CHAPTER I
INTRODUCTION

1.1 Background Information

Changing climate and a warming world are the key issues today and the world community faces many risks from climate change. 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. Ii is a real threat to the lives in the world that largely affects water resources, agriculture, coastal regions, fresh water habitats, vegetation and forests, snow cover and melting and geological processes such as landslide, desertification and flash floods, frequent flooding, prolonged drought, and has long-term affects on food security as well as in human health (G.Malla, 2008).

The Intergovernmental Panel on Climate Change (IPCC) forecasts that there will be an increase during this century in the average global surface temperatures by 2.8ºC on average, with best-guess estimates of the increase ranging from 1.8 to 4.0ºC (IPCC 2007a), brought about by the increase in the atmospheric concentration of greenhouse gases and assuming no emission control policies are instituted. Many analyses confirmed that temperature increased in 20th century has been greater than in any centuries before. According to D. Doglos (1995), the magnitude of warming was rapid in the 19th century than in the 17th and 18th centuries in Nepal.

In recent time, many studies have confirmed that there is the large variability in climate. The degree of variability can be described by the difference between long- term statistics of meteorological elements calculated for different periods. In this sense, the measure of climatic variability is the same as the measure of climate change. Climatic variability is often used to denote deviations of climate statistics over a given period of time (such as a specific month, season or year) from the long –term climate statistics relating to corresponding calendar period. In this 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 agriculture 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 growing periods due to climate 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 agricultures.

1.2 Weather condition and climate change in Nepal

Nepal experiences climate of tropics to the alpine region. This difference in climatic condition is attributed to the large elevation range within short north to south. There are four seasons: Spring, Autumn, Summer and Winter. The mean annual temperature of the country is 15^0C. The maximum temperature generally occurs in May or early June which starts decreasing from October ad reaches minimum of the year in December or January. Here, 80% of the total annual rainfall occurs from second week of June to September (SOHAM 2007). The mean annual precipitation is 1800mm. Due to diverse topographical structure; there is great variation in rainfall within the country. The southern slopes of Himalayas receive greater than 5000 mm of precipitation while the north central portion receive relatively very less (SOHAM 2007). In the Eastern Himalayas the increase in temperature ranges from 0.01^0C to 0.06^0C per year and annual mean temperature is expected to increase by 2.9^0C by the middle of the century (Ebi *et al.* 2007; Shrestha *et al.* 1999b; UNEP 2002). The average temperature estimate is supposed to be higher compared to other developing countries. Thus, global warming may have serious impact on lives and livelihoods of local communities in the Himalayan region. The changes in climatic pattern such as temperature, rainfall, snowfall have been observed since last decades. The five key sectors: water resources, agriculture system, forestry, biodiversity, and human health have been identified as most vulnerable to climate change in case of Nepal (Sundmann 2007). Food and fiber, biodiversity, water resources and land degradation are put in the category of highly vulnerable with high level of confidence (PAN 2009).

1.3 Agriculture in Nepal

Agriculture is the largest sector and backbone of Nepalese economy. Nepalese agricultural sector contributes about 42% of the total GDP. According to JAFTA 2000 the total cultivated (agriculture) land including grassland in the country is 4,061,631 ha which constitutes 27.6% of the total area of the country. The mountain region has 10% of its total area under cultivation in 2000. The corresponding proportions are 27.2% and 55.2% in the Hill and Terai (Subedi, 2003)

The monsoon rainfall in Nepal is characterized by considerable amount of interannual variability, which has direct effect in the substantial variations in the country's agricultural production (Devkota, 2004). Extreme climatic anomalies have the profound impact on the agricultural output of Nepal. Nepal has about 4 million hectare of agricultural land of which about 65% is under rain fed condition. The Terai planes in the South constitute about 43%of the total cultivated land of which just 0.92million ha has irrigation facilities (Devkota, 2004). The average yields of the principal crops (rice, wheat and maize) are 10 to 30 % lower than the other south Asian countries. The agricultural sectors still account for 42% of gross domestic product of Nepal (MOPE,2001).

In Nepal the annual agricultural output comes from both the summer and winter crops (Devkota, 2004). The summer crop (paddy, maize, millet) is reffered to as Barkhebali and the winter crop as Hiundebali. The barkhebali crop season occurs across summer season (May-Sept) and its harvesting period is autumn (Oct-Nov) or early winter (Dec-Feb) which depends upon local agro climatic conditions and the crop specific cultural practices. The summer monsoon system is considered to be responsible for the performance of barkhebali. Whereas, both summer monsoon and western disturbances are considered to be responsible for hiundebali production.

1.4 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 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).

1.5 Problem statement

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.

1.6 Research Questions

The research question of this study is mention below.

- What is the relationship between climatic parameters and crop yield?

1.7 Objectives of the study

The main objective of the study is to analyze the climatic impact on agriculture with preference to rice, maize and wheat considering maximum temperature, minimum temperature, rainfall and the crops yields.

The specific objectives of the study are:

- To analyze temperature and rainfall pattern in Kavre and Jumla district.
- To study relationship between rainfall and crop yield.
- To study relationship between the temperature (both maximum and minimum) and crops yield.

1.8 Overview of contents

Chapter 1 includes the introductory part that covers Background, problem statement and objectives of the study. Chapter 2 describes about literature review, various literature especially impact of climate change on agricultural food production have been reviewed. Chapter 3 includes methodology adopted to undertake the research work. It consists of research design, and methods of data collection. Chapter 4 consist study area. Chapter 5 contains the results obtained so far. Chapter 6 includes the discussion and Chapter 7 includes conclusion and recommendations regarding the study.

CHAPTER II

LITERATURE REVIEW

2.1 Climate and agriculture in Nepal

Nepal has a wide variation of climates from subtropical in the south, warm and cool in the hills and cold in the mountains within a horizontal distance of less than 200km (UNEP, 2001; Shankar and Shrestha, 1985; Chalise, 1994). The amount of precipitation varies considerably from place to place because of rugged terrain (Shankar and Shrestha, 1985). The length of the regular and systematic observations of climatological and hydrological data in Nepal is only about 50 years (Mool et.al,2001) The longest systematic temperature and precipitation data have been available for Kathmandu since1921 recorded by Indian Embassy under British rule (Shrestha et.al. 1999). The existing climatological and hydrological stations are generally located at the lower elevations. The high mountain areas with very low population density and negligible economic activities are mostly left without any hydrological and meteorological stations. The meteorological observations in high mountain areas were only initiated in 1987 after the establishment of Snow and Glacier Hydrology Section in the department of Hydrology and Meteorology of Nepal (Mool et.al. 2001).

Nepal is highly vulnerable to climate change. It suggested that more than 1.9 million people are highly climate vulnerable and 10 million are increasingly in risk, with climate change likely to increase this number significantly in the future (MoE, 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 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).

Excessively rainfall longer drought periods, landslides and floods affect agriculture in that extent that it directly affect 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 0.06^0c. 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 0.04^0c.

Climate change will have a significant impact on agriculture in many parts of the world (IPCC, 1998). Particularly vulnerable are subsistence farmers in the tropics, who make up a large portion of the rural population and who are weakly coupled to markets (IPCC, 2001b). Agriculture in tropical Asia is vulnerable to frequent floods, severe droughts, cyclones and storm surges the can damage life and property and severally reduce agricultural production and could threaten food security in many developing countries in Asia. Reduced food production may have several adverse impacts for these people such as loss of income to farmers, loss of nutritional base, increased suffering illness due to hunger, loss of life due to starvation etc (Hohmeyer, 1997). Risk levels of climate change often increase exponentially with altitude; therefore, small changes in the mean climate can induce large changes in agricultural risks in mountain areas.

Agriculture is likely to get affected positively and negatively. Negative effects are feared to be larger than the positive effects. Some studies have been conducted for evaluating the potential effects of climate change on agriculture in global level (Kane et al. 1992; Rosenzweig & Parry 1994; Darwin et al. 1995), regional level (Adams et al. 1990, 1993; Mendelsohn et al. 1994) and farm level (Kaiser et al. 1993; Easterling et al.1993). Some others are conducted in the effects of climate change on crop yields (Anresen and Dale 1989; Dixon et al.1994; Kaufmann & Snell 1997; Wu 1996). Increased temperature during the the growing season can reduce yields because crops speed through their physiological development producing less grain. More rapid plant development and modification of water and nutrient budgets in the field (Long 1991) will make existing farming technology unsuitable.

The higher temperatures also increase the process of evapotranspiration and decreases soil moisture availability. Because global warming is likely to increase rainfall, the net impact of higher temperatures on water availability is a race between higher evapotranspiration and higher precipitation. As the precipitation is not regular, the race will be won by higher evapotranspiration (Cline 2008). Rain fed agriculture is likely to be affected adversely by the climate change.

In one hand, higher concentration of CO_2, carbon fertilization, increases plant photosynthesis and thus crop yields (Rosenzweig &Hillel 1998, Kimball 1983). Enhanced photosynthesis can increase the yield of C3 crops such as wheat, rice and soybeans, but not of the C4 crops such as sugarcane and maize (Cline 2008). On the other hand, increase in the temperature and changes in precipitation parrern have the potential to affect crop yields either positively or negatively (Reilly et al. 2001). Chang (2002) estimates crop yield response models and finds the negative effects associated with some climate changes. Physical effects of temperature rise on crop yield are feared more damaging in tropical and subtropical countries than in the temperate countries.

Initial National Communication of Nepal to the UNFCCC notes that there will be growing negative impacts on ecosystems and people's livelihoods with predicted increase in temperatures and change in rainfall patterns in the future (MoPE 2004). Nepal's agricultural sector is highly dependent on the weather, particularly on rainfall. Given the low productivity increase of the last few years compared to population growth, climate change is likely to have serious consequences for the agriculture. Most of the population is directly dependent on a few crops, such as rice, maize and wheat. The predicted decrease in precipitation from November to April would adversely impact the winter and spring crops, threatening food security. Higher temperatures, increased evapotranspiration, and decreased winter precipitation may bring about more droughts in Nepal (Alam and Regmi 2004). Increased water evaporation and evapotranspiration may also mean that crops will require more water through irrigation.

In the mid-hill and high mountain regions increasing temperature has led to the expansion of agro-ecological belts into higher altitudes and increased length of growing period for some crop species. Conversely, high hill animal herders have reported decline in fodder and forage production that has aggravated the prevalence of livestock parasites. In the mid-hills, decreasing soil moisture availability (due to change in rainfall and temperature) resulted in early maturation of crops, crop failures and reduced agricultural productivity. In addition, decreasing run-off water to fed natural streams (used for irrigation) and re-charging natural ponds, reservoirs and lakes have been reported. In the Terai region similar issues were noted, particularly reduced recharge rate of ground water that has resulted in a reduction of discharge of water in shallow and even deep tube- wells for irrigation for crops.

2.2 Climatic parameters

The major climatic parameters which strongly influence the growth and the yield of crops 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 rain fall determines the rice cropping season and rain fall during the crop growing season is considered to be more beneficial than of f season rain fall. Ride is very much sensitive to water stress so the rain fall 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 rain fall amounts and distribution, soil water reserves and evaporation losses combined 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 rain fall station, is said to have severe rain fall deficiency if its total rainfall for at least three consecutive months is within the lowest five percent of the historical rainfall record. It has serious deficiency if the rain fall is between 5 to 10 %.

Table 2.1: Amount of water requirements of rice, wheat and maize

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 silking and soft dough stage	70-75 day (green) 95-100 days (grain corn	Tasseling silking and grain filling	Water logging for 36 hr. will injure plants.

(Source: PCARRD/USDA, 1986)

2.2.2 Temperature

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

Table 2.2: Temperature Requirements of rice, wheat and maize

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 tasselling and silking prevent seed set. Temperature of 13.6^o and lower greatly retards flowering and maturity.

(Source: PCARRD/USDA, 1986)

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 vapour 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 the 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. According to Murty and Sahu (1987) grain yield correlated positively with solar radiation. Rice responds positively to solar radiation during the last 45 days before harvest if the yield is at least 4 t ha^{-1} (Yoshida, 1978) and water is not limiting to the crop

Table 2.3: Radiation wavebands and their significant for plant life

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
Photosynthetically 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

(Source: PCARRD/USDA, 1986)

Table 2.4: Light and daylight requirements of rice , wheat and maize

Crop	Light Requirement	Day length Requirements
Rice	Requires direct sun mostly. Optimum light intensity is 32.3-86.1 flix	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 flowring	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 32.3-86.1klux	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.

(Source: PCARRD/USDA, 1986)

Similarly wind movements, water table, humidity have the profound effect on the crop.

CHAPTER III
RESEARCH METHDOLOGY

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).

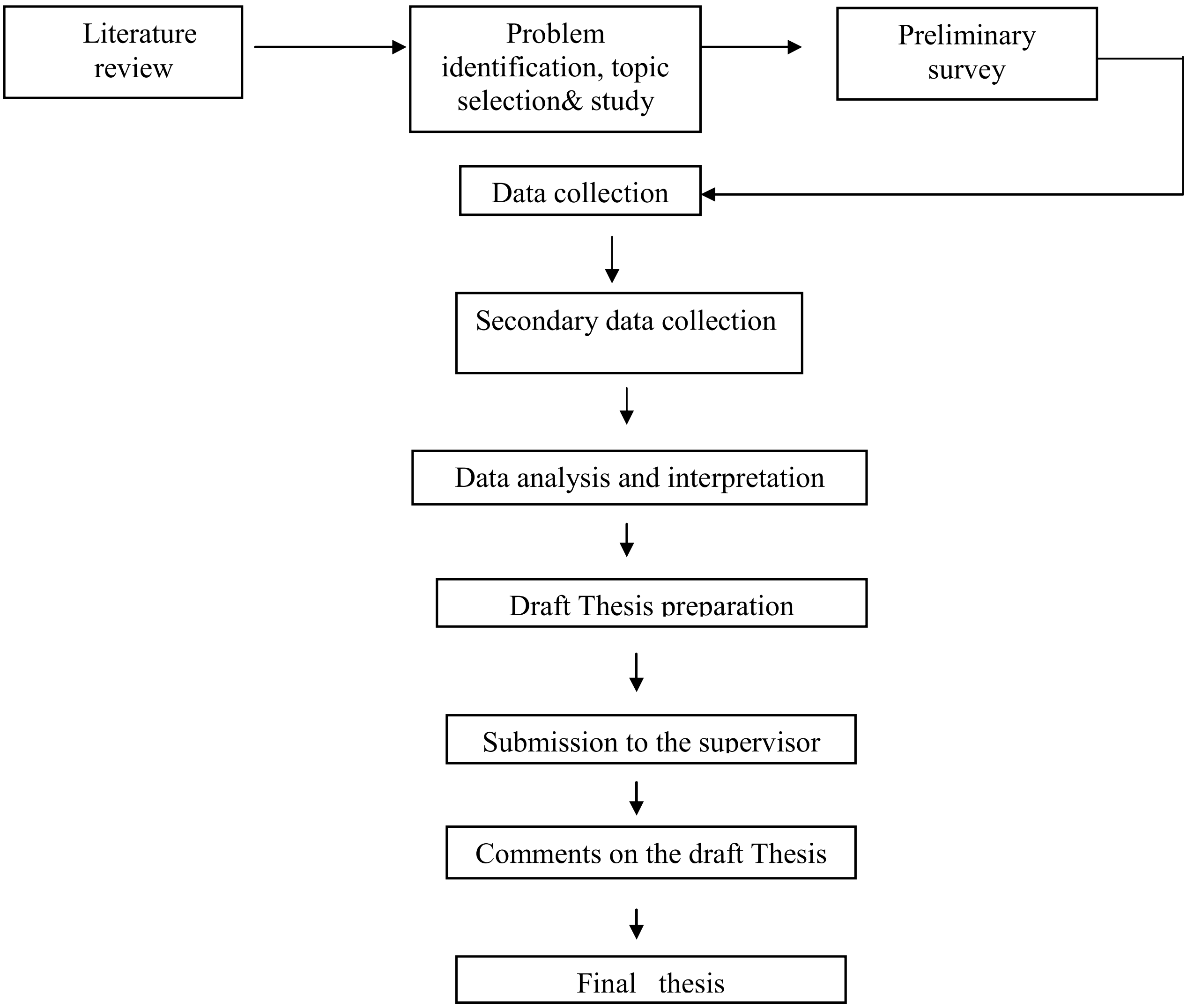

Figure 3.1: Flow Diagram of Research Design

3.2 Basic data sources

The study is based on the secondary source of information. For the source hydrological and meteorological data of Panchkhal 1036 and Jumla 310 stations from the 1990-2009 were collected from Department of Hydrology and Meteorology (DHM), Government of Nepal and analyzed. The climate variables such as temperature, rainfall are utilized to explore the relation of climate to the rice, maize and wheat yields based on 20 years records. The annual cereal yields of Kavre and Jumla District from 1989-2008 were used and analyzed, taken from Ministry of Agriculture (MoA). Relevant study reports, publications and maps were also collected and reviewed 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

$\overline{X}$= Mean of the variable = $\sum Xi/N$

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 computations are done over both the spatial and temporal domains. If X_1.X_2………..,X_n represents the series of values then the arithmetic mean of the series is given by

$\overline{X}$=Mean of the Variable = $\sum Xi/N$

Where, N is the total number of values in the series;X_1 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

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

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 to +1. If x and y are 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,x_j); i=1,2,3…..n is the bivariate distribution, then

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

Where $\overline{x}$ and $\overline{y}$ 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 $(b_0,b_1,b_2\ldots\ldots b_k)$are the regression coefficient, X and Y are two variables and c is a constant.

3.3.5 Backwards 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 (Garcia et.al. 2007).

CHAPTER IV

STUDY AREA

4.1Kavreplanchowk district

4.1.1 Background information

Kavreplanchowk district lies between the north latitudes of $27^{0}20^{'}$ and $27^{0}85^{'}$ and the eastern longitudes of $85^{0}24^{'}$ and $85^{0}49^{'}$. Kavrepalanchowk district is predominantly rural with an average population density of about 327 persons per square kilometer. The district belongs to one of the densely populated among hill districts of Nepal. Banepa, Dulikhel and Panuati municipalities are the larger urban centers. The main part of the district lies in the hills and mountain between Mahabharat Lekh and lesser leading to agro-climatic variations in different pockets of the district. The topographical setting of the district is made up of undulated terrain, tars, lowland areas and riverbanks. The alttitude ranges from 318m to 3,018m above sea level (msl). Geographically the district can be divided into two major geophysical settings the mountain land and plateau. About 80% of the total land mass of the district fall under the mountain region and rest 20% belong to plain valley and plateau (District profile of Kavreplanchowk, 2001).

The general information of the district is presented in table 4.1 below.

Table 4.1: General Information of the District

Population 2001	385,672
Population growth% per annum	1.72
Regional/Urban center	Kathmandu
Length of existing roads (km.)	723.6
• Black topped	76.6
• Gravelled	61.0
Area of district (sq./km.)	1404.86
Area of forest /scrub land (sq./km.)	616.49
Area of grass land (sq./km.)	37.51
Others areas (sq./km.)	12.85
Road density (pop/km of road	533
Road density (Agriculture land sq km/km of road)	0.85

(Source: District profile of Kavreplanchowk, 2001)

4.1.2 Occupation

The main occupation of the people of the district is agriculture and animal husbandry. About 78% of the populations are dependent on agriculture for their livelihood. They cultivate Rice, Wheat and Maize as the major cereal crops, and fruits, vegetables and medicinal herbs also occupy the significant space. Cow, buffalo are reared for milk, goat, chickens for meat. Non agriculture activity includes business, tourism and government jobs (District profile of Kavreplanchowk, 2001).

4.1.3 Population

According to the draft 2001 population census, the total population of the district is 385,672 with 188,947 male and 196.725 female populations. Out of this population 176,832 are economically active population. There about 70,509 households and settlements randomally scattered over the district. The average household size is 5.5. the average population growth rate is 1.9 percent and population density is 275 inhabitants per sq. km (Draft population census, 2001).

4.1.4 Socio-economic status

Agriculture is the major source of income and employment in the district. The agriculture alone provides employment for over about 92% of the economically active population. 78% of people are engaged in agriculture including livestock and fishing. According to 1997 ICIMOD Relative indicators of Development district has a rank of 33 out of 75 districts for overall development index, while it is ranked 42in terms of Poverty Deprivation and Infrastructural development Indices.

It is estimated that more than 505 of the total population in the district are unable to produce sufficient food from their own-farm resources, and large share of population have to purchase food from their off-farm laboring and remittances. A huge number of economically active population from the poor household, therefore, seek non-farm/off-farm employment as daily wage-workers within and outside of the for their subsistence (District profile of Kavreplanchowk, 2001).

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4.1.5 Climate

Due to different geo-physical conditions of the climate varies from sub-tropical to temperate. The climate of the district changes according to the altitude. It is hot along the bank river. The climate is sub-tropical in the middle mountain and cool temperature in the high mountain region. The average maximum and minimum temperature of the district is 28^0c and 9^0c respectively. The average annual rainfall in the district is 1,785mm (District profile of Kavreplanchowk, 2001).

4.1.6 Soil

The major part of the soil is occupied by colluvial and residual soils. General category of soil varies from light to medium texture on sloping level terraces and heavy textuire soil in the river valley. The residual soil is used as cropland and saturated with the ground water (District profile of Kavreplanchowk, 2001).

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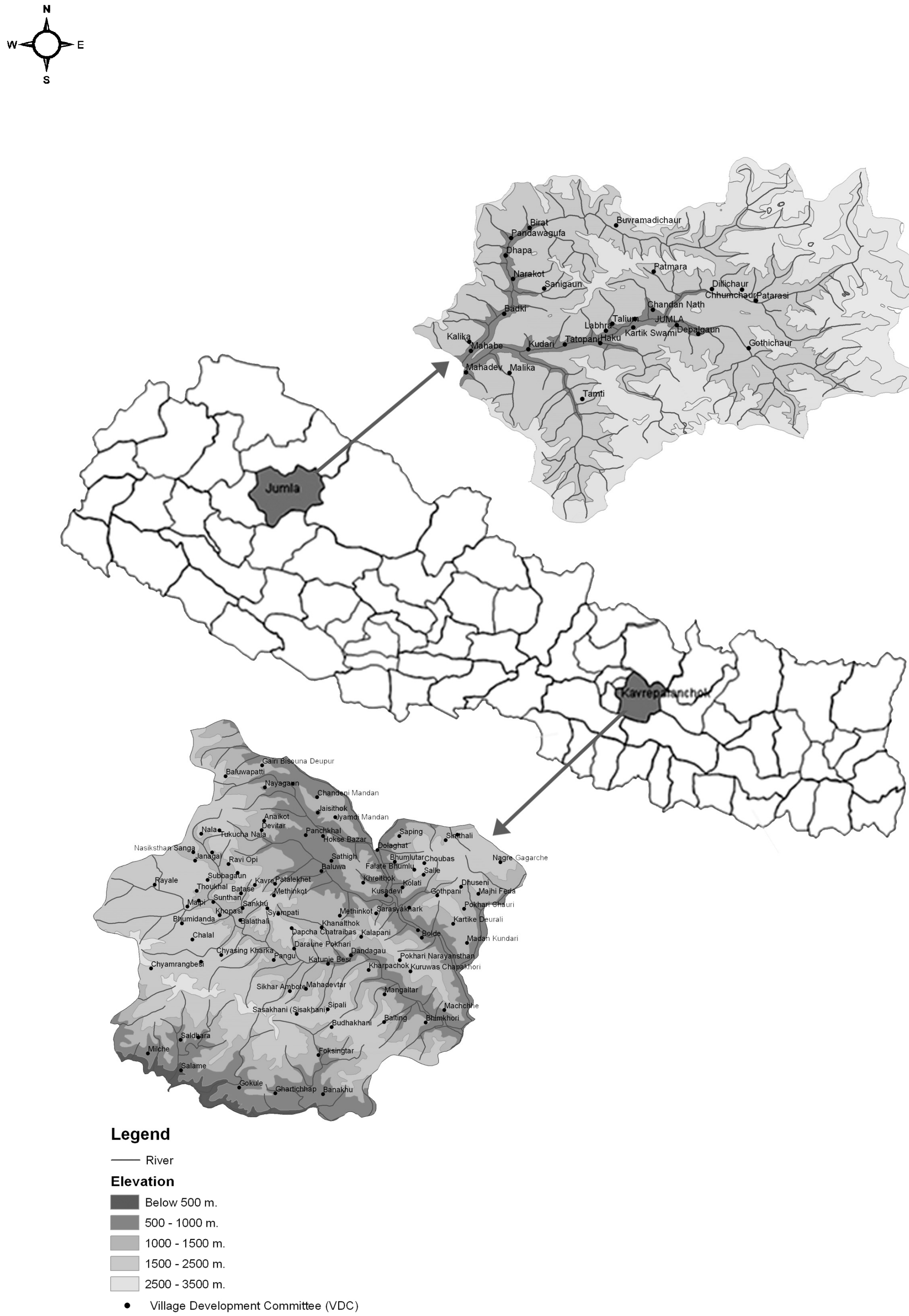

Map 4.1; Location map of Kavreplanchowk and Jumla District

4.2 Jumla district

4.2.1 Background information

Jumla is one of the mountainous district of Mid –western development reagion of Nepal. It is the zonal headquarter of Karnali zone. The total area of the district is 2531sq.km. Though the rural district it is full of natural and cultural resources. The district boundary is Dolpa in east, Kalikot in west, Mugu in north and jajorkot in south. Khalnga bajaar situated in height of 7500ft. above the sea level is the Headquarter of this district. Khalnga Bajar is situated in the lap of Tila river. The district lies between the north latitudes of 28^{0} 58 $^{'}$and$29^{0}30^{'}$ and the eastern longitudes of $82^{0}18^{'}$ and $82^{0}19^{'}$. There are 30 VDCS and 9 ilakas in the district. The district comprises of hills, mountains and hilly valleys. The district varies in altitude from 7000ft of Nagma village upto 21077ft of Patarshi Himal. The total cultivated land is 39468ha. 3131ha. of land is irrigated. The total area cover by forest is 106430ha. Sisne Himal, Patrashi Himal, are the mountain of this district. Pandav cave is famous topographic feature of this district (District profile of Jumla, 2001).

Table 4.2: General Information of the District

Population 2001	86,603
Regional/Urban center	Surkhet/ Nepalganja
Length of existing roads (km.)	232km
Area of district (sq./km.)	2531sq.km
Area of forest /scrub land (ha.)	106,430
Area of agricultural land (Ha.)	26,761
Others areas (Ha.)	121,174

(Source: District profile of Jumla, 2001)

4.2.2 Occupation

Agriculture is the main occupation of the people. Though the agriculture is the main occupation the district faces scarcity of food every year because of the traditional method farming . the farming is not sufficient to fulfill the demand of growing population. Animal huasbandry and horticulture is also carried on this district. Animals are reared for milk , meat and wool. apple farming and collection of medicinal herb is famous activity of this district (District profile of Jumla, 2001).

4.2.3 Population

According to the census of 2001, the total population of district is 86603. Increase the population of male is 44680 and female population is 41923. At the end of fiscal year 2063/64 the total household dependent on agriculture was 16102. The literacy rate is 37% and sex ratio is 105 (District profile of Jumla, 2001).

4.2.4 Climate

The temperate and sub- temperate type of climate prevails in this district. Sub polar type of climate is also found on small part of this district. The average maximum temperature is 27.2^0c and minimum average temperature 7.5^oc. In winter temperature falls up to -4.2^0c. The average rainfall is 136.8mm (District profile of Jumla DDC, 2001).

4.2.5 Soil

It consists of sedimentary to low grade metamorphic rock. Soil range from boulder gravel and sand whereas the bank of Tila river comprises of clayey soil suitable for paddy production (District profile of Jumla DDC, 2001).

CHAPTER V

RESULTS

Any change in the temperature and precipitation ultimately affects crop yield. In his regard, an attempt has been made to investigate the effect of climate variability on the paddy, wheat, maize productions during transplant, maturity and harvest periods of the Kavre and Jumla districts.

5.1. Analysis of temperature

Temperature records from 1990-2009 shows an increasing trend at both kavreplanchowk and Jumla districts. In case of Kavre, over the last 20 years the mean temperature increases by 0.02^0 per year and the highest and lowest values of maximum temperature respectively are 29.99^0C in 2009 and 12.85^0 in 1997. In addition, the mean annual maximum temperature increases at the rate of 0.04^0C per year and mean annual minimum temperature by 0.019^0C per year. Similarly, in the case of seasonal temperature at Kavre, winter, spring and autumn temperature trends closely resemble the yearly distribution, in which the autumn season shows the greatest and the spring season shows the lowest rate of increase. The time series of annual maximum, minimum and the seasonal distributions of temperature including linear trends are depicted in figures 5.1, 5.2 and 5.3 respectively.

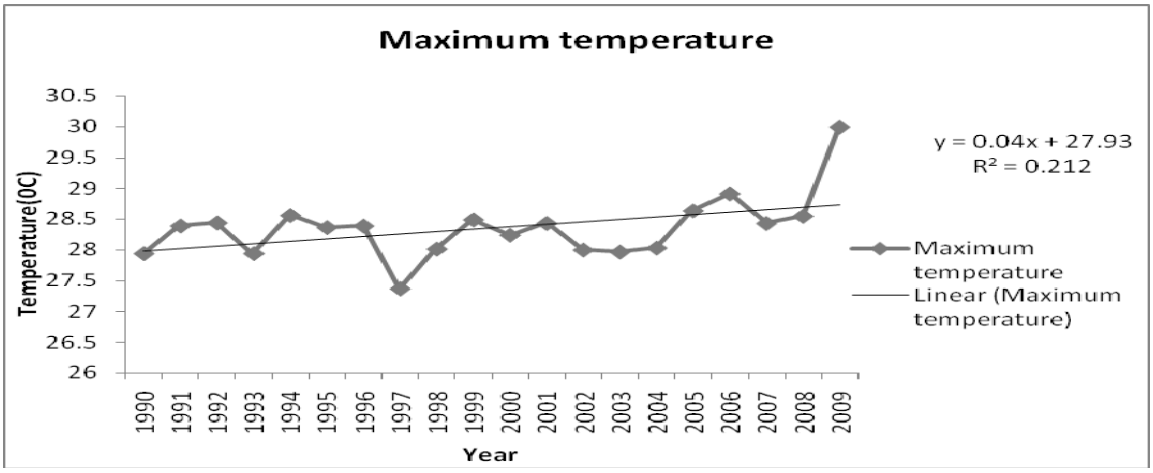

Figure 5.1: Maximum mean temperature at Kavre District

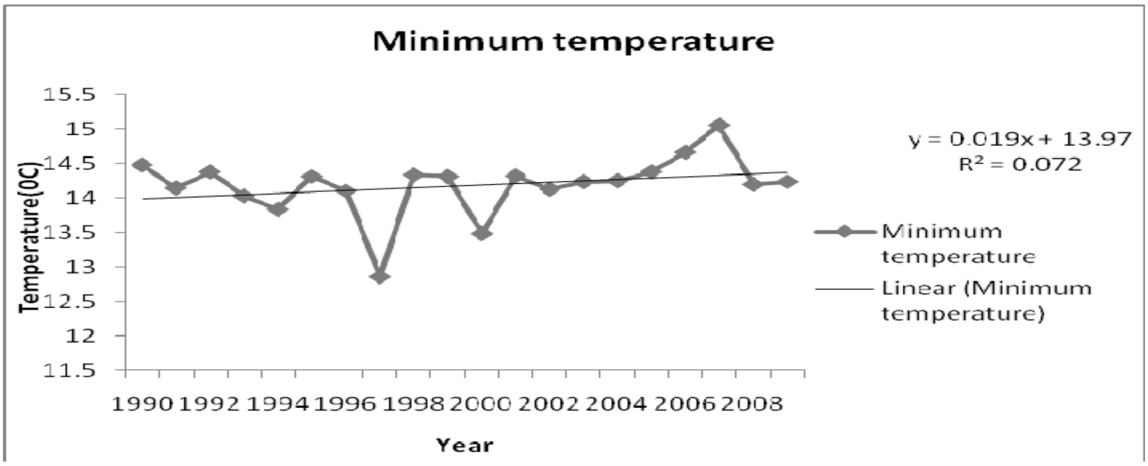

Figure 5.2: Minimum mean temperature at Kavre

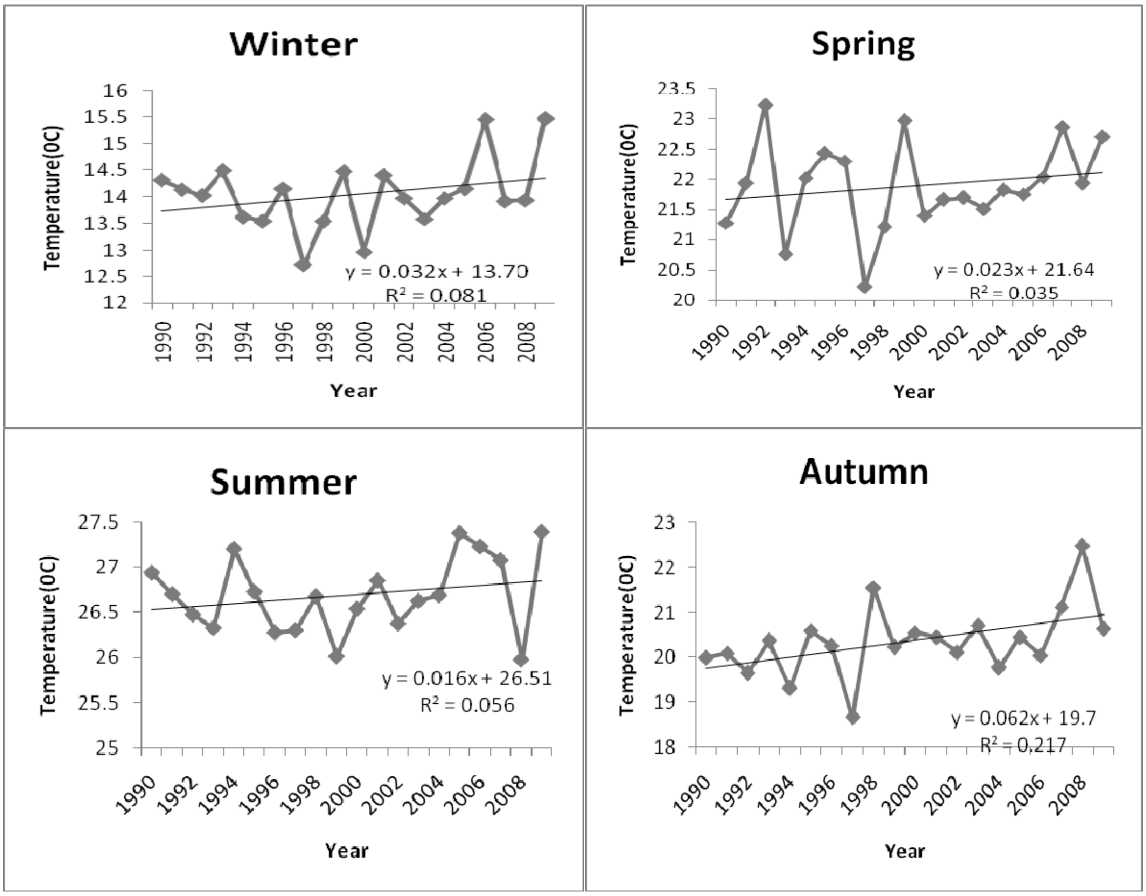

Figure 5.3: Seasonal distributions of temperature at Kavre district.

The mean temperature for Jumla district increases by 0.064^0C per year. The highest maximum temperature for Jumla is 22.12^0C in year 2009 and the lowest is 2.13^0C in 2000. In addition, the mean annual maximum temperature is increases at the rate of 0.09^0C per year and mean annual minimum temperature is increases at the rate of 0.036^0C per year. Similarly, in the case of seasonal temperature distribution at Jumla winter, spring,autumn trends closely resemble the yearly distribution, in which the winter season shows the greatest and the autumn season shows the lowest rate of increase. The time series of annual maximum, minimum and the seasonal distributions of temperature are depicted in figure 5.4, 5.5 and 5.6 respectively. Temperature records from 1990-2009 shows an increasing trend at both kavreplanchowk and Jumla district.

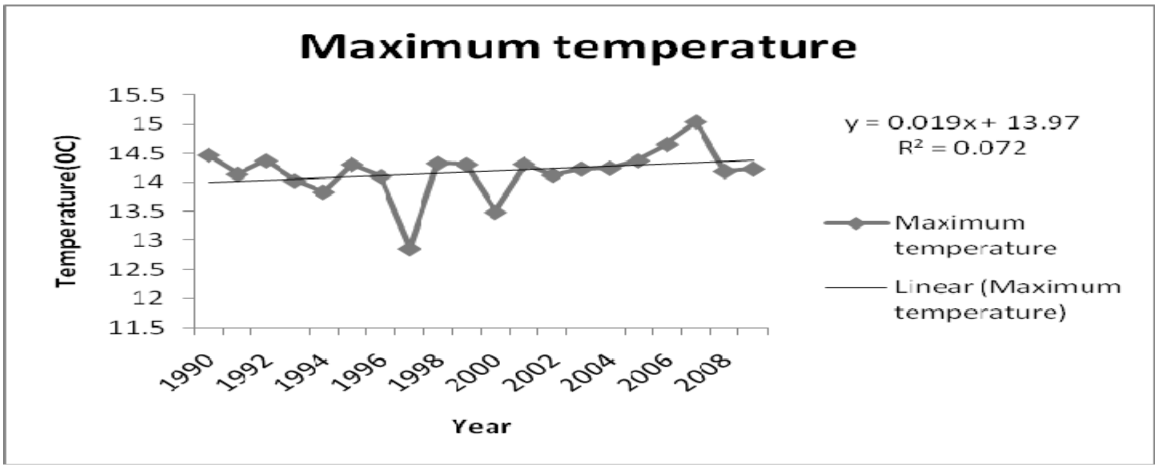

Figure 5.4: Maximum mean temperature at Jumla District

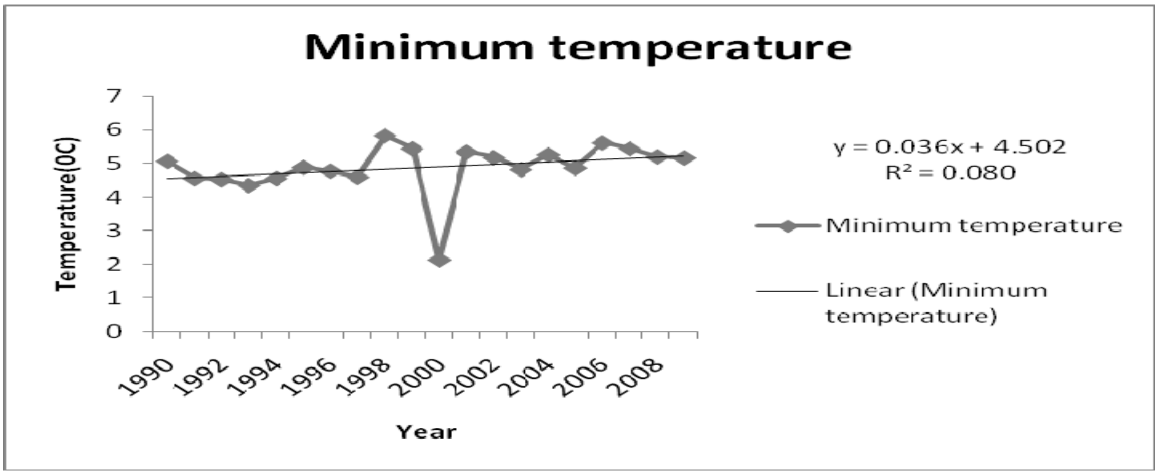

Figure5.5: Minimum mean temperature at Jumla district

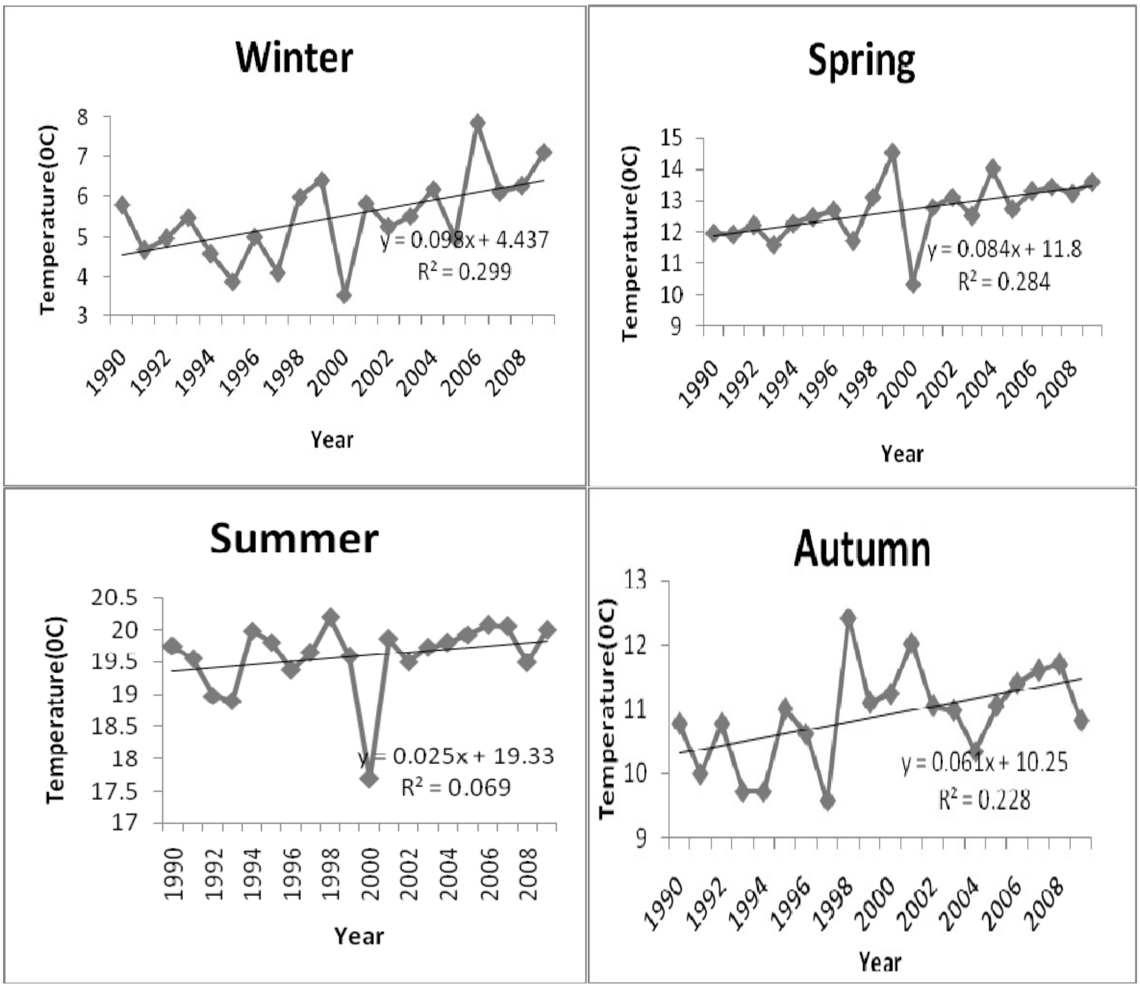

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Figure 5.6: Seasonal distributions of temperature at Jumla district.

5.2. Analysis of precipitation

The mean annual precipitation at Kavre district is found as 1144.9mm with coefficient of variation 9.85% of the mean. The analysis of seasonal distribution of rainfall shows that the most of precipitation falls on monsoon season which contributes about 78.5% of the total annual rainfall while winter season shows driest period with least precipitation. The highest and lowest recorded temperature for Kavre district during this period was 34^0c and 3^0c in April 2009 and in January 1999, respectively. Pre-monsoon accounts 13.2% and post-monsoon accounts 5.02% of the normal precipitation. The mean Rainfall during winter, pre-monsoon, monsoon and post-monsoon are 35.7, 151.9, 899.7 and 57.5mm respectively. The seasonal contribution of rainfall is shown in figure 5.7 and 5.8.

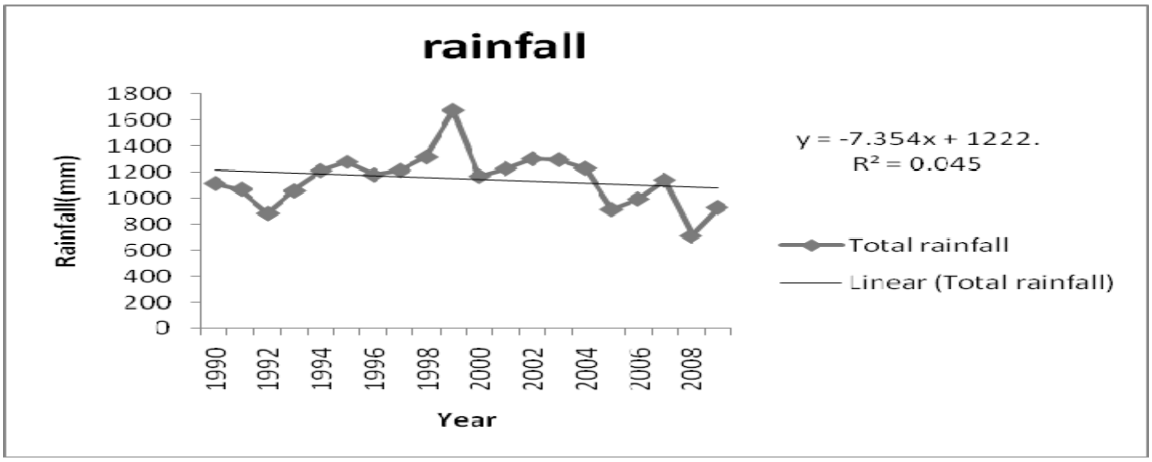


Figure 5.7: Total annual rainfall at Kavre district

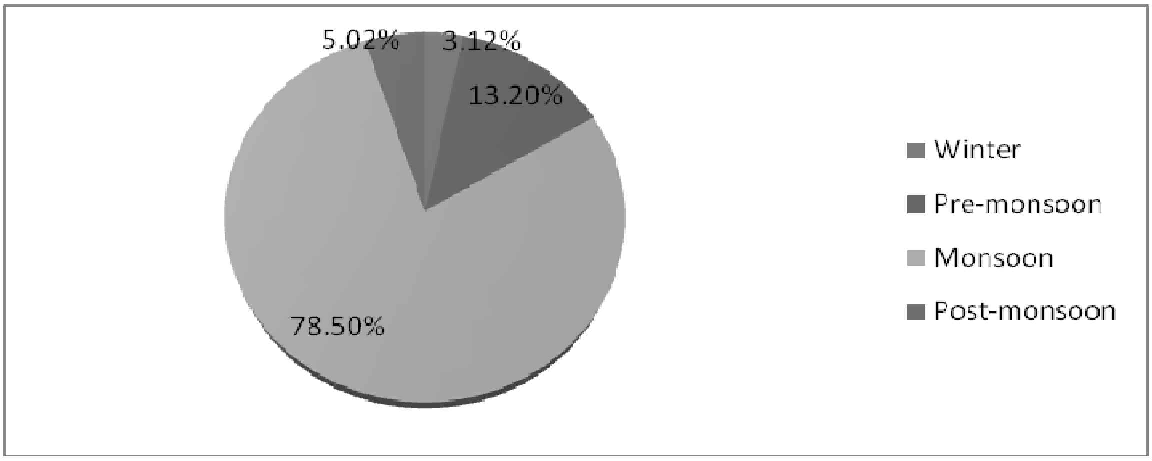


Figure 5.8: Seasonal Contribution of rainfall at Kavre District

The mean annual precipitation at Jumla district is found as 797.8mm with coefficient of variation of 8.89%. The highest and lowest recorded temperature for Jumla district during this period was 28.1^{0}c and -9.1^{0}c in June 2005 and in February 2000, respectively. The analysis of seasonal distribution of rainfall shows that the majority of precipitation occurs on monsoon season which contributes about 66.7% of the total annual rainfall while post-monsoon season can be consider as dry period with least precipitation. Pre-monsoon accounts 18.04% and winter accounts 5.30% precipitation. The mean Rainfall during winter, pre-monsoon, monsoon, post-monsoon is found 78.8, 143.9, 532.4, 42.6mm respectively. The seasonal contribution of rainfall is shown in figure 5.9 and 5.10.

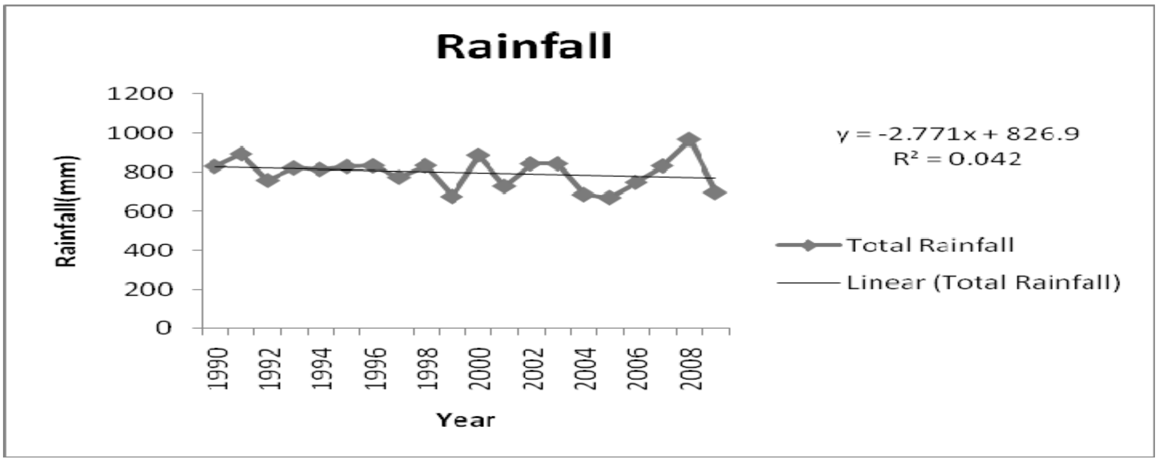


Figure 5.9: Total annual rainfall at Jumla district

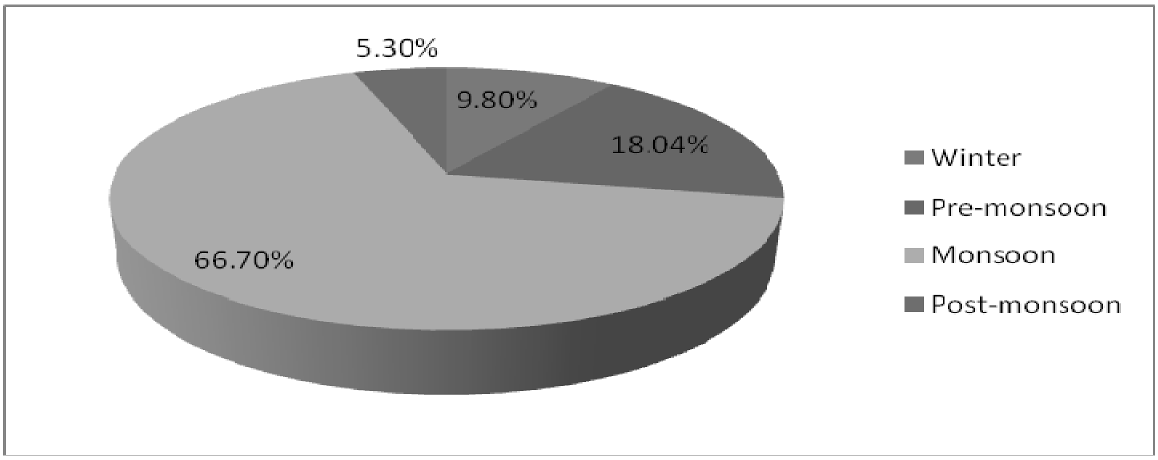


Figure 5.10: Seasonal Contribution of rainfall at Jumla District

5.3 Impact of climate variability on agriculture

The Present study attempts to determine the impacts of climate variability on agriculture taking rice, wheat and maize as an example. The study focuses the correlation analysis between rice, wheat and maize yield and maximum and minimum temperature and rice, wheat and maize yield and rainfall. Further analysis is made to investigate the effect of climate variability on the plantation, maturity and harvesting period of yield.

5.3.1 Variability in temperature

The relationships between maximum and minimum temperatures and agricultural yields (rice, wheat and maize) of both Kavre and Jumla districts are analyzed. There is always a threshold 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 rice yield and temperature (both maximum and minimum) are shown in figures 5.11and 5.12 respectively. It is well notice that the effect of rice yield is more dependent in minimum temperature than the maximum temperature in Kavre district. Rice yield in harvesting period shows a negative correlation for maximum temperature i.e., increase in maximum temperature has a large negative impacts on net production furthermore the increase in minimum temperature in both maturity and harvesting period shows negative impact.

In case of Jumla district, rice yield in general depends more on minimum temperature. During maturity periods rice yield shows a negative correlation with maximum temperature and during transplant period, minimum temperature shows a negative correlation with the yield.

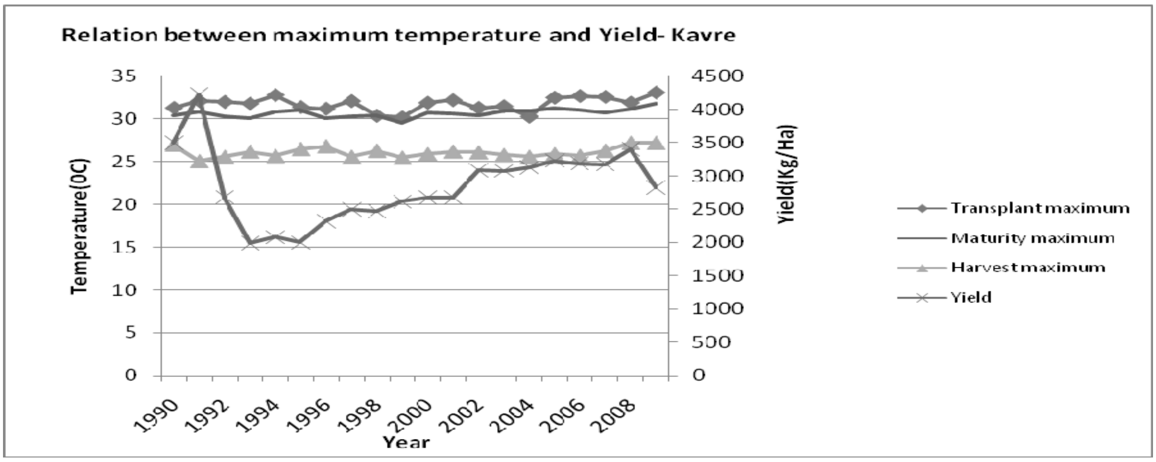


Fig 5.11: Relation between maximum temperature and rice yield at Kavre.

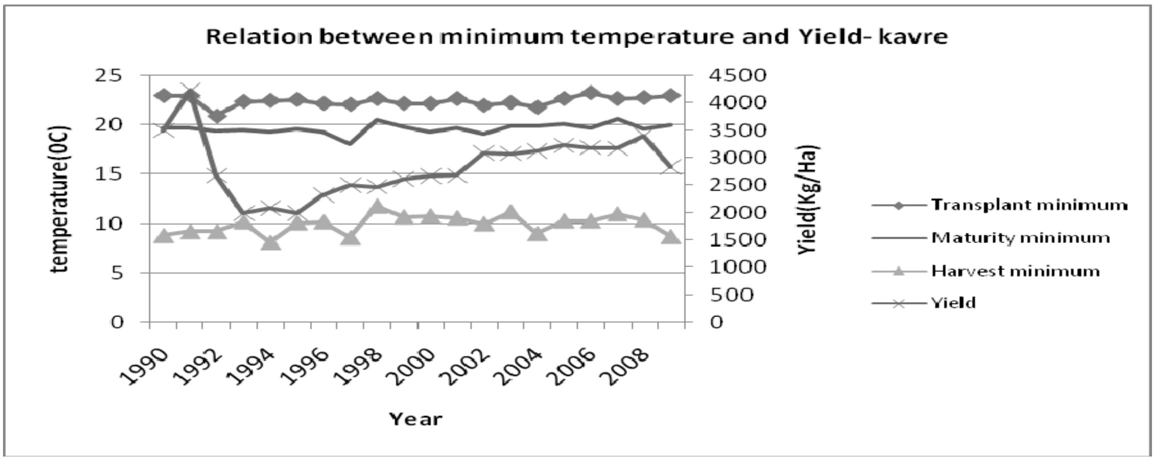
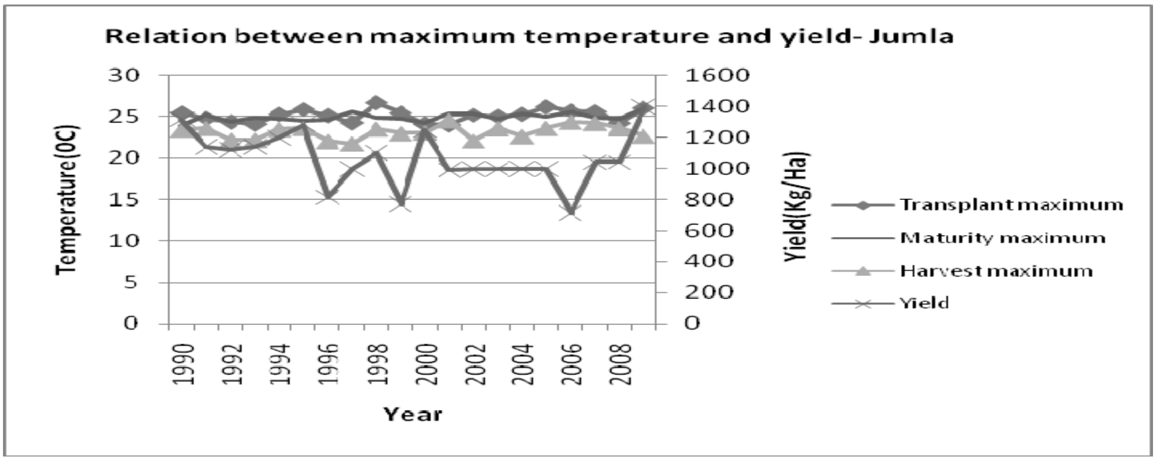


Fig 5.12: Relation between minimum temperature and rice yield at Kavre.



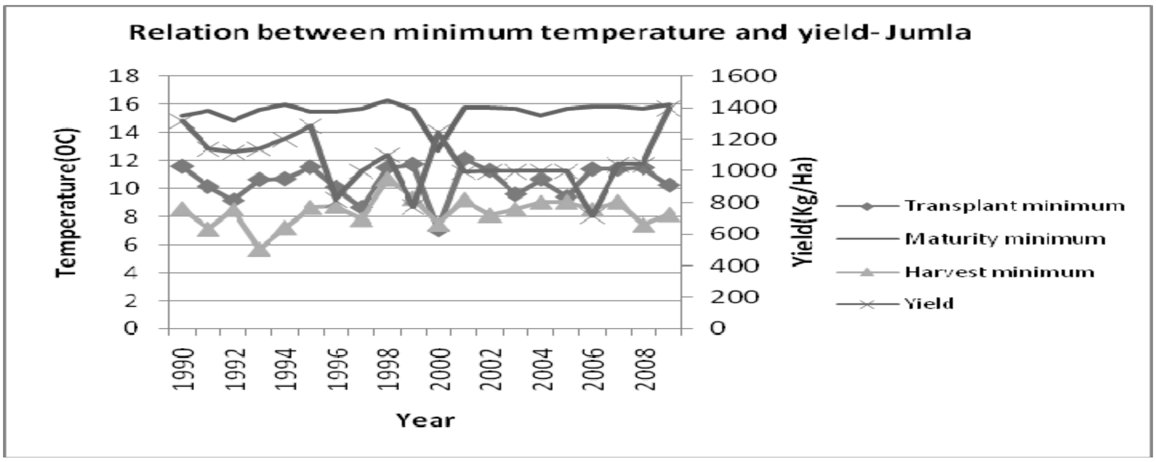
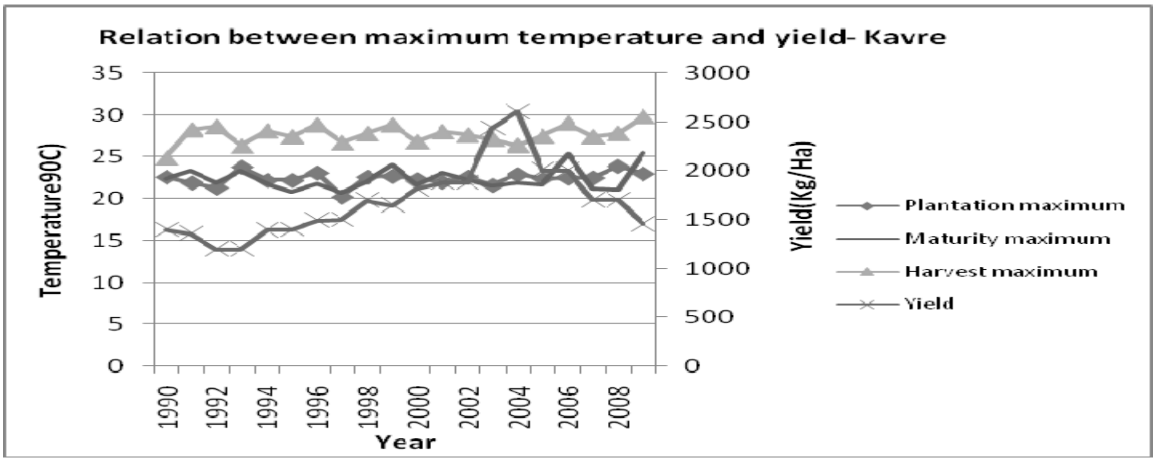


Fig 5.13: Relation between maximum and minimum temperature and rice yield at Jumla.

A relationship between wheat yield and temperature (maximum and minimum) are present in figures 5.13 and 5.14 respectively. It is well notice that the effect of wheat yield is more dependent in minimum temperature than the maximum temperature in Kavre district. Wheat yield in harvesting period shows a negative correlation for maximum temperature i.e., increase in maximum temperature has a large negative impacts on net production and the increase in minimum temperature in plantation and maturity period also shows negative impact. In case of Jumla district wheat yield is more dependent on minimum temperature. Wheat yield in plantation period shows a negative correlation for maximum temperature and for minimum temperature, maturity period shows a negative correlation.



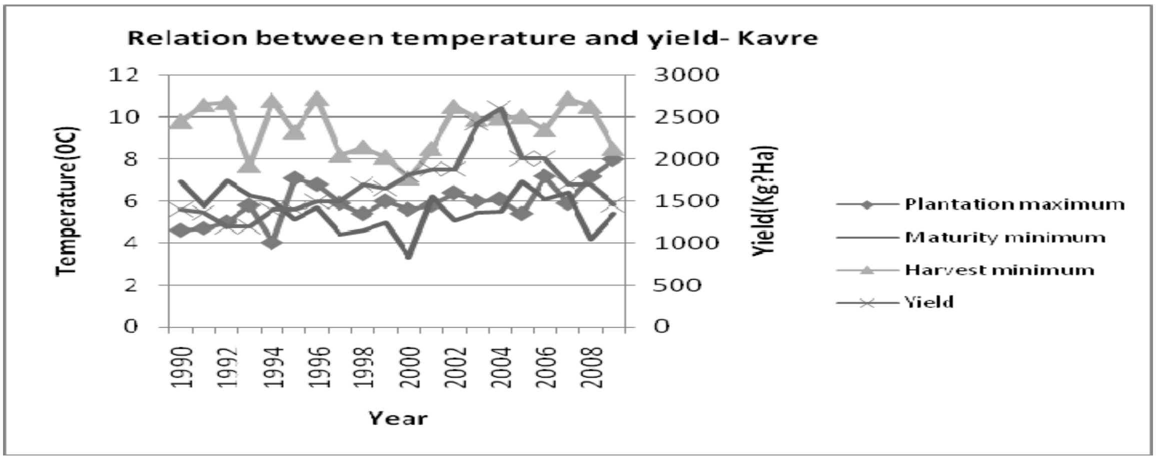
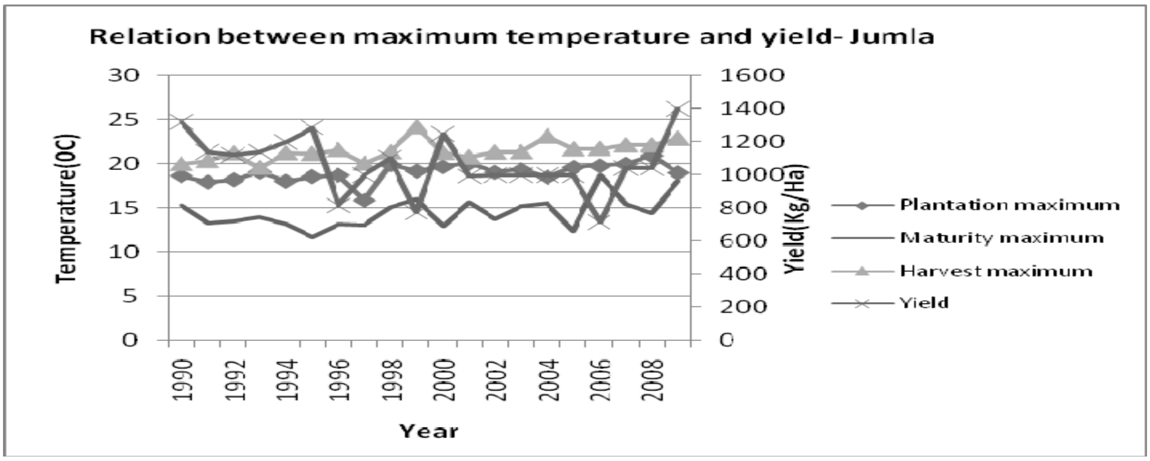


Fig 5.14: Relation between maximum and minimum temperature and wheat yield at Kavre.



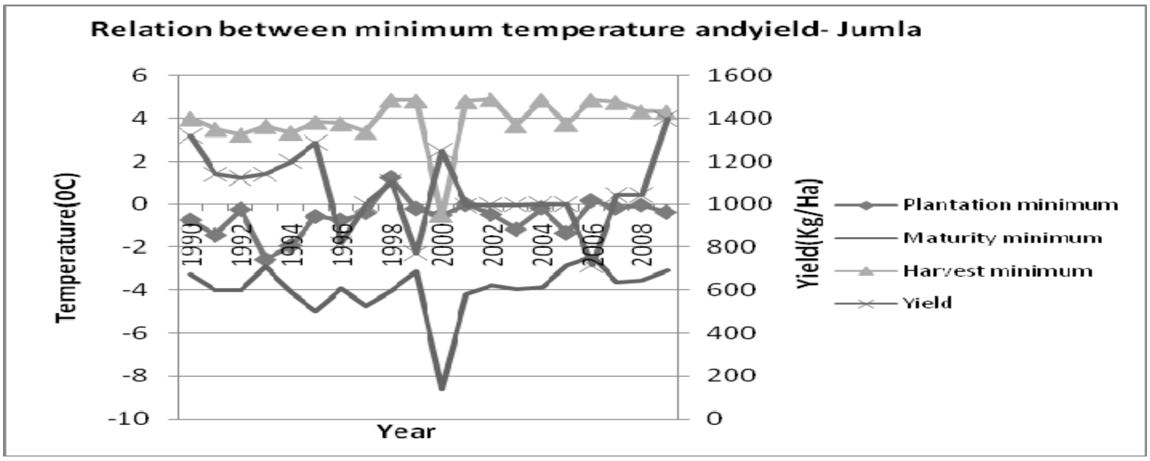
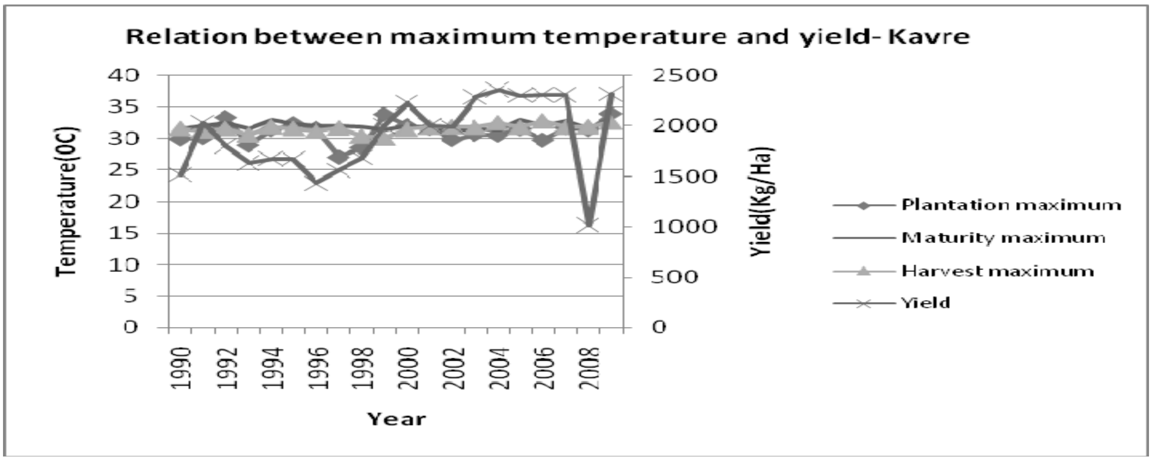


Fig 5.15: Relation between maximum and minimum temperature and wheat yield at Jumla.

A relationship between maize yield and temperature (maximum and minimum) are shown in figures 5.15 and 5.16 respectively. It is well notice that the effect of maize yield is more dependent in minimum temperature than the maximum temperature in Kavre district. Maize yield is somehow affects with minimum temperature but not significant.

In case of Jumla district maize yield is more dependent on minimum temperature. Maize yield in whole plantation to harvesting period shows a negative correlation for maximum temperature and for minimum temperature i.e., increase in minimum temperature has large negative impacts on production of maize.



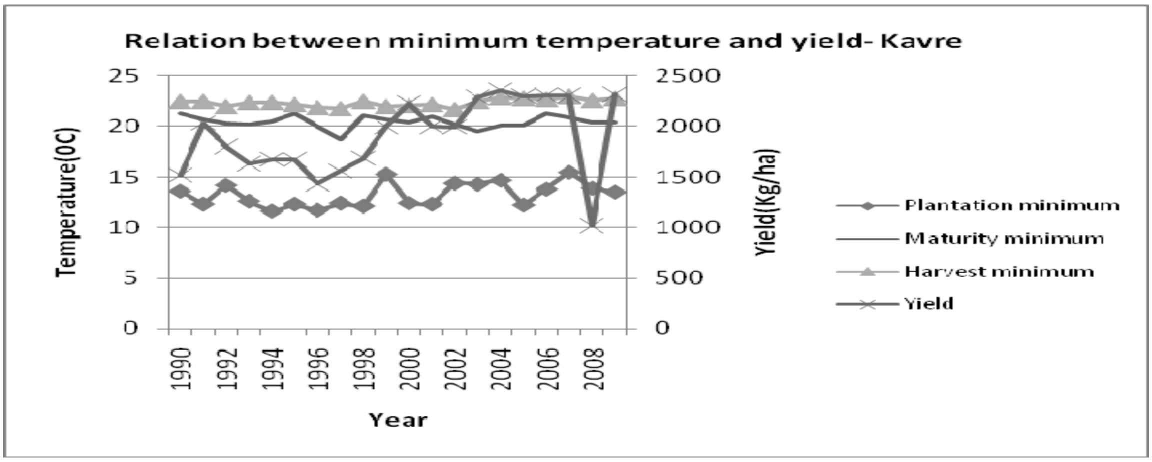


Fig 5.16: Relation between maximum and minimum temperature and maize yield at Kavre

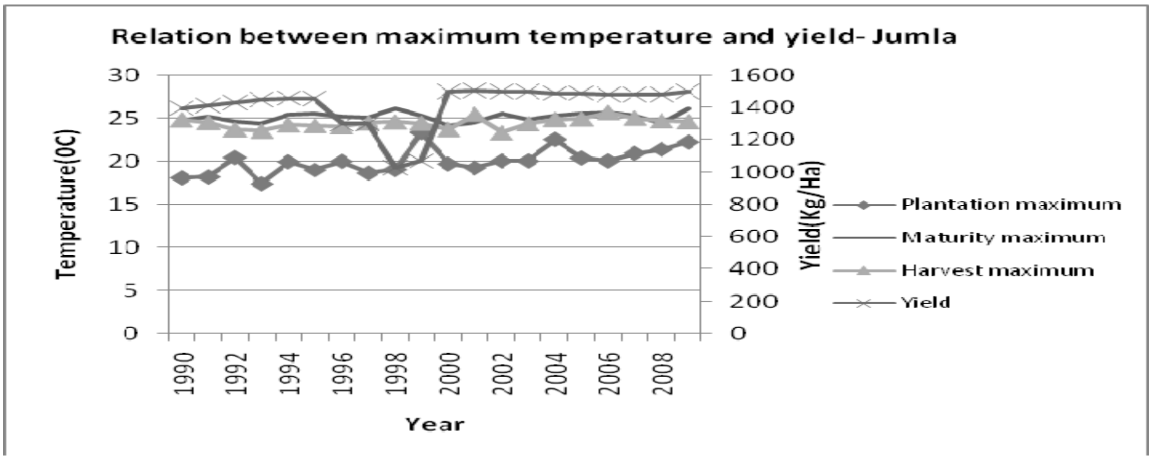


Fig 5.17: Relation between maximum temperature and maize yield at Jumla

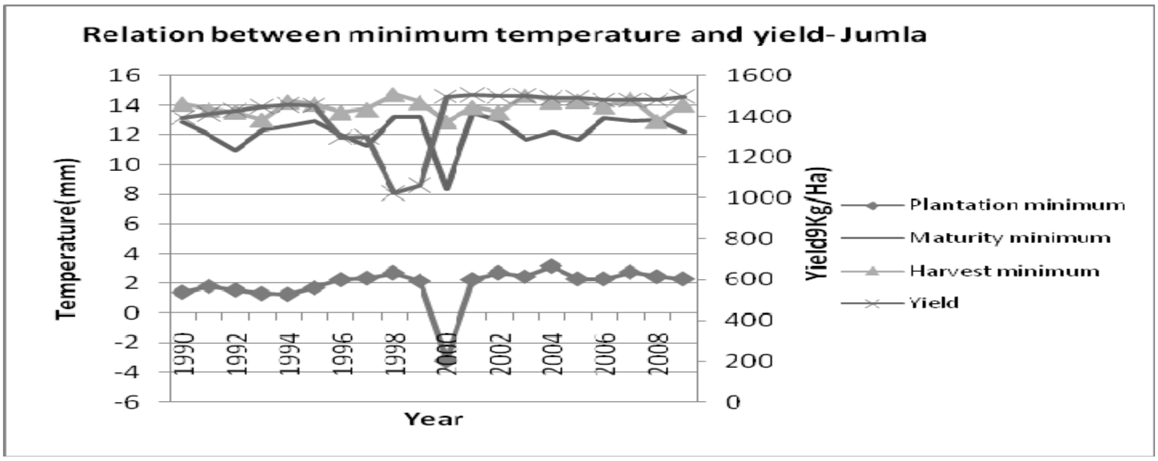


Fig 5.18: Relation between minimum temperature and maize yield at Jumla

5.3.2 Variability in rainfall

The relationship between rainfall and rice, wheat and maize yield are analyze as shown in figures 5.17, 5.18 and 5.19 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 Kavre district, a poor relationship between rice, wheat, and maize yield and rainfall obtain during plantation to harvesting period. The poor relationship between yield and rainfall can be, either the rainfall is adequate 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.

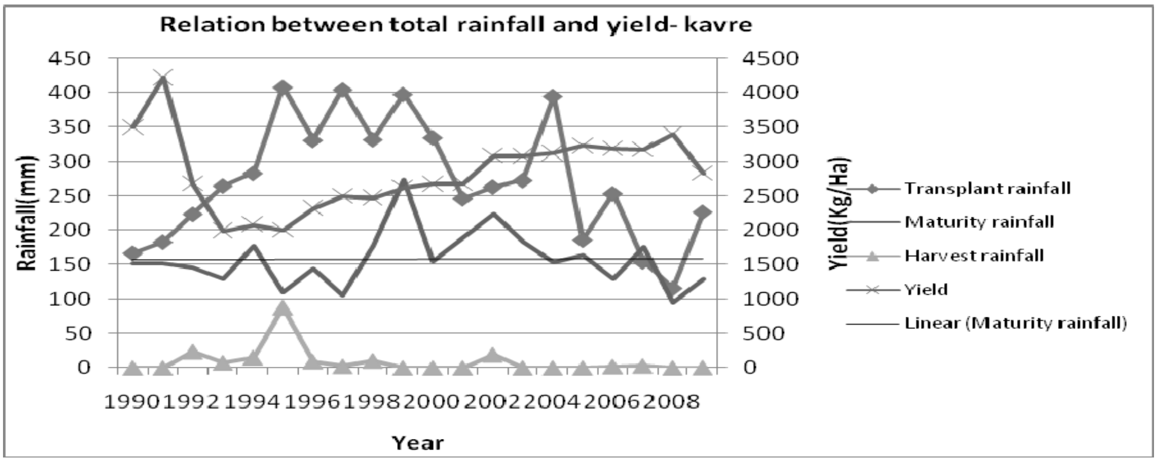
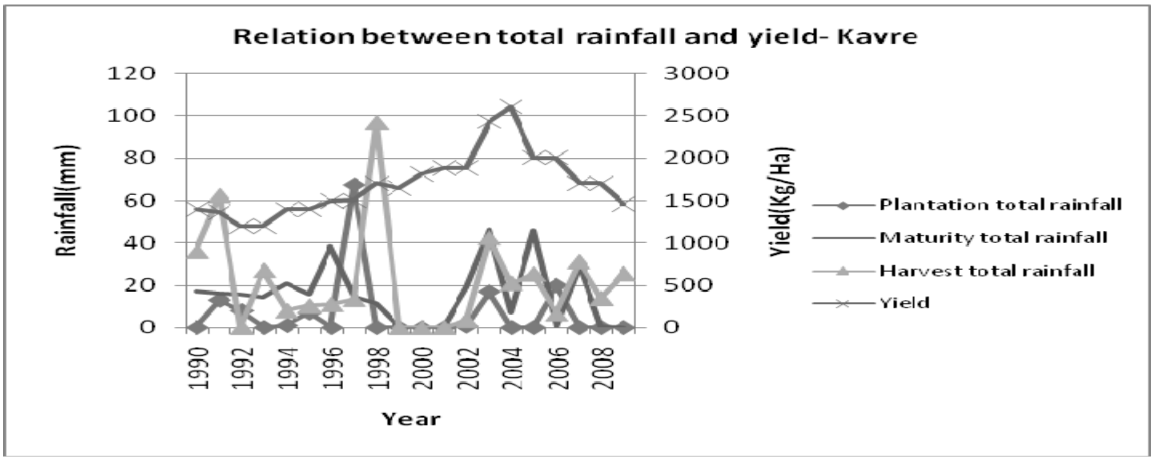


Fig 5.19: Relation between total rainfall and rice yield at Kavre.



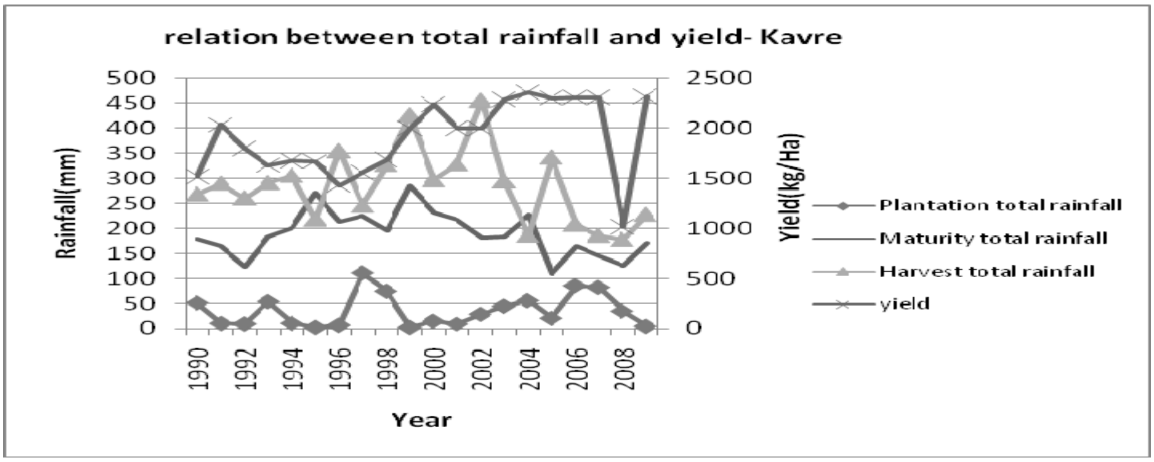


Fig 5.20: Relation between total rainfall and wheat and maize yield at Kavre

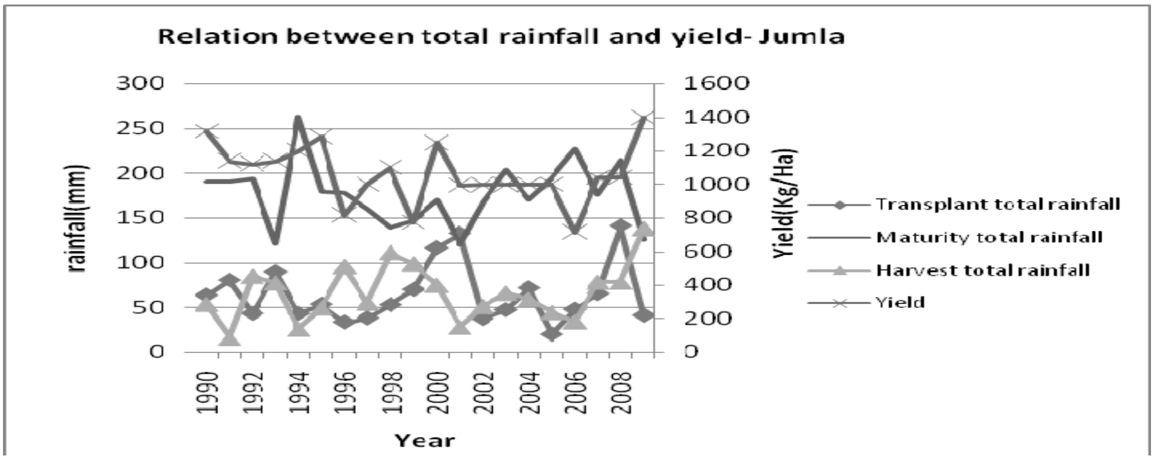


Fig 5.21: Relation between total rainfall and rice yield at Jumla

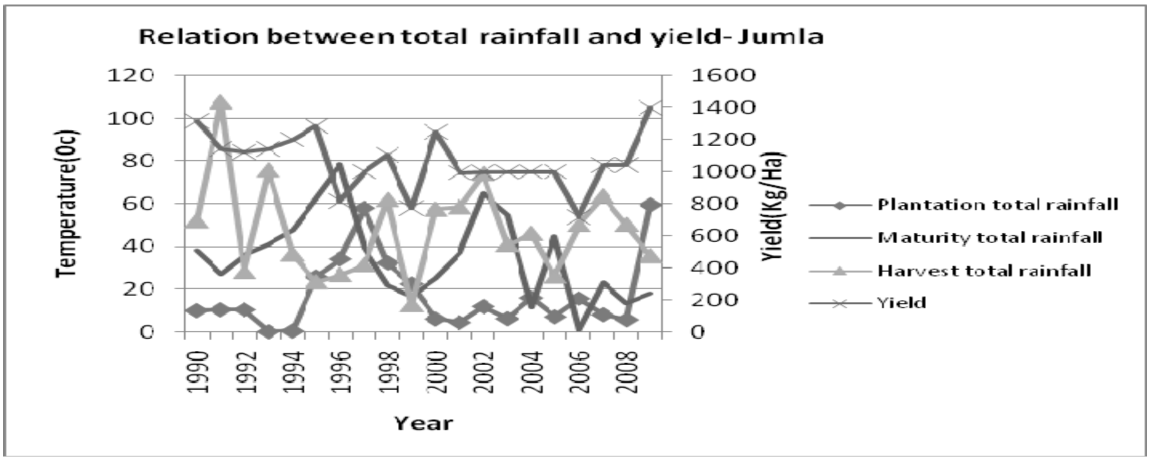


Fig 5.22: Relation between total rainfall and wheat yield at Jumla

In case of the jumla district, poor relationship of rice yield and rainfall obtain in transplant period. In case of maize yield significantly good but in poor relationship in maturity period. But for maize yield poor relationship observe in harvesting period.

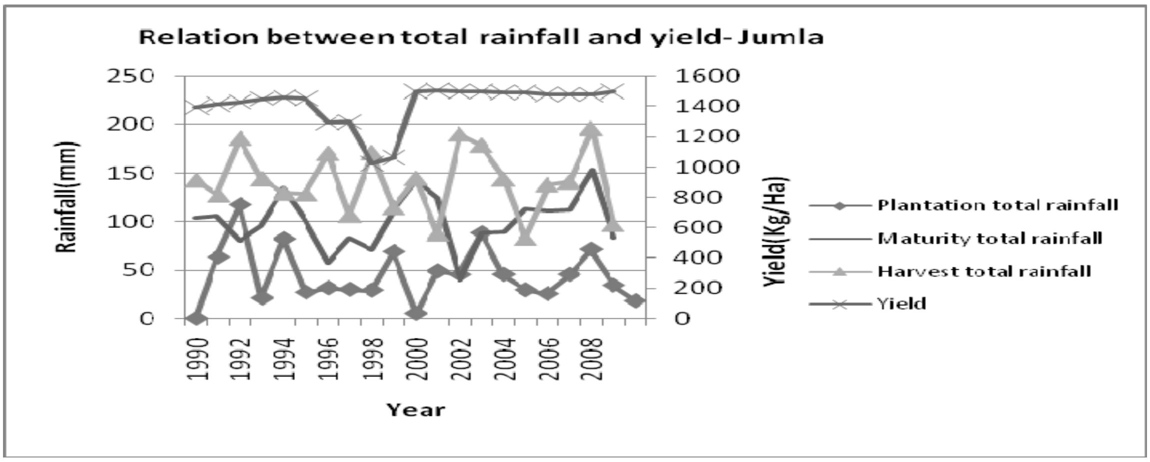


Fig 5.23: Relation between total rainfall and maize yield at Jumla

5.3.3 Relation with variability of temperature

The correlation analysis is analyzed between maximum and minimum temperature and rice, wheat and maize yield of both Kavre and Jumla district. The analysis carried out all the plantation, maturity and harvesting period. The result presents in table 5.1, 5.2 and 5.3. The analysis of rice during transplant stage shows the positive correlation for both district but in harvest period shows negative correlation for Kavre district and in maturity stage shows negative correlation for Jumla district i.e., increase in maximum temperature, there will be decrease in net yield. In minimum temperature transplant period shows positive correlation but both maturity and harvest period shows negative correlation for kavre district. In case of jumla district transplant shows negative correlation whereas maturity and harvest period shows positive correlation.

In case of wheat, maximum temperature shows positive correlation for plantation and maturity however minimum temperature shows negative correlation for kavre district and harvest period shows negative for maximum and positive correlation for minimum temperature. In case of Jumla district plantation period shows negative and both maturity and harvest shows positive correlation for maximum and negative for minimum temperature.

For the maize yield, all three period shows positive correlation for maximum and minimum in kavre district. However all period shows negative for Jumla district. It depicts that maize in Jumla is more sensitive to the variation of the minimum temperature.

5.3.4 Relation with the variability of rainfall

The analysis is carried out between rainfall and rice, wheat and maize yield for both kavre and Jumla district. The analysis of rice during both transplant and harvest period shows negative correlation for Kavre district. It can be said that yield does not depend upon rainfall .In Jumla both maturity and harvest period shows positive correlation which shows it depend upon rainfall.

In case of wheat, plantation and maturity period shows negative correlation but harvest period shows positive correlation in kavre district. In jumla district plantation and harvest period shows positive correlation.

In case of maize, plantation and harvest period shows negative correlation for kavre district. In jumla district, plantation and maturity shows positive correlation.

The correlation between temperature (maximum and minimum) and crops yield ; and rainfall and crops yield are Present in table 5.1, 5.2 and 5.3and figures 5.20, 5.21, 5.22 and 5.23 respectively below.

Table 5.1 Correlation between temperature and rainfall and rice yield

S.N	Parameters			Stations			
			Kavre			Jumla	
		Transplant	Maturity	Harvest	Transplant	Maturity	Harvest
1	Mean maximum temperature	31.76	30.68	26.11	25.15	24.94	23.18
2	σ_{max}(T)	0.823	0.702	0.588	1.01	0.66	1.09
3	Mean minimum Temperature	22.45	19.64	9.96	10.52	15.47	8.33
4	σ_{min}(T)	0.532	1.111	0.988	1.41	0.78	1.28
5	Mean Rainfall	272.53	157.89	9.09	64.68	176.34	65.93
6	CV of Rainfall	32.46	57.47	218.78	57.81	35.72	86.78
7	SD of Rainfall	88.46	65.29	19.88	38.93	62.88	40.65
8	T_{max} corr. With Rice yield	0.034	0.036	-0.454	0.166	-0.29	0.005
9	T_{min} corr. With Rice yield	0.256	-0.059	-0.144	-0.097	0.14	0.19
10	Rain corr. With Rice Yield	-0.22	0.018	-o.231	-0.0676	0.234	0.0783

Table 5.2 Correlation between temperature and rainfall and wheat yield

S.N	Parameters			Stations			
			Kavre			Jumla	
		Plantation	Maturity	Harvest	Plantation	Maturity	Harvest
1	Mean maximum temperature	22.41	22.36	27.64	19.01	14.5	21.46
2	σ_{max}(T)	0.818	1.521	1.117	1.31	2.21	1.46
3	Mean minimum Temperature	5.94	5.57	9.49	-0.58	-3.93	3.90
4	σ_{min}(T)	0.985	1.278	1.182	1.07	1.487	1.45
5	Mean Rainfall	6.705	14.65	21.70	17.14	35	47.98
6	CV of Rainfall	232.46	134.61	111.13	179.39	76.66	64.14
7	SD of Rainfall	15.58	19.26	24.12	27.28	26.75	30.91
8	T_{max} corr. With Wheat yield	0.085	0.044	-0.136	-0.017	0.036	0.011
9	T_{min} corr. With Wheat yield	-0.04	-0.175	0.053	0.05	-0.21	-0.22
10	Rain corr. With Wheat Yield	-0.009	-0.099	0.201	0.206	-0.0718	0.011

Table 5.3 Correlation between temperature and rainfall and maize yield

S.N	Parameters			Stations			
			Kavre			Jumla	
		Plantation	Maturity	Harvest	Plantation	Maturity	Harvest
1	Mean maximum temperature	31.07	32.08	31.61	20.04	25.18	24.48
2	σ_{max}(T)	1.75	0.875	0.676	1.77	0.93	0.76
3	Mean minimum Temperature	13.25	20.48	22.37	1.89	12.23	13.88
4	σ_{min}(T)	1.208	0.834	0.375	1.41	1.343	0.66
5	Mean Rainfall	35.96	189.59	284.89	46.53	100.37	141.24
6	CV of Rainfall	90.32	35.15	26.70	72.88	51.31	36.51
7	SD of Rainfall	32.47	63.95	76.09	34.49	47.88	50.17
8	T_{max} corr. With Maize yield	0.234	0.396	0.134	-0.33	-0.24	-0.09
9	T_{min} corr. With Maize yield	0.095	0.0266	0.326	-0.55	-0.50	-0.39
10	Rain corr. With Maize Yield	-o.o27	0.201	-0.021	0.067	0.165	-0.111

Index: Mean, Standard Deviation (σ), Coefficient of Variation (CV), Correlation Coefficient of Maximum Temperature (T_{max}), Minimum temperature (T_{min}) and Rainfall during cropping periods using the data of 1990-2009. The temperature is expressed in ^{o}C and rainfall in mm.

During three different periods at Kavre, rice yield production is statistically insignificantly inversely related with rainfall during transplant and harvest periods insignificantly higher correlation with rice yield. In harvest period, all three parameters show negative correlation but in case of Jumla all three parameters are positive in harvest period (Table 5.1). In case of Jumla, in transplant period the result shows poor relation between rice yield and maximum temperature and negative relation with minimum temperature and rainfall. Result shows that for rice production, Kavre is the favorable place than the Jumla district and response of climate change at Jumla district is positive.

During cropping periods at kavre, wheat yield production is inversely related with minimum temperature and rainfall during transplant and maturity; maximum temperature during harvest period and strong correlation in harvest period (Table 5.2). In case of Jumla, wheat production is inversely related with maximum temperature during transplant period, minimum temperature during maturity and harvest period, rainfall during maturity period (Table 5.2).

During cropping periods at Kavre, maize yield production is inversely related with rainfall during transplant and harvest period. During all three cropping periods strong correlation shows with maximum temperature and during harvest period with minimum temperature (Table 5.3). In case of Jumla, during all three cropping periods, maize yield production is inversely related with maximum and minimum temperature and during harvest period with rainfall (Table 5.3).

CHAPTER VI
DISCUSSION

6.1 Climate change and present situation

In Jumla, the average maximum annual temperature is found as 0.09^0 C which is higher than Nepal average of 0.06^0C (Climate change policy 2011) but that of Kavre (0.04^0 C) is lower than Nepal average. This rate of increase is higher in the mountains than in hilly regions. According to IPCC Fourth assessment Report 2007, the linear warming trend over the last 50 years is 0.13^0C per decade. Based on the records from 1979, the mean Nepal temperature is increasing at 0.4^0C per decade. Globally the annual number of warm nights/ cold nights increased/decreased by about 25/20 days since 1951 (Alexander *et.al*., 2005) 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. In the study area, the trends in maximum temperature showed increasing trend towards hilly to mountains. In the Kavre the average annual maximum temperature increases at the rate of 0.04^0C per year but in Jumla 0.09^0C per year is higher than Kavre district. Various studies suggest the pattern of temperature increase in Nepal. Regional mean maximum trends in Nepal from 1997-2000 shows increasing temperature trends (0.06^0C/year) in the higher elevation in the northern part of the country compare to the lower elevation in the south and show the warm trends of (0.04^0C/year) (Shrestha *et.al.* 1999).

Nepal lying in the southern edge of the Himalayas is affected profoundly by the monsoonal circulation of South Asia. Though small in size, it has a complex fragile topography with altitude ranging from almost sea level almost in the south to the highest place on the earth (Mount Everest) in the north just within a span of about 200km. This large north-south variation of topography gives rise to different climatic regions. These hills/mountains and the Himalayas are very sensitive to climate change and variability.

The mean annual precipitation in Kavre district is found as 1144.9mm and in Jumla district 797.8mm. Change in the annual rainfall cycle, intense rainfall and lounger droughts have been observed. Similarly, both days and nights are presently warmer. The number of days with 100mm of heavy rainfall is increasing. The timing and duration of rainfall is changing (Climate change policy 2011). Because of erratic rainfall pattern agricultural production has been affected thereby threatening the food security of hill and mountain peoples. The studies conducted in Nepal projects shows that warming in all months 2^0C or higher throughout the year (Regmi & Adhikari 2007b). The volume of precipitation has increased from 1989 to 2009 but distribution of rainfall is not uniform so no significant trend is observed. This suggests that Kavre and Jumla are going to have erratic rainfall pattern. 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; Nayaju *et al.* 2004; SOHAM 2007). In IPCC fourth assessment report, an increase in precipitation is projected in the Asian monsoon (Meehl *et al.* 2007). The recent study stated that Dolakha district experiencing the greatest decreasing trend in Monsoon (SOHAM 2007) winter rainfall is expected to decrease all over the country, which is supported by the present study.

6.2 Climate change impact on agriculture

The relationship among climate, crop and the animal production is complex. The success of crop production entirely depends on weather condition, and livestock are fundamental part of livelihood.

6.2.1 Agricultural productivity and food security

Food security means people have access to sufficient, safe and nutritious food to meet the dietry needs for active and healthy life (FAO 1996). The agricultural production is influenced by the number of environmental and non-environmental factors (Nayaju *et al.* 2004). The climate, soil characteristics, seed quality, water availability, labor etc plays crucial role in determining the agricultural production along with socio-economical status of people (Kandlikar & Risbey 2000).

According to CBS, 64% of the cultivated land is totally dependent on monsoon rainfall (CBS 2006), which makes country's agricultural production highly vulnerable to precipitation pattern. If climate change adversely affect the crop production, it will have direct impact on the livelihood of several millions people residing here. The temperature increase is expected to reduce maize and wheat production while climatic variability will pose serious threat leading to famine and death of the poorest at first (PAN 2009). Some estimates suggest that rice production will increase with high precipitation and moderate increase in temperature (NARC 2009). In fruits and vegetables, increase in flowering and decrease in fruiting have been noted (Peadhananga *et.al* 2009). The changes in rainfall can cause devastating effect on crops leading to crop failure and ultimately food scarcity in the region (Regmi & Adhikari 2007). The overall negative impacts that can be accounted in agricultural sector are reduced crop production due to climate related risks such as drought, erratic rainfall etc; loss of fertile soil due to increased incidences of flood; landslide, soil erosion; introduction of new pest and diseases in crops leading in agricultural productivity and threatening food security.

Maize, wheat and potato are three major crops in the study area. Now a day, very few people cultivate wheat, buckwheat and barley in high altitudes but before farmers used to cultivate these crops. The plantation of rice in lower altitude is increasing. People started poly-cropping technique, planting millet in the field of maize, before they used to sow mustard in maize field. Farmers use different hybrid varieties of maize and improved varieties of potato as promoted by various institutions and government agencies. Local land races of potato have been totally replaced by the improved varieties.

Twenty years (1990-2009) precipitation and temperature data for growing seasons and annual productivity of rice, wheat and maize were correlated using Pearson's correlation. In Kavre and Jumla district growing season (harvesting period) of rice is September-October and growing season of wheat are March-April-May and May-June for respective district. Likewise growing season of maize are June –July and August-September-October in Kavre and Jumla district.

The impact is assessed for each crop based on the cropping periods of respective crop. Yield of rice, wheat, and maize is in growing trend, but fluctuates over the years. The correlation between rice yield and temperature, rice yield and rainfall in harvest period is statically insignificantly negative trend in Kavre district but positive trend in Jumla district. The positive correlation trend of all parameters in harvest period shows the response of climate change positively. It implies that the effect of climate change is more prominent which was clearly seen because of lack of irrigation facility, rough soil structure and arid climate. In Kavre, the effect might be minimized because of availability of irrigation facility, humid climate and assess to chemical fertilizer. Similarly, the correlation between wheat yield and rainfall in harvest period is statistically insignificantly positive. The correlation between wheat yield and minimum temperature in harvest period also shows positive trend whereas wheat yield and maximum temperature is insignificantly negative in Kavre district. The correlation between wheat yield and rainfall and maximum temperature is insignificantly positive but yield and minimum temperature is insignificantly negative in Jumla district. Similarly, the correlation between maize yield and temperature is positive but yield and rainfall is insignificantly negative in Kavre district. While that of correlation between maize yield and rainfall and temperature is insignificantly negative in Jumla district. This indicates that, the increase in maximum temperature in Kavre is not favorable for rice yield but it is favorable in Jumla district. But decrease in minimum temperature in Kavre district is favorable for wheat yield but it is not favorable in Jumla district. The increase in precipitation in the study areas is not favorable for maize yield.

The growth and development (physiological function) of any crop is governed by climatic parameters. The optimum range of air temperature for rice is 22-30^{0}C and effect of humidity is high on crop as shown in table below. The mean annual maximum temperature of Kavre and Jumla showed increasing trend that may account for better prospective of rice production. An increase in temperature upto 4^{o}C and rainfall upto 20% could increase yield from 0.09 to 7.5 percent (Nayaju *et al.* 2004).

Table 6.1: Optimum range of air temperature for successful growth of crops

Crops	Maximum air temperature ^{0}C	Minimum air temperature ^{0}C	Average air temperature ^{0}C	Effect of humidity
Rice	**48**	**12**	**22-30**	**High**
Maize	**45**	**10**	**25**	**Very high**
Wheat	**35**	**5**	**15-20**	**Medium**
Potato	**30**	**10**	**20**	**Very high**

(Source: Nayaju *et al.* 2004)

The study area is mountainous with rugged topography. Majority of people are living below poverty line. There was no much difference in the educational status of the household head in both districts. The main occupation of the household head is agriculture in the study area. The land which is considered to be the principal asset in the rural areas. Majority of this was under rain fed condition. So, there is need in diversification of crop in limited land for food self-sufficient.

CHAPTER VII

CONCLUSION AND RECOMMENDATION

7.1 Conclusion

Over the last 20 years the mean temperature increases by 0.02^0 c at Kavre district and 0.064^0 c at Jumla district. Climate change in agriculture is observed in the study area. It is revealed that there is increasing rate of temperature and erratic and uneven precipitation pattern in the area. This has significantly altered the cropping pattern including yields of the major cereal crops in the studied area.

The impact is assessed for each crop based on the cropping periods of respective crop. Yield of rice, wheat, and maize is in growing trend, but fluctuates over the years. The correlation between rice yield and temperature, rice yield and rainfall in harvest period is negative at Kavre district but positive at Jumla district.

Similarly, the correlation between wheat yield and rainfall and minimum temperature in harvest period is positive whereas wheat yield and maximum temperature is negative at Kavre district. The correlation between wheat yield and rainfall and maximum temperature is positive but yield and minimum temperature is negative at Jumla district.

Similarly, the correlation between maize yield and temperature is positive but yield and rainfall is negative at Kavre district. While that of correlation between maize yield and rainfall and temperature is negative at Jumla district. The result has shown that extreme fluctuation in weather has caused negative impact on production in Jumla than that of Kavre district.

7.2 Recommendation

- 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.
- Adaptation technologies together with awerness raising programs should be promoted in the areaand their knowledge andskills should be enhanced to combat with climate change.

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Annex:

Annex 1: Crop calendar of paddy Cultivated in Nepal

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Season
Mountain (Rainfed)												
		Mai-P	Mai-P	//////////////////////////			Mai-H	Mai-H	Mai-H			Summer
//////////////////////				Whe-H	Whe-H					Whe-P	Whe-P	Winter
Hills (Partial Irrigation Rainfed)												
				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

INDEX :

Mai-Maize

Whe-Wheat

Pad-Paddy

P-Plantation

TP-Transplantation

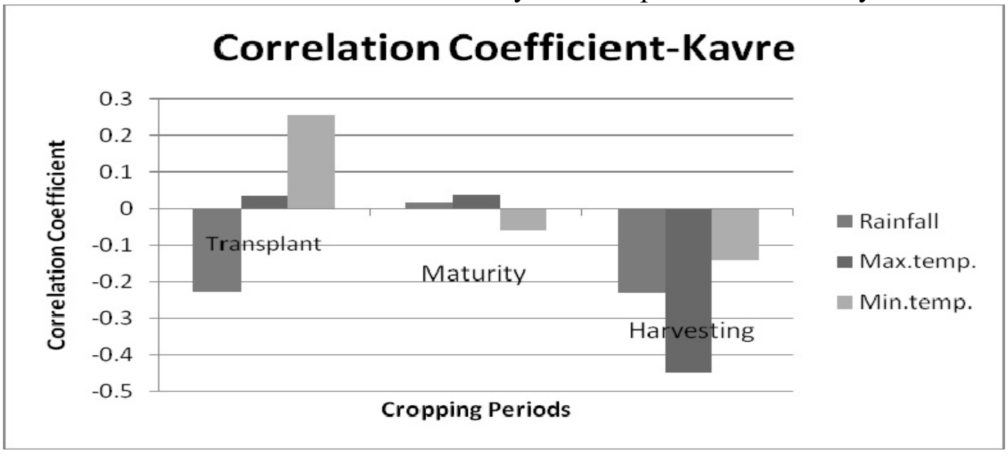
H-Harvesting

////-crop growing phage

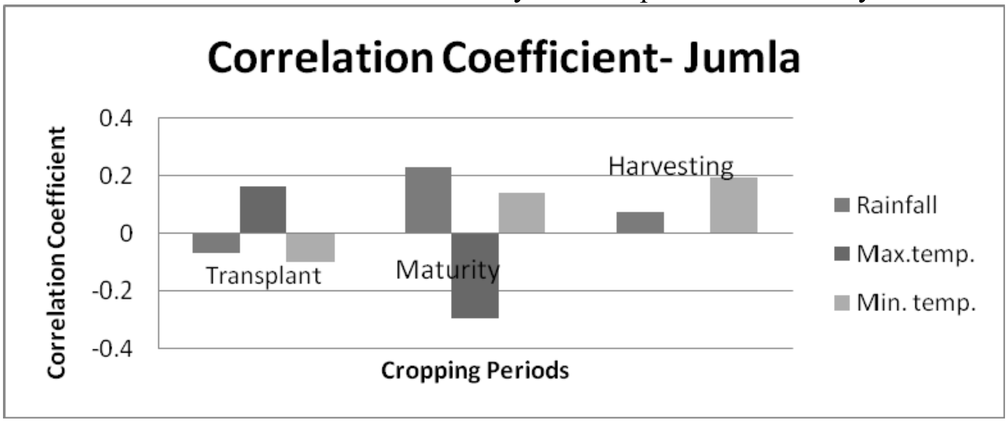
(Source: FAO and WFP (2007)

Annex 2

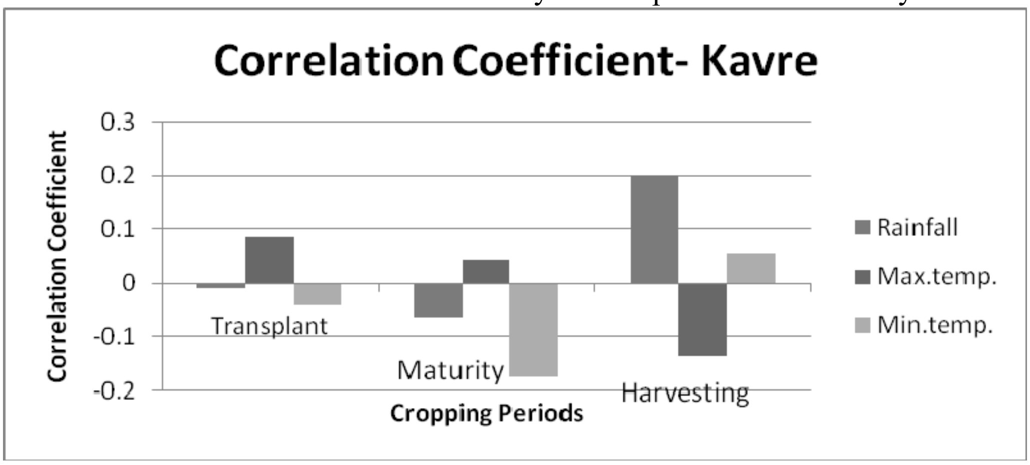
Annex 2.1: The correlation between rice yield -temperature and rice yield-rainfall (Kavre).



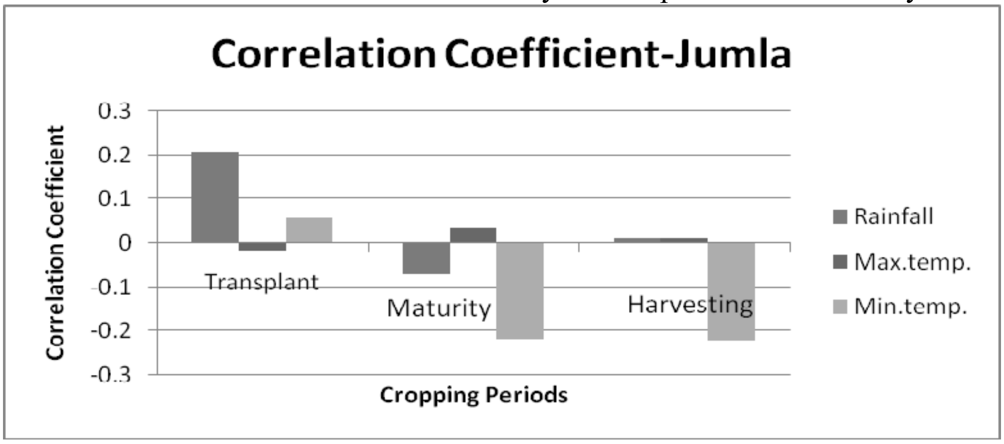
Annex 2.2: The correlation between rice yield -temperature and rice yield-rainfall (Jumla)



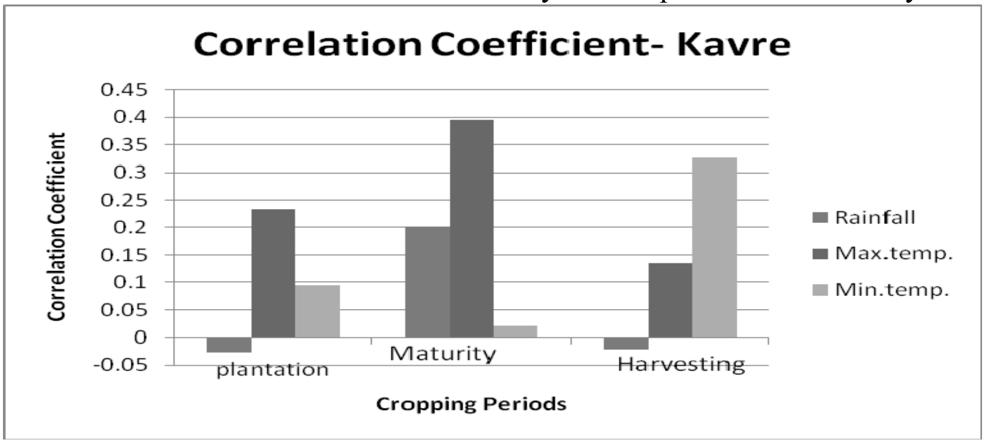
Annex2.3: The correlation between wheat yield-temperature and wheat yield-rainfall(Kavre)



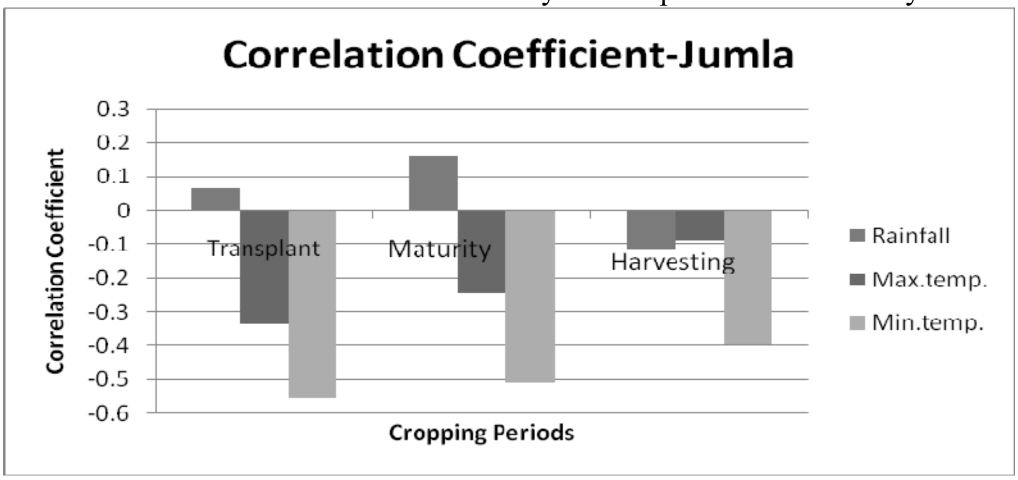
Annex 2.4: The correlation between wheat yield-temperature and wheat yield-rainfall (Jumla)



Annex 2.5: The correlation between maize yield-temperature and maize yield-rainfall (Kavre)



Annex 2.6: The correlation between maize yield-temperature and maize yield-rainfall (Jumla)



Annex 3: Productivity Data of Kavre and Jumla District between 1990-2009.

Year	Kavreplanchowk District			Jumla District		
	Rice Yield	Wheat Yield	Maize Yield	Rice Yield	Wheat Yield	Maize Yield
1990	3500	1400	1516	1318.5	1318.5	1397
1991	4225	1360	2034	1140	1140	1414
1992	2682	1195	1800	1122	1122	1431
1993	1991	1200	1631	1140	1140	1450
1994	2083	1395	1676	1200	1200	1459
1995	2000	1400	1670	1286	1286	1456
1996	2322	1493	1430	816	816	1298
1997	2500	1500	1558	1000	1000	1300
1998	2475	1700	1685	1103	1103	1025
1999	2618	1650	2000	772	772	1066
2000	2675	1815	2235	1248	1248	1500
2001	2678	1883	2000	994	994	1508
2002	3086	1883	1996	998	998	1501
2003	3079	2435	2287	998	998	1501
2004	3127	2609	2360	1000	1000	1492
2005	3229	2008	2302	1000	1000	1492
2006	3190	2008	2306	714	714	1481
2007	3175	1703	2306	1042	1042	1481
2008	3398	1703	1014	1042	1042	1481
2009	2829	1457	2318	1400	1400	1500

Source: MoAC