
yield

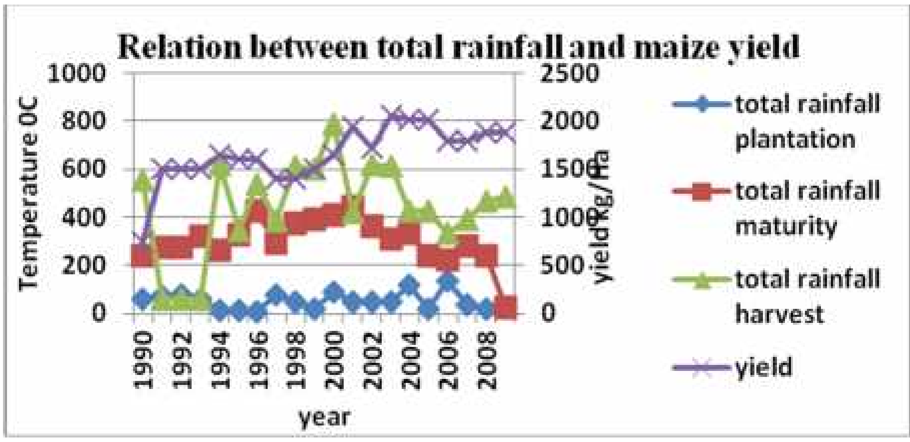
ANNEX-III



Relation between toal rainfall and paddy yield
600
400
200
0
4000
2000
0
yield (kg/Ha)
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
year
total rainfall transplant
total rainfall maturity
total rainfall harvest



Relation between total rainfall and wheat yield
250
200
150
100
50
0
Temperature°C
3000
2000
1000
0
yield (kg/Ha)
year
total rainfall plantation



Relation between total rainfall and maize yield
1000
800
600
400
200
0
Temperature 0C
2500
2000
1500
1000
500
0
yield kg/ha
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
year
total rainfall plantation
total rainfall maturity
total rainfall harvest
yield

ANNEX-IV

Maximum temperature-Nuwakot

Year	Jan	Feb	march	april	may	june	july	august	sept	oct	nov	dec
1990	22.2	22.4	25.2	29.8	31.2	31.7	29	29	29	29	26	22
1991	20	23	29.3	31.9	31.3	30.2	30.1	30.1	28.8	28.5	25.5	21.5
1992	19.5	23	24.5	31.5	31.2	30.3	30.2	29.4	28.3	28.4	26	21.6
1993	19	23	24.5	30.9	30.6	30.9	29.8	29.6	28.7	28.5	26.3	22
1994	19.7	21.8	26.8	30.2	32	30.8	30.5	30	29.3	28.2	25	21.2
1995	19.7	21.4	26.8	31.1	32.8	29.9	30.3	30.2	29.3	28.4	24.6	21.5
1996	19.7	22.2	28.1	32	33.5	29.7	29.6	29.5	29.5	27	24.9	22
1997	19.2	20.9	26.9	27.3	31.6	30.625	29.675	31.2	29.8	27.7	25	22
1998	19.9	22.8	29.5	29.5	31.2	32	29.4	29.5	30.2	29.5	24.3	21.8
1999	19.2	a25.4	29.5	33.8	31.2	30.9	29.4	29.3	30	27.9	24.5	21.6
2000	20.5	21	26.9	31.7	30.3	30.2	30	29.7	28.8	29	25.3	21.6
2001	20.7	24.6	28.3	32.1	31.3	30.6	31.4	31.2	30.5	28.8	25.6	21.3
2002	20.5	22.8	28.1	29.8	30.5	31.7	31	30.8	30.2	28.9	25.3	22.4
2003	21.1	21.3	25.8	31.3	31.5	31.5	31.2	30.2	31.2	29.3	25.8	24.8
2004	21.8	23	26.4	30.4	30.2	30.2	30.6	30.5	31.3	27.5	26.2	25.9
2005	23.7	24.5	27.1	29.3	29.3	31.6	30.4	30.6	30.2	27.3	25.2	24.2
2006	23.5	27	29.7	31.5	31.3	30.7	31.4	30.9	30.4	27.6	25.9	21.5
2007	22.7	23.3	28.3	31.5	31.3	31.1	30.6	31	30.4	28.1	25.8	21.1
2008	19.5	22.6	27.7	31.5	31.8	31.6	30.8	31	30.7	28.7	25.9	23
2009	22.8	24.1	30	32.9	32.6	33.4	30.9	30.9	30.8	28.9	24.3	22.3

Source(DHM,2009)

ANNEX-V

Minimum temperature-Nuwakot

Year	jan	feb	march	april	may	june	july	august	sept	oct	nov	dec
1990	10.2	9.9	11.2	16.8	19.2	21.2	21.5	21	20.7	18.1	14.3	9.1
1991	8	11.2	14.2	18.2	19.9	21.3	21.1	21.3	20.4	17.5	14.2	9.3
1992	9.55	10.5	14.1	18.5	19.7	21.2	20.5	21.2	20.2	1706	14.3	9.2
1993	8.8	10.4	14.3	18.8	19.4	21.4	20.4	22.1	20	17.1	13.5	9.4
1994	11.2	10.3	14.4	13.3	17.2	18.9	20.3	20.6	20.2	17.1	12.7	9.6
1995	10.1	10.5	16.5	12.5	20.2	19	21	21.2	20.5	17.8	13.3	10.1
1996	9.1	11.4	16.8	19.7	21.5	21.5	22.7	22.1	21.3	18.2	14.1	10.5
1997	8.5	9.9	15.1	16.3	19.9	21.4	22.1	21.3	16.2	13.2	9.3	10.3
1998	8.4	12.1	15.8	18.7	21	23.3	22.6	22.3	22	20	15.4	10.9
1999	9.2	13.6	16.6	21.8	20.5	21.9	21.9	22	21.5	18.4	14.3	11.3
2000	903	9.8	14	19.4	20.7	22	22.1	21.7	20.5	18.8	14.7	9.4
2001	9.2	11.7	15.5	19	19.8	22	22.4	22	20.8	18.3	14.2	10.2
2002	8.7	11.8	14.8	17.3	19.7	21.3	21.6	21.6	20.8	17.8	13.8	10.4
2003	8.3	10.8	14.4	18.5	19.6	21.4	21.8	21.9	21.1	18.6	14.1	9.5
2004	7.9	10.6	17.3	17.9	19.2	19.6	20.2	21	20.5	16.9	13.2	10.8
2005	8.2	8.9	13.1	13.6	16	20.3	19.8	19.8	20.4	16.9	14.8	9.6
2006	801	12.6	14.8	17.1	20.2	21.8	22.2	20	20.3	17.7	14	9.9
2007	8.1	8.4	14.3	17.1	19.9	21.7	21.6	21.9	20.5	17.9	14.3	9.2
2008	8	9.2	14.6	18.2	18.8	21.3	22.3	21.5	20.7	15.4	13.7	10.1
2009	9.5	10.7	15.9	19	19.9	21.7	22.1	21.8	21	18.1	12.4	9.4

Source(DHM,2009)

ANNEX-VI

Rainfall –Nuwakot

year	dec	jan	feb	mar	april	may	J une	july	august	sept	oct	nov	dec
1990	5.6	0	46.8	65.3	23.4	140.1	173.2	404	552	129.9	131.2	12.9	5.6
1991	5.6	1.5	24.8	30.5	13.15	236.5	173.5	409.2	562.8	250	80	12.9	5.6
1992	2.8	15.3	30.8	37.4	23.05	164.5	240.3	420	560.8	256	43	12.9	5.4
1993	0	33	34.5	37.4	33.75	167.1	370.2	422.1	560.28	383.8	17	0	0
1994	14	30.6	45.2	58.8	37.9	165.6	169.2	458.1	616	361.6	2	24.8	14
1995	4	7.8	35.2	38.3	21.5	97.6	533	345.8	343.4	178.7	55.8	44	4
1996	0	69.4	10.6	31.6	40	477.7	395.2	402.8	536.2	217.4	45.6	0	0
1997	13.92	29.2	7.6	12.8	18.4	110	275.5	487.2	383.1	292.2	28.2	17.4	13.9
1998	70	0.4	27.2	110.8	13.8	239.8	278.8	601.6	610.7	257.4	55.9	4.6	0
1999	0	4.6	12.6	0	8.6	209.8	242.8	729.4	600.3	388.4	136.5	0	0
2000	0	2	12	23.6	7	306.9	403.7	514.3	788.2	426.7	5	0	0
2001	0	10	16.6	19.6	13.3	194.8	567.5	567	420.3	281.4	18.4	0	
2002	3.2	42.3	26.4	194	34.35	203.6	294.6	584.6	617.3	233.2	36.4	4	0
2003	6.4	30	65	68	47.5	19.2	210.2	691.6	612.7	454.9	13	0	6.4
2004	0	38.8	0	18.2	19.4	168	240	584	425.9	234.4	160.2	27.4	0
2005	0	53.5	9.7	41.3	31.6	43.3	243.7	427	426.7	226	98.5	0	0
2006	20.7	0	0	21.1	0	133.3	236.4	296.2	332.7	77	0	0	20.7
2007	0	0	46.4	31.4	23.2	80	322	433.2	390.8	212	0	0	0
2008	0	3.2	0	30.6	1.6	112.6	382.6	230.7	464.5	197.1	0	0	0
2009	22.3	22.8	24.1	30	23.45	22.48	384	283	506	198	7	8	9.2

Source(DHM,2009)

ANNEX-VII

Major crop yield–Nuwakot (Kg/ha)

Year	yield paddy	yield wheat	Yield maize
1990	2538	1560	1500
1991	2363	1550	1505
1992	2000	1500	1500
1993	2251	1579	1650
1994	2300	1579	1603
1995	2315	1579	1600
1996	2355	1777	1398
1997	2300	1723	1400
1998	2353	1671	1500
1999	2440	1889	1643
2000	2460	1921	1945
2001	2550	1912	1723
2002	3016	1993	2050
2003	3011	2019	2017
2004	3011	2492	2017
2005	3000	2335	1800
2006	3033	2050	1800
2007	3050	2050	1881
2008	3148	2100	2170
2009	3242	2498	2170

Source(MOA,2009)

ANNEX-VIII

CROP-CALENDER

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Season
Mountain (Rain fed)												
		Mai-P	Mai-P	///////////////////////////			Mai-H	Mai-H	Mai-H			Summer
///////////////////////				Whe-H	Whe-H					Whe-P	Whe-P	Winter
Hills (Partial Irrigation Rain fed)												
				Pad-TP	Pad-Tp			Pad-H	Pad-H			Summer
		Mai-P	Mai-P				Mai-H	Mai-H				summer
		Whe-H	Whe-H	Whe-H					Whe-P	Whe-P	Whe-P	winter
Hill (irrigated)												
		Pad-TP	Pad-TP			Pad-H	Pad-H					Spring
	Mai-P	Mai-P			Mai-H	Mai-H						Spring
		Whe-H	Whe-H	Whe-H					Whe-P	Whe-P	Whe-P	winter
Tarai (Rainfed)												
					Pad-Tp	Pad-Tp		Pad-H	Pad-H	Pad-H		Summer
			Mai-P	Mai-P			Mai-H	Mai-H				Summer
		Whe-H	Whe-H						Whe-P	Whe-P		Winter
Tarai (Irrigated)												
						Pad-TP	Pad-TP					Late-summer
	Mai-p	Mai-P			Mai-H	Mai-H						Spring
		Pad-TP	Pad-TP			Pad-H	Pad-H	Pad-h				Spring
	Mai-H	Mai-H							Mai-p	Mai-P		Winter

<u>INDEX :</u>

Mai-Maize

Whe-Wheat

Pad-Paddy

P-Plantation

TP-Transplantation

H-Harvesting

////-crop growing phage

(Source: FAO and WFP (2007))