CROP PLANNING UNDER VARIABLE WEATHER CONDITION IN INDONESIA

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

IRRIGATION WATER MANAGEMENT

By

HENDRIKUS KESU

DEPARTMENT OF WATER RESOURCES DEVELOPMENT AND MANAGEMENT
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE -247 667 (INDIA)

JUNE, 2011

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the dissertation entitled **"Crop Planning Under Variable Weather Condition In Indonesia "** in partial fulfilment of the requirement for the award of the **Master of Technology (M.Tech) in Irrigation Water Management (IWM)** in the Department of Water Resources Development and Management (WRD&M), Indian Institute of Technology Roorkee, is an authentic record of my own work carried out during a period from July 2010 to June 2011, under guidance of **Prof.S.K. Tripathi**, Professor, Department of Water Resources Development and Management, Indian Institute of Technology Roorkee, Roorkee, Uttarakand, India.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Hendrikus Kesu
(Enrolment No. 09547003)
Candidate

Date : June 2011
Place : Roorkee

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date : June 2011
Place : Roorkee

Prof. S.K. Tripathi
Professor,
Department of Water Resources
Development and Management
IIT Roorkee
Roorkee - 247667

ACKNOWLEDGEMENTS

I wish to record my sincere thanks with a profound sense of gratitude to DR. S.K Tripathi, Professor at WRD&M, Indian Institute of Technology (IIT) Roorkee for valuable guidance and encouragement in preparation of this Dissertation.

Thanks are also due to DR. Nayan Sharma Professor and Head of Department WRD&M for his interest & encouragement. Special thanks also due to my colleagues for their kind support and help.

I have no word to adequately express my most sincere and heart-felt gratitude to my parents, parents in law, my wife and my daughter, my brother and sister, for their love and inspiration which are the cornerstone of my all achievements.

Hendrikus Kesu
Place : Roorkee
Date : June , 2011

ABSTRACT

The problem that now faced by farmers in Nusa Tenggara Timur Province in generally and especial in my region, Ngada District, is the lack of water for irrigation. The most of the water supply comes from rainfall. Rainfall occurred only four months a year from November until February. Average rainfall about 2165 mm/year.

Effective agricultural business is depended on the natural resource such as climate and soil, which is used integrally manner. Studying the behavior of the climate, especially rainfall has increased at least efficient water use, reduce the risk of natural disasters, floods and drought on food crops. Planting crop depending upon the use of rainfall data although it is simple.

The most prudent action is to adjust the agricultural patterns with local climate patterns. This effort is carried out with "understanding the local climate" to minimize the risk of failure caused by climatic irregularities in the production of food crops can be done through the distribution of climatic regions with the determination of applications for the cropping pattern of plant growth.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

I.1 GENERAL

Crop Planning plays an important role in agricultural. In the crop planning, the farmers should make decision during the crop planning periods. The decisions that the farmers have to make include;

- Which crops to grow;
- What amount of the water and land to allocate to each crops;
- When to grow, when to harvest, when to sell.

However, it is difficult to make the right decisions. This is because the farmers have to take into account uncertain factors such as weather, demand, and supply as well as resources limitations. These factors results in uncertainties in yield and price, which significantly affect the return to producers.

According A.K Singh & N.P Singh in Agricultural Terminology, Crop Planning is the selection of particular variety of crop based on the following conditions ; climate or weather, soil type, minimum support prices, marketing facilities, local requirements. Based on this terminology, the kinds of conditions above we can say as the constraints to developed a decision crop planning model.

A decision planning model is developed to establish a solution for this problem by taking into account the resource limitations as its major constraints. In order to make decisions under uncertainty, forecasting of uncertain factors is crucial step since it can estimate the probable outcomes of the final output. This study will be focus only the impact natural resources such as climate or weather and soil type as of the Ngada district that is my study area.

Weather is the condition of the atmosphere in terms of heat, humidity, pressure and wind at a given time (from a few hours to about two weeks) and place or small area. These four are the basic elements of weather. Climate is a much broader term than weather. Climate is an expression of the synthesis of day-to-day values of meteorological elements that affect the locality as mean (integration or totality of weather) through large space and time (usually a month or more period). It is defined as the collective probable state of atmosphere within a specified interval of time and space at that locality area.

Knowledge of the weather pattern of an area is helpful in interpreting the reason for poor or successful crop harvests. All this is due to fact that plant has its own definite optimal requirements of light, temperatures (of soil and air), and atmospheric and soil moisture. Without these weather elements at desired limits a plant cannot proceed at an economically desirable rate to flowering and seed formation.

Agro-climatology is broadly " the study of aspects of climate (micro and macro) that are relevant to agricultural problems involving soil, plant and animal." It is application of meteorological knowledge to the problems of agriculture. Since plant and plant climate are partly interdependent, the term agro-climatology or agro-climate denotes the condition and effects of varying air and soil temperatures, varying amounts of sunshine and soil moisture under both macro and micro influences on crop growth and agricultural efficiency broadly.

A study agro-climatic classification for this area is needed, because by the classification system, the suitability of different crops to the various areas in large measure is controlled by climate interacting with soil. Thus it is important to delineate homogenous soil climate zones, not only to interpret cropping pattern as they exist, but also to locate inappropriate land use if any, and to project new cropping pattern in consideration of ecological factors.

Each crops has its own set of optimum and tolerable environmental condition under which it can grow efficiently. This means any crop will not be profitable unless adapted to the conditions of the region in which it is produced. Stability of yield over different seasons decides the success of crop variety for long standing cultivation. Though the cultivation period has been determined through accumulated long experience and also from cultivation tests, the various growth stages of crops are subjected to prevailing weather conditions or restrictions, mere broad climatic generalizations being of much less value) shaw 1955. The relationship between growth stage and weather parameters, particularly temperature and moisture, has, therefore, to be classified to adjust management practices and production of new variety.

I.2 BACKGROUND OF STUDY

The area of the Ngada district has a total 162,041 ha, only about 2.63% which can be used as irrigated land, which is usually planted with rice, which is the staple food of Indonesian society today and approximately 8.94 % is rainfed paddy fields, and upland is 4.78 %. So we can calculate the area of land was highly dependent on rainfall is 13.72 %.

Agricultural business in the District Ngada using the traditional system, in which the area of land owned by farmers about 0.5 ha to 1 ha. In irrigated areas usually planted rice, and upland areas usually planted with corn or other types of crops, such as peanuts, soybeans, red beans, cassava, and etc.

Most of the irrigation schemes take water directly from the stream (without reservoir). So, the reliability of the scheme is very low because the scheme very depend of the season, especially rainy season. This condition has an impact on the low production growth for the paddy in the lowland.

Production of food crops in the district Ngada still low, it is influenced by several factors, among others:

- The low rainfall, which is around 2165 mm / year.
- High climate variability coupled with inadequate water distribution systems in this region makes water security is uncertain, which leads to frequent crop failures.
- Traditional practices are still used and lack of information such as agricultural technology, market prices, weather information and etc.

I.3 OBJECTIVES OF STUDY

The general objectives of study is determining the optimal cropping planning under variable weather condition and minimizing the risk of failure caused by climatic irregularities or uncertainty in the production of food crops

The specific objective of the study are :

1. Analysis of agro climatic characteristic of the Ngada district area and selecting variety of crops.
2. Optimization cropping pattern under area allocation according to water available in lowland area.

I.4 METHODOLOGY

The methodology for this study is as follows :

1. Analyzing weather data for data from 1994 to 2010, to determine the value of parameters that will be used in assessment Potential Evapotranspiration.
2. Analyzing Agro climatic Characteristic and Water Requirement of the crops. By this analyzing , the result are expected, first we can determine the type of crops that can grow well in the region, the secondly we can design a suitable cropping pattern by taking into account the water requirement of the type of crops, type of soil and land to be irrigated, climatic condition, value of produce and socio – economic aspect.
3. Finally, for considering the economical factor and management, we should optimizing the programming models concerned with the efficient allocation of limited resources (area allocation and water availability) to know activities with the objective of meeting a desirable goal (such as maximizing profit and minimizing cost). For this purpose we use linear programming.

CHAPTER II

GENERAL DISCRIPTION OF THE STUDY AREA

2.1 POPULATION

Ngada district consists of 9 subdistrict, 78 villages and 16 urban villages. With an area of 1.620,92 km2 and is inhabited by 138.050,00 inhabitants in the year 2008. The most widely subdistrict is Riung 327,94 km2, and the smallest areas is the subdistrict Jerebuu area of 82,26 km2.

The population density Ngada district section is equal to 85 per km2 . The highest density is the sub district Bajawa is 139 per km2 and the lowest density is the sub district Riung Barat is 24.94 per km2.

Table 2.1 Population, Area and Population Density By District 2008

No	Sub District	Population	Area (Km2)	Population Density	% of Total Population
1	Aimere	14,864.00	152.50	97.47	10.77
2	Jerebuu	7,992.00	82.26	97.16	5.79
3	Bajawa	32,930.00	133.30	247.04	23.85
4	Golewa	34,827.00	250.72	138.91	25.23
5	Bajawa Utara	8,309.00	167.38	49.64	6.02
6	Soa	11,947.00	91.14	131.08	8.65
7	Riung	14,388.00	327.94	43.87	10.42
8	Riung Barat	7,795.00	312.49	24.94	5.65
9	Wolomeze	4,998.00	103.19	48.43	3.62
	Total	**138,050.00**	**1,620.92**	**85.17**	**100.00**

Source : BPS, Ngada in Figures 2009(District Statistical Officer, Ngada)

2.2 GEOGRAPHIC AREA

Ngada district lies between 8^0- 9^0 South Latitude and $120^0 45'$- $121^0 50'$ East Longitude. The Northern part is bordered by the Flores Sea, bordering the Southern part of the Savu Sea, bordering the Estern and Western Nagekeo district bordering the Manggarai Timur district.

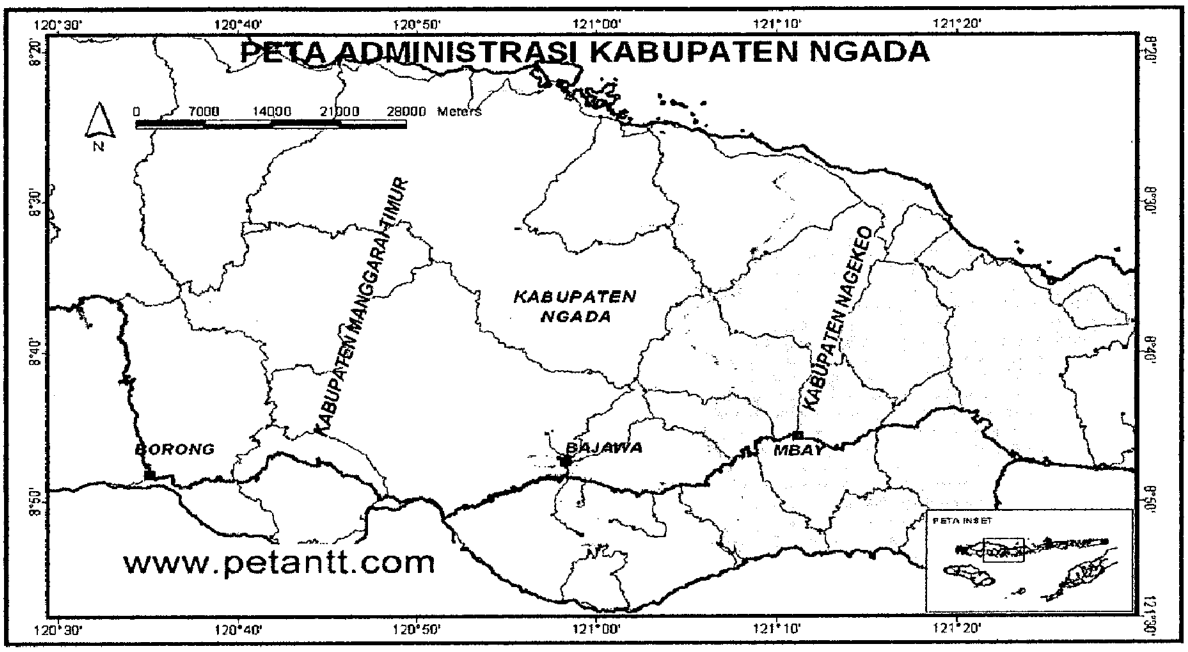


Fig.2.1 Map of Ngada District

Ngada District classified as tropical and temperate regions, stretching most of the forest and savanna. We know that the District Ngada including tropical areas so that the temperature change was not influenced by the replacement of the season, but is determined by the difference in elevation from sea level.

That condition is one factor that determines the livelihoods of the population and types of crops / livestock are cultivated / maintained. In Table 2.2 shows that the vast territory which is reaches 0-500 m from sea level is 47.14 percent and those 501-1000 m from sea level is 37.08 percent and 1000 m to the top from sea level is 15.78 percent.

Table 2.2 Topography in Ngada By Sub District And Height

No	Sub District	Height (m) from Sea Level					Area (Km2)
		0 -250	251 - 500	501- 750	751 - 1000	> 1000	
1	Aimere	152.50					152.50
2	Jerebuu		35.38	35.38	11.00		82.26
3	Bajawa					133.30	133.30
4	Golewa	47.99		43.75	36.63	122.35	250.72
5	Bajawa Utara		103.24	31.50	32.63		167.37
6	Soa		49.89	41.25			91.14
7	Riung	218.88		30.00	79.06		327.94
8	Riung Barat	22.50	83.12		206.87		312.49
9	Wolomeze		50.38	10.24	42.57		103.19
	Total	441.87	322.01	192.12	408.76	255.65	1,620.41

Source : BPS, Ngada in Figures 2009(District Statistical Officer, Ngada)

2.3 LAND USE PATTERN

Regarding land use pattern it is seen that more than 16.35 % of the district area is under cultivation. The cultivation area of divided into two kind of land ; Wetland dan Dryland. Wetland area divided into two kind of lands ; Irrigated and Rain fed area, All detailed of land use area are shown in Table 2.3

The slope of the land between 0-2% with an area of 20,100 ha (6.62%). 2-6% with an area of 13,020 ha (4.29%), 8 - 15% area of 34,910 ha (11.49%), 15 - 25% area of 81,962% (26.98%), 25 - 40% area of 115,516 ha (38 , 03%) and >40% area of 38,250 ha (1.59%).

2.4 ECONOMIC CONDITION

The economic conditions in the year 2008 according to Ngada in Figures 2009 are as follows; The most of residents work as farmers is 71.40 % from the total of population, with income per capita Rp. 2.504.406,- in the year 2007 and increased to Rp. 2.588.649,- in the year 2008 or equivalent with $ 287,63 USD

Table 2.3 Land Use Pattern 2008

No	Types of Land	Area (Ha)		% of Total Area
1	Forest		91,768.27	56.63
2	Barren and Uncultivable Land		18,494.00	11.41
3	Land put to non-agricultural Use		4,100.00	2.53
4	Low land (Wetland)		6,515.00	4.02
	Irrigated Area	*4,259.00*		
	Rainfed land	*2,256.00*		
7	Upland (Dryland)		19,980.04	12.33
8	Current Fallows		5,261.00	3.25
9	Permanent Grazing		15,922.69	9.83
	Total		162,041.00	100.00

Source : BPS, Ngada in Figures 2009(District Statistical Officer, Ngada)

Tabel 2.4 Occupational Distribution of Population 15 year of Age and Over in the year 2008

No	**Types of Job**	Population	% of Total Area
1	Profesional , Technical Workers	2,470.00	3.88
2	Admistrative and Managerial Workes	557.00	0.87
3	Clerical Workes	1,691.00	2.65
4	Sales Workers	4,121.00	6.47
5	Service workers	*2,009.00*	3.15
6	Farmers, Forestry,Fishery	*45,514.00*	71.40
7	Production,Equipment Operators,Related Workers	*6,428.00*	10.08
	Transportation		-
8	Others	951.00	1.49
	Total	63,741.00	100.00

Source : BPS, Ngada in Figures 2009(District Statistical Officer, Ngada

CHAPTER III

REVIEW OF LITERATURES

2.1 REFERENCE CROP EVAPOTRANSPIRATION

The rate of evaporation from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of watering is defined as reference crop evapotranspiration and is denoted as ETo. The concept of the atmosphere independently of crop type, crop development and management practices. Factors affecting ETo are climatic parameters. Consequently, ETo is climatic parameter and can be computed from weather data.

The concept of the reference evapotranspiration was introduced to study the evaporative demand of the atmosphere independently of crop type, crop development and management practices. As water is abundantly available at the reference evapotranspiring surface, soil factors do not affect ET. Relating ET to a specific surface provides a reference to which ET from other surfaces can be related. It obviates the need to define a separate ET level for each crop and stage of growth. ETo values measured or calculated at different locations or in different seasons are comparable as they refer to the ET from the same reference surface.

ETo expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. The FAO Penman-Monteith method is recommended as the sole method for determining ETo. The method has been selected because it closely approximates grass ETo at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters. Moreover, procedures have been developed for estimating missing climatic parameters.

Chiew et al. (1994) estimated ETo using the Penman-Monteith and FAO methods and class-A pan data for 16 Australian locations with a wide range of climate conditions and reported that the FAO-24 Penman ETo, estimates are generally 20% to 40% higher than the Penman-Monteith estimates. There is reasonably good agreement between the Penman-Monteith and FAO-24 radiation methods although, on average,the radiation method ETo,estimates are 10-20% higher than Penman-Monteith estimates. The FAO-24 Blaney-Criddle method, which uses only temperature data, gives similar monthly ETo, estimates as Penman-Monteith, and is therefore adequate for applications where only long-trem ET, estimates are required. The comparisons also show that there is a satisfactory correlation between class-A pan data and Penman-Monteith ETo.

The FAO Penman-Monteith method is recommended as the sole method for determining ETo. The method has been selected because it closely approximates grass ETo at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters. Moreover, procedures have been developed for estimating missing climatic parameters.

Table 3.1 show the climate data requirements for the Penman-Monteith and FAO-24 methods,

Typical ranges for ETo values for different agroclimatic regions are given in Table 3.2. These values are intended to familiarize inexperienced users with typical ranges, and are not intended for direct application.

Table 3.1 Climate data requirements for the Penman-Monteith and FAO-24 methods					
Data Requirement	Penman-Monteith	FAO-24 Penman	FAO-24 corrected Penman	FAO-24 radiation	FAO-24 Blaney-Criddle
Average Daily Temperature	Y	Y	Y	Y	Y
Maximun Temperature	Y	Y	Y		
Minimun Temperature	Y	Y	Y		
Average Relative Humidity	Y	Y	Y	y	
Maximum relative humidity	Y	Y	Y		
Minimum relative humidity	Y	Y	Y		y
Total wind speed	Y	Y	Y		
Ratio of day/night wind			y		
Daytime wind			y	y	y
Sunshine hours	Y	Y	Y	Y	y

Source : Chiew et al. (1995) Y indicates that continuous recorded data are required. y indicates that only estimated data are required. In general, estimates of long-term conditions may be used.

Tabel 3.2 Average ETo for different agroclimatic regions in mm/day			
Regions	Mean daily temperature (°C)		
	Cool ~ 10°C	Moderate 20°C	Warm > 30°C
Tropics and subtropics			
- humid and sub-humid	2 - 3	3 - 5	5 - 7
- arid and semi-arid	2 - 4	4 - 6	6 - 8
Temperate region			
- humid and sub-humid	1 - 2	2 - 4	4 - 7
- arid and semi-arid	1 - 3	4 - 7	6 - 9

Source : FAO Irrigation and Drainage Paper No. 56

2.2 METHODS OF ETo CALCULATION

Reliable estimates of reference crop evapotransporation (ETo) is essential for efficient irrigation management and improved water use efficiency. Four different methods viz. (i) the Blaney Criddle (ii) the Radiation Method (iii) the Modified Penman and (iv) the Penman Montieth for the calculation of ETo have been used in this study and the obtained results were compared with the measured USWB pan evaporation data to find out the most suitable method for this region. In the first three methods ETo was calculated as per the procedure given in FAO Irrigation and Drainage paper no.27 (Doorenbos and Pruitt, 1977) and for the Penman Monteith method as given by FAO Irrigation and Drainage paper no.56.

2.2.1 Blaney Criddle Method

$$ETo = c. [p.(0.46*Tmean+8)] \qquad (3.1)$$

Where,

ETo = reference crop evapotranpiration in mm/day;

P= mean daily % of total annual daytime for a given month and latitude and;

c= adjustment factor which depends on minimum relative humadity,sunshine hours dan day time.

2.2.2 Radiation Method

$$ETo = [c. (W * Rs)] \qquad (3.2)$$

Where,

ETo = reference crop evapotranpiration in mm/day;

W= weighing factor which depends on temperature and altitude;

Rs= total solar radiation in mm/day;

c= adjustment factor which depends on humidity and day time wind.

2.2.3 Modified Pennman Method

$$ETo = c\,[\,W.Rn + (1-W).f(u).(ed-ea)\,] \quad (3.3)$$

Where,

ETo= reference crop evapotranspiration in mm/day;

W= weighing factor which depends on temperature and altitude;

Rn= net total solar radiation in mm/day;

f(u)= is wind related function, f(u)= 0.27(1+u2/100);

u^2= wind velocity at 2 m height (ms^{-1});

(ed-ea)= difference between the saturation vapour pressure at mean air temp and the mean actual vapour pressure of the air,both in mbar.

2.2.4 Penman Monteith Method

$$ETo = \frac{0.408\Delta\,(Rn-G) + \gamma\,\frac{900}{T+273}\,u_2\,(es - ea)}{\Delta+\gamma(1+0.34u_2)} \quad (3.4)$$

Where,

ETo= reference crop evapotranspiration [mm d^{-1}];

Rn= net radiation at the crop surface [MJ^{-2} day^{-1}];

G= soil heat flux [MJ^{-2} day^{-1}];

T= mean daily air temperature at 2 m height [^0C];

u_2= wind speed at 2 m height [ms^{-1}];

es= saturation vapour pressure [kPa];

determined for a field, for an outlet command area or for an irrigation project, depending upon the net need and adding the appropriate losses at various stages of the crop.

2.4 AGROCLIMATIC CLASSIFICATION

Suitability of any region, before planning for agricultural pursuits, has to be properly understood, Systematical appraisal of climate conditions for estimating potential of crop coupled with other local environmental factors is essential for appropriate practices in agricultural production. Local soil and climatic conditions (rather rainfall, soil type, temperature and weather phenomena) have much to do with this variables response and form the factors in deciding the quantum of yield. It is thus essential to properly delineate the whole area into various fairly precise zones, called agroclimatic zones, and study response for evaluation of crops and their varieties in each for finalizing the best possible crop, its variety and practices to be followed for optimum yields.

There are many ways to classify climates of any region. More than two dozen climate classifications have been reported. These may be descriptive, genetic, or rational. But none fulfils significant application to potential production. These aspect had been discussed by Burgos (1958). Climate classification is only a method of arranging various data of climatic parameters, singly or grouped into set so as to simplify them to identity analogies and demarcate a country or region into homogenous zones as much as possible, proper interpretation and convenience of mapping where boundaries between zones are not rigid but as transition belts of varying widths (Critchfield 1968). But the classification should fulfill the specific agricultural needs as stressed by Burgos (1958).

determined for a field, for an outlet command area or for an irrigation project, depending upon the net need and adding the appropriate losses at various stages of the crop.

2.4 AGROCLIMATIC CLASSIFICATION

Suitability of any region, before planning for agricultural pursuits, has to be properly understood, Systematical appraisal of climate conditions for estimating potential of crop coupled with other local environmental factors is essential for appropriate practices in agricultural production. Local soil and climatic conditions (rather rainfall, soil type, temperature and weather phenomena) have much to do with this variables response and form the factors in deciding the quantum of yield. It is thus essential to properly delineate the whole area into various fairly precise zones, called agroclimatic zones, and study response for evaluation of crops and their varieties in each for finalizing the best possible crop, its variety and practices to be followed for optimum yields.

There are many ways to classify climates of any region. More than two dozen climate classifications have been reported. These may be descriptive, genetic, or rational. But none fulfils significant application to potential production. These aspect had been discussed by Burgos (1958). Climate classification is only a method of arranging various data of climatic parameters, singly or grouped into set so as to simplify them to identity analogies and demarcate a country or region into homogenous zones as much as possible, proper interpretation and convenience of mapping where boundaries between zones are not rigid but as transition belts of varying widths (Critchfield 1968). But the classification should fulfill the specific agricultural needs as stressed by Burgos (1958).

Rs= total solar radiation in mm/day;

c= adjustment factor which depends on humidity and day time wind.

2.2.3 Modified Pennman Method

$$ETo = c\,[\,W.Rn + (1-W).f(u).(ed-ea)\,] \tag{3.3}$$

Where,

ETo= reference crop evapotranspiration in mm/day;

W= weighing factor which depends on temperature and altitude;

Rn= net total solar radiation in mm/day;

f(u)= is wind related function, f(u)= 0.27(1+u2/100);

u^2= wind velocity at 2 m height (ms^{-1});

(ed-ea)= difference between the saturation vapour pressure at mean air temp and the mean actual vapour pressure of the air,both in mbar.

2.2.4 Penman Monteith Method

$$ETo = \frac{0.408\Delta\,(Rn-G) + \gamma\,\frac{900}{T+273}\,u_2\,(es-ea)}{\Delta+\gamma(1+0.34u_2)} \tag{3.4}$$

Where,

ETo= reference crop evapotranspiration [$mm\ d^{-1}$];

Rn= net radiation at the crop surface [$MJ^{-2}\cdot day^{-1}$];

G= soil heat flux [$MJ^{-2}\cdot day^{-1}$];

T= mean daily air temperature at 2 m height [^0C];

u_2= wind speed at 2 m height [ms^{-1}];

es= saturation vapour pressure [kPa];

ea= the actual vapour pressure [kPa];

(es – ea)= saturation vapour pressure deficit [kPa];

Δ= slope vapour pressure curve [kPa^{0}C];

γ = psychometric constant [kPa^{0}C];

and 900 is the conversion factor for daily – basis calculation.

2.3 CROP WATER REQUIREMENT

Crop water requirement is defined as the quantity of water utilized by the plant during its growing period; this water may be supplied either entirely by rainfall, entirely by irrigation or by combination of both. The estimation of water requirement of crop is essential for crop planning on farm and also is the basis on which an irrigation project designed. Water requirement includes the losses due to evapotranspiration (ET) or consumptive use (Cu) plus the losses during the application of water (unavoidable losses) and the quantity of water required for special operations like land preparation, pre-sowing irrigation and transplanting. It may thus we expressed as follows:

WR = ET or CU + application losses + special needs

2.3.1 Net Irrigation Requirement

The net irrigation requirement is the depth of irrigation water, exclusive of precipitation, carry over soil moisture or ground water contribution or other gains soil moisture that is required consumptively for crop production. It is the amount of water required to bring the soil moisture level in the root zone to field capacity.

2.3.2 Gross Irrigation Requirement

The total amount of water applied through irrigation is termed as " gross irrigation requirement". In the words, it is net irrigation requirement plus losses in water application and other losses. The gross irrigation requirement can be

Agricultural classification the objective is for choice of efficient crops (many tropical and subtropical crops are highly sensitive to moisture and temperature) and locations for their optimum efficiency so that best cropping patterns can be followed for maximum possible economic production per nit area and time under suitable agronomic practices and crop varieties.

Classification system varies according to the purpose for which classification is made. In regard to agricultural needs, the suitability of different crops to the various areas in large measure is controlled by climate interacting with soil climatic zones, not only to interpret cropping pattern as they exist, but also to locate inappropriate land use if any, and to project new cropping patterns in consideration of ecological factors.

2.4.1 Koppen's Classification

Koppen (1936) divided the world climate based on precipitation and temperature, into five principal groups;

GROUP A: Tropical/megathermal climates

- **Tropical rainforest climate** (*Af*): All twelve months have average precipitation of at least 60 mm (2.4 in). These climates usually occur within 5–10° latitude of the equator. In some eastern-coast areas, they may extend to as much as 25° away from the equator. This climate is dominated by the Doldrums Low Pressure System all year round, and therefore has no natural seasons.
- **Tropical monsoon climate** (*Am*): This type of climate, most common in southern Asia and West Africa, results from the monsoon winds which change direction according to the seasons. This climate has a driest month (which nearly always occurs at or soon after the "winter" solstice for that side of the

equator) with rainfall less than 60 mm, but more than (100 − [total annual precipitation {mm}/25]).

- **Tropical wet and dry or savanna climate** (*Aw*): These climates have a pronounced dry season, with the driest month having precipitation less than 60 mm and also less than (100 − [total annual precipitation {mm}/25]).

GROUP B: Dry (arid and semiarid) climates

These climates are characterized by the fact that precipitation is less than potential evapotranspiration.[8] The threshold is determined as follows:

- To find the precipitation threshold (in millimeters), multiply the average annual temperature in °C by 20, then add 280 if 70% or more of the total precipitation is in the high-sun half of the year (April through September in the Northern Hemisphere, or October through March in the Southern), or 140 if 30%–70% of the total precipitation is received during the applicable period, or 0 if less than 30% of the total precipitation is so received.
- If the annual precipitation is less than half the threshold for Group B, it is classified as *BW* (desert climate); if it is less than the threshold but more than half the threshold, it is classified as *BS* (steppe climate). If it's more than the threshold, the area does not have a Group B climate.
- A third letter can be included to indicate temperature. Originally, *h* signified low latitude climate (average annual temperature above 18 °C) while *k* signified middle latitude climate (average annual temperature below 18 °C/64 °F), but the more common practice today (especially in the United States) is to use *h* to mean that the coldest month has an average temperature

that is above 0 °C (32 °F), with *k* denoting that at least one month averages below 0 °C.

- Desert areas, situated along the west coasts of continents at tropical or near-tropical locations, are characterized by cooler temperatures than encountered elsewhere at comparable latitudes (due to the nearby presence of cold ocean currents) and frequent fog and low clouds, despite the fact that these places rank among the driest on earth in terms of actual precipitation received. This climate is sometimes labelled *BWn* and examples can be found at Lima, Peru and Walvis Bay, Namibia. The *BSn* category can be found in foggy coastal steppes.
- On occasion, a fourth letter is added to indicate if either the winter or summer is "wetter" than the other half of the year. To qualify, the wettest month must have at least 60 mm (2.4 in) of average precipitation if all twelve months are above 18 °C (64 °F), or 30 mm (1.2 in) if not; plus at least 70% of the total precipitation must be in the same half of the year as the wettest month — but the letter used indicates when the *dry* season occurs, not the "wet" one. This would result in Khartoum, Sudan being reckoned as *BWhw*, Niamey, Niger as *BShw*, El Arish, Egypt as *BWhs*, Asbi'ah, Libya as *BShs*, Ömnögovi Province, Mongolia as *BWkw*, and Xining, China as *BSkw* (*BWks* and *BSks* do not exist if 0 °C in the coldest month is recognized as the *h/k* boundary). If the standards for neither *w* nor *s* are met, no fourth letter is added.

GROUP C: Temperate/mesothermal climates

These climates have an average temperature above 10 °C (50 °F) in their warmest months, and a coldest month average between −3 °C (26.6 °F) and 18 °C (64 °F). Some climatologists, particularly in the United States, however, prefer to observe

0 °C (32 °F) rather than −3 °C (26.6 °F) in the coldest month as the boundary between this group and Group D; this is done to prevent certain headland locations in or near New England — principally Cape Cod — and such nearby islands as Nantucket and Martha's Vineyard, from fitting into the Maritime Temperate category noted below; this category is alternately known as the *Marine West Coast* climate, and eliminating the aforementioned locations indeed confines it exclusively to places found along the western margins of the continents, at least in the Northern Hemisphere. This also moves some mid-latitude areas – such as parts of the Ohio Valleyand some areas in the Mid-Atlantic States, plus parts of east-central Asia – from humid subtropical to humid continental.

The second letter indicates the precipitation pattern — *w* indicates dry winters (driest winter month average precipitation less than one-tenth wettest summer month average precipitation; one variation also requires that the driest winter month have less than 30 mm average precipitation), *s* indicates dry summers (driest summer month less than 30 mm average precipitation and less than one-third wettest winter month precipitation) and *f* means significant precipitation in all seasons (neither above mentioned set of conditions fulfilled).

The third letter indicates the degree of summer heat — *a* indicates warmest month average temperature above 22 °C (72 °F) with at least 4 months averaging above 10 °C (50 °F), *b*indicates warmest month averaging below 22 °C, but with at least 4 months averaging above 10 °C, while *c* means 3 or fewer months with mean temperatures above 10 °C.

- The order of these two letters is sometimes reversed, especially by climatologists in the United States.

Group C climates are subdivided as follows:

- **Dry-summer subtropical** or **Mediterranean climates** (*Csa*, *Csb*): These climates usually occur on the western sides of continents between the latitudes of 30° and 45°. These climates are in the polar front region in winter, and thus have moderate temperatures and changeable, rainy weather. Summers are hot and dry, due to the domination of the subtropical high pressure systems, except in the immediate coastal areas, where summers are milder due to the nearby presence of cold ocean currents that may bring fog but prevent rain.
- Under the Köppen-Geiger classification, dry-summer subtropical (*Csb*) extends to additional areas not typically associated with a typical Mediterranean climate, such as much of the Pacific Northwest, much of southern Chile, parts of west-central Argentina, and northern Spain and Portugal.[11] Many of these areas would be Oceanic (*Cfb*), except dry-summer patterns meet Köppen's *Cs* minimum thresholds. Additional highland areas in the subtropics also meet *Cs* requirements, although they too are not normally associated with Mediterranean climates.
- **Humid subtropical climates** (*Cfa*, *Cwa*): These climates usually occur in the interiors of continents, or on their east coasts, mainly in the high 20s and 30s latitude (although they may occur as far north as 46°N in Europe). Unlike the Mediterranean climates, the summers are humid due to unstable tropical air masses, or onshore Trade Winds. In eastern Asia, winters can be dry (and colder than other places at a corresponding latitude) because of the Siberian high pressure system, and summers very wet due to the Southwest Asian monsoonal influence.

- **Maritime Temperate climates or Oceanic climates** (*Cfb*, *Cwb*, *Cfc*): *Cfb* climates usually occur on the western sides of continents between the latitudes of 45° and 55°; they are typically situated immediately poleward of the Mediterranean climates, although in Australia and extreme southern Africa this climate is found immediately pole ward of the humid subtropical climate, and at a somewhat lower latitude. In western Europe, this climate occurs in coastal areas up to 63°N latitude. These climates are dominated all year round by the polar front, leading to changeable, often overcast weather. Summers are cool due to cloud cover, but winters are milder than other climates in similar latitudes.
- *Cfb* climates are also encountered at high elevations in certain subtropical and tropical areas, where the climate would be that of a subtropical/tropical rain forest if not for the altitude. These climates are called "Highlands"
- The **temperate climate with dry winters** (Cwb) is a type of climate characteristic of the highlands inside the tropics of Mexico, Peru, Bolivia, Madagascar, Zambia, Zimbabwe and South Africa but it is also found in central Argentina, outside the tropics. Winters are noticeable and dry and summers very rainy. In the tropics the rainy season is provoked by the tropical air masses and the dry winters by subtropical high pressure. Temperate temperatures are the consequence of altitude which become cooler year-round.
- **Maritime Subarctic climates** or **Subpolar Oceanic climates** (*Cfc*): These climates occur pole ward of the Maritime Temperate climates, and are confined either to narrow coastal strips on the western pole ward margins of

the continents, or, especially in the Northern Hemisphere, to islands off such coasts.

GROUP D: Continental / Micro thermal Climate

These climates have an average temperature above 10 °C (50 °F) in their warmest months, and a coldest month average below −3 °C (or 0 °C in some versions, as noted previously). These usually occur in the interiors of continents, or on their east coasts, north of 40° North latitude. In the Southern Hemisphere, Group D climates are extremely rare due to the smaller land masses in the middle latitudes and the almost complete absence of land between 40°-60° South latitude, existing only in some highland locations.

- The second and third letters are used as for Group C climates, while a third letter of *d* indicates 3 or fewer months with mean temperatures above 10 °C *and* a coldest month temperature below −38 °C (−36 °F).

Group D climates are subdivided as follows:

- **Hot Summer Continental climates** (*Dfa*, *Dwa*, *Dsa*): *Dfa* climates usually occur in the high 30s and low 40s latitudes, with a qualifying average temperature in the warmest month of >22°C. In eastern Asia *Dwa* climates extend further south due to the influence of the Siberian high pressure system which also causes winters here to be dry, and summers can be very wet because of monsoon circulation.
- **Warn Summer Continental or Hemiboreal climates** (*Dfb*, *Dwb*, *Dsb*): *Dfb* and *Dwb* climates are immediately north of Hot Summer Continental climates, generally in the high 40s and low 50s in latitude in North America and Asia, and also in central and eastern Europe and Russia, between the

Maritime Temperate and Continental Subarctic climates, where it extends up to high 50s and even lowest 60 degrees latitude.

- **Continental Subarctic or Boreal (taiga) climates** (*Dfc*, *Dwc*, *Dsc*): *Dfc* and *Dwc* climates occur pole ward of the other Group D climates, mostly in the 50 s and low 60 s North latitude, although it might occur as far north as 70° latitude.
- **Continental Subarctic climates with extremely severe winters** (*Dfd*, *Dwd*): These climates occur only in eastern Siberia. The names of some of the places that have this climate — most notably Verkhoyansk and Oymyakon — have become veritable synonyms for extreme, severe winter cold.

GROUP E: Polar climates

These climates are characterized by average temperatures below 10 °C (50 °F) in all twelve months of the year:

- **Tundra climate** (*ET*): Warmest month has an average temperature between 0 °C (32 °F) and 10 °C (50 °F). These climates occur on the northern edges of the North American and Eurasian landmasses, and on nearby islands.
- **Ice Cap climate** (*EF*): All twelve months have average temperatures below 0 °C (32 °F). This climate is dominant in Antarctica (e.g., Scott Base) and in inner Greenland (e.g., Eismitte or North Ice).Occasionally, a third, lower-case letter is added to *ET* climates if either the summer or winter is clearly drier than the other half of the year; thus Herschel Island ('Qikiqtaruk', in Inuvialuit) off the coast of Canada's Yukon Territory, becomes *ETw*, with Pic du Midi de Bigorre in the French Pyrenees acquiring an *ETs* designation. If the precipitation is more or less evenly spread throughout the year, *ETf* may be

used, such as for Hebron, Labrador. When the option to include this letter is exercised, the same standards that are used for Groups C and D apply, with the additional requirement that the wettest month must have an average of at least 30 mm precipitation (Group E climates can be as dry or even drier than Group B climates based on actual precipitation received, but their rate of evaporation is much lower). Seasonal precipitation letters are almost never attached to *EF* climates, mainly due to the difficulty in distinguishing between falling and blowing snow, as snow is the sole source of moisture in these climates. *GROUP H:* ***Alpine climates***, The Alpine climates are considered to be part of group E, example ;The Cascade Mountains, The Rocky Mountains, The Andes, The Himalayas, The Tibetan Plateau, The Eastern Highlands of Africa, The Snowy Mountains of Australia, The West Coast Range of Tasmania, The Alps.

2.4.2 Thornthwaite's Classification

The main limitation of koppen's widely used classification is lack of rational basis for selecting temperature precipitation values for different climatic zones. Thornthwaite improved on this by introducing the water balance concept. He introduced the concept of potential evapotranspiration and compared the potential evapotranpiration with precipitation in order to obtain a Moisture Index. Although a water surplus in one season can not prevent deficiency in another, the former may compensate to subsoil moisture, and ground water. For this reason thornthwaite (1948) assumed that a surplus of 6 inch in one season will counteract the deficiency of 10 inch in another.

$$Im = 100s\text{-}60d/n \text{ or } 100(P\text{-}PET)\text{-}60(PET\text{-}P)/PET \qquad (3.5)$$

Where,

S = water surplus (P-PET)

D = water deficiency (PET-P)

N = water needed (PET)

This method is determined potential evapotranspiration specifies it as an expression of day length as well as temperature. Hence the potential evapotranspiration can be used as an index of thermal efficiency. It is not nearly a growth index but express growth in terms of the water needed for growth.

By Mather (1955) , the weighting factor of 0.6 for the aridity index in moisture index formula was eliminated, and the revised moisture index of the thornthwaite and mather method can be written as :

$$MAI = 100 (P/PET - 1) \tag{3.6}$$

Where,

MAI = Moisture Index

P = Precipitation (mm)

PET = Potential evapotranspiration (mm)

Table 3.3 The moisture regions according to this revised classification	
Climate Type	Moisture Index
A – Perhumid	100
B4 – Humid	80 – 100
B3 – Humid	60 – 80
B2 – Humid	40 – 60
B1 – Humid	20 – 40
C2 – Moist Subhumid	0 – 20
C1 – Dry Subhumid	-33.3 – 0
D – Semiarid	-66.7 - -33.3
E – Arid	-100 - -66.7

2.4.3 Hargreeves Classification

Hargreeves (1971) defined a moisture available index (MAI) as the ratio at the rainfall value expected with 75% probability for the concerned period to the estimated potential evapotransporation.

Table 3.4 The moisture deficit classification suggested by Hargreeves	
Climate Type	Moisture Index
Very deficient	0 – 0.33
Moderately deficient	0.34 – 0.67
Somewhat deficient	0.68 – 1.00
Adequate moisture	1.00 – 1.33
Excessive moisture	1.34

It was further sub devised that if the ratio is 0 – 0.33 during all months in a region, the climate of the region is classified as very arid. If there are only 1 – 2 months with MAI values exceeding 0.34 in the year, the climate is classified as arid, and if there are 3 – 4 consecutive such as months the climate is considered semiarid.

2.4.4 SCHMIDT-FERGUSON CLASSIFICATION

The Classification of Schmidt-Ferguson climate have utilized in forest and estates areas in Indonesia. The criteria based on Q value, it is comparison between dry month (DM) and wet month (WM), and multiple 100%

$$(Q = DM/WM \times 100\%).$$

The criteria of wet month and dry month:

Type of Months	**Monthly Precipitation**
Wet month (WM)	> 100 mm
Humid month (HM)	60-100 mm
Dry month (DM)	< 60 mm

Classification of Schmidt-Ferguson climate was based on Q value, and classified to eight climate types:

Table 3.5 Classification of Schmidt-Ferguson Climate		
Climate type	Q value (%)	Condition of climate and vegetation
A	< 14.3	Very wet region, tropical rain forest
B	14.3 – 33.3	Wet region, tropical rain forest
C	33.3 – 60.0	Somewhat wet region, deciduous forest, in dry season
D	60.0 – 100.0	Moderately climate, seasonal forest

E	100.0 – 167.0	Somewhat dry climate, savanna forest
F	167.0 – 300.0	Dry climate, savanna forest
G	300.0 – 700.0	Very dry climate, grass
H	> 700.0	Extremely dry climate, grass

2.4.5 Oldeman Classification

In oder to to classify the various rainfall distribution, the length of the wet period (= number of consecutive wet months) and the length of the dry period (= number of consecutive dry months) were related to the possible rice-based cropping patterns. Climate Oldeman is classified to 5 types based on number of wet month consecutively, whilst subdivision consists of 4 depend on dry month consecutively. The criterion of the wet and dry month are as follows ; if the average monthly rainfall bigger than 200 mm, its called wet month, if the average monthly rainfall about 100 – 200 mm, its called humid month and dry month if the average rainfall is less than 100 mm

Table 3.6 Criteria of Climate Oldeman

Main Type	Wet month consecutively	Sub Division	Dry month respectively
A	> 9	1	< 2
B	7 – 9	2	2 – 3
C	5 – 6	3	4 – 6
D	3 – 4	4	> 6
E	< 3		

Table 3.7 Interpretation of Climate Oldeman for Farming Systems

Climate type	Farming system	Cropping pattern
A1 A2	Suitable for rice field, low yield because of low radiation	Rice-rice-rice or rice-rice-secondary crop
B1	Suitable for rice field, high yield if harvesting in dry season	Rice-rice-rice or rice-rice-secondary crop
B2	Suitable for 2 times past ripping rice field, in dry season for secondary crop	Rice-rice-secondary crop
C1	Rice field 1 time, and 2 times secondary crop	Rice + 2 secondary crop
C2, C3, C4	Rice field 1 time, and 1-2 times secondary crop	Rice + 1-2 secondary crop
D1	Rice field 1 time, and 1 times secondary crop	Rice + 1 secondary crop
D2, D3, D4	Only rice field 1 time or 1 times secondary crop	Rice field or secondary crop
E	Only 1 time secondary crop	Secondary crop

CHAPTER IV

WEATHER DATA AND ANALYSIS

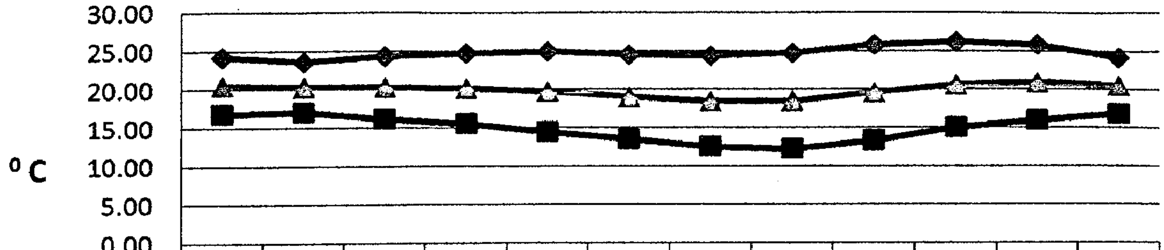
4.1 TEMPERATURE.

The temperature surrounding the crop plays an important role in crop development and production. Some species can survive at low temperature and often need a cool period for fruit setting, while other species only produces at an optimal rate above certain threshold temperature. Temperature regulate the rate of most biochemical processes in the plant. In general, the temperature is positively related to the rate of many processes, although above certain critical levels enzymes will denature and the metabolism of the plant will come to a complete stop.

Temperature also plays a role in the rate of evaporation and transpiration. It is therefore of obvious importance to know the temperature fluctuations in a region. Temperature is measured quite frequently in meteorological observation sites because of the simplicity of the equipment needed. Temperature is generally given as the mean monthly maximum temperature, the mean monthly minimum temperature.

In this study area, temperature data has recorded from 1994 until 2010 ; its shown in Fig 4.1

Fig.4.1 Monthly Average Temperature from 1994 until 2010



	Jan	Peb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmax	24.2	23.6	24.3	24.7	24.9	24.5	24.3	24.7	25.8	26.1	25.8	24.2
Tmin	16.8	17.0	16.2	15.5	14.4	13.5	12.5	12.2	13.3	15.0	15.9	16.7
Tmean	20.5	20.3	20.2	20.1	19.7	19.0	18.4	18.4	19.5	20.6	20.8	20.5

Month

These data were recorded from Bajawa station which located at the altitude of 1070m from sea level. The air temperature drops with increasing altitude from sea level. Ngada district divided into several zone with different of the altitude, this had an impact on the condition temperatures of the any zones.

Oldeman (1977) calculated the regression equations to correlate the maximum and minimum temperature with different altitude for each the year, based on the data for Indonesia (latitudes 5^0 N and 8^0 S) , its shown in table 4.1, which Y is expressed in degree Celsius and X in meters above sea level.

For calculating the temperatures in any different level by using this regression equation, firstly we should find the correlation value between the value which resulted by this regression equation and the values which recorded in observation station (Fig 4.1) on the same altitude.

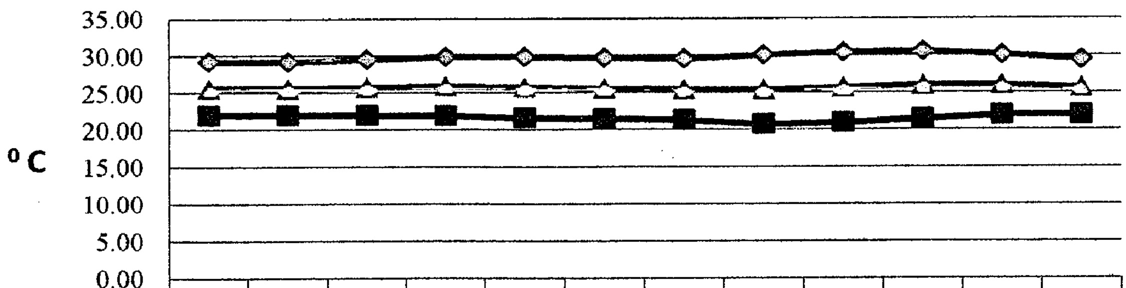
The result of correlation is 0.90 for maximum temperature, 0.78 for minimum temperature and 0.55 for optimum temperature.

Table 4.1 Regression equation of Max and Min Temperature for different Altitudes		
Month	**Maximum Temperature**	Minimum Temperature
January	Y=30.8 - 0.0062X	Y=23.3 - 0.0054X
February	Y=30.7 - 0.0061X	Y=23.3 - 0.0053X
March	Y=31.1 - 0.0062X	Y=23.3 - 0.0053X
April	Y=31.4 - 0.0061X	Y=23.2 - 0.0052X
May	Y=31.4 - 0.0061X	Y=22.9 - 0.0051X
June	Y=31.2 - 0.0061X	Y=22.7 - 0.0051X
July	Y=31.1 - 0.0061X	Y=21.6 - 0.0051X
August	Y=31.6 - 0.0061X	Y=22.0 - 0.0052X
September	Y=32.0 - 0.0062X	Y=23.3 - 0.0054X
October	Y=32.2 - 0.0064X	Y=22.8 - 0.0055X
November	Y=31.7 - 0.0063X	Y=23.3 - 0.0054X
December	Y=31.0 - 0.0062X	Y=23.3 - 0.0054X

- Zone I

In Zone I, Fig.4.2 shows the temperature conditions at the altitude of 0 m to 250 m from the sea level , where the conditions temperature as follows;

Fig.4.2 Monthly Average Temperature from 1994 until 2010



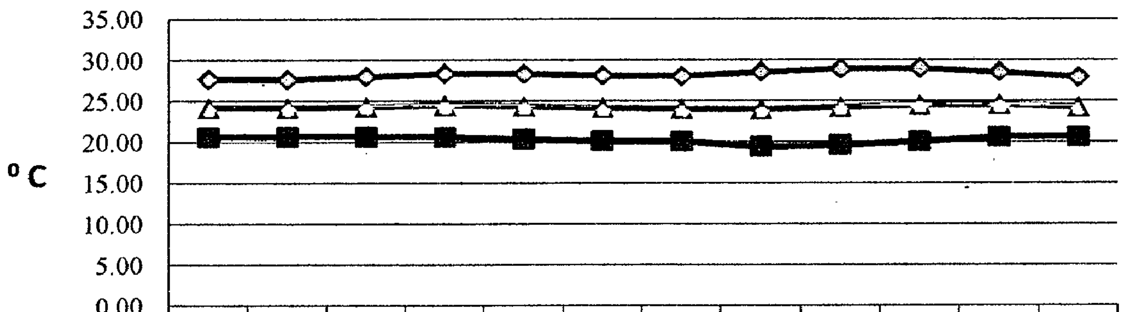
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmax	29.25	29.18	29.55	29.88	29.88	29.68	29.58	30.08	30.45	30.60	30.13	29.45
Tmin	21.95	21.98	21.98	21.90	21.63	21.43	21.33	20.70	20.95	21.43	21.95	21.95
Tmean	25.60	25.58	25.76	25.89	25.75	25.55	25.45	25.39	25.70	26.01	26.04	25.70

Month

- Zone II

In Zone II, Fig.4.3 shows the temperature conditions at the altitude of 250 m to 500 m from the sea level , where the conditions temperature as follows;

Fig.4.3 Monthly Average Temperature from 1994 until 2010



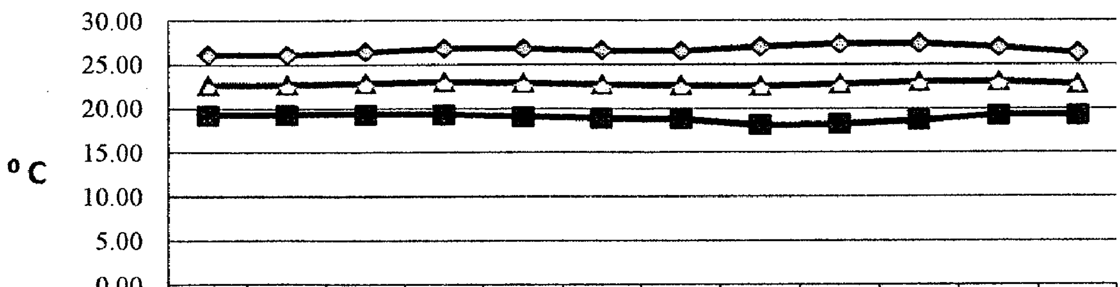
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmax	27.70	27.65	28.00	28.35	28.35	28.15	28.05	28.55	28.90	29.00	28.55	27.90
Tmin	20.60	20.65	20.65	20.60	20.35	20.15	20.05	19.40	19.60	20.05	20.60	20.60
Tmean	24.15	24.15	24.33	24.48	24.35	24.15	24.05	23.98	24.25	24.53	24.58	24.25

Month

- Zone III

In Zone III, Fig.4.4 shows the temperature conditions at the altitude of 500 m to 750 m from the sea level , where the conditions temperature as follows;

Fig.4.4 Monthly Average Temperature from 1994 until 2010



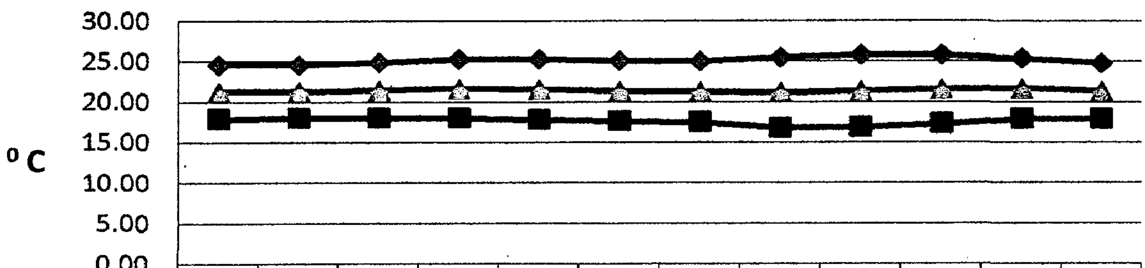
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmax	26.15	26.13	26.45	26.83	26.83	26.63	26.53	27.03	27.35	27.40	26.98	26.35
Tmin	19.25	19.33	19.33	19.30	19.08	18.88	18.78	18.10	18.25	18.68	19.25	19.25
Tmean	22.70	22.73	22.89	23.06	22.95	22.75	22.65	22.56	22.80	23.04	23.11	22.80

Month

- Zone IV

In Zone IV, Fig.4.5 shows the temperature conditions at the altitude of 750 m to 1000 m from the sea level , where the conditions temperature as follows;

Fig.4.5 Monthly Average Temperature from 1994 until 2010



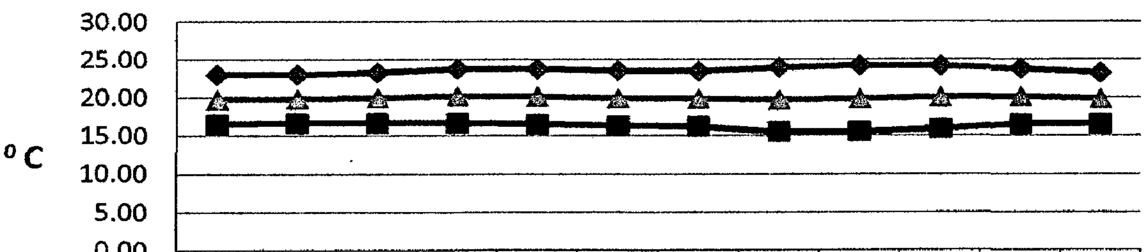
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmax	24.6	24.6	24.9	25.3	25.3	25.1	25.0	25.5	25.8	25.8	25.4	24.8
Tmin	17.9	18.0	18.0	18.0	17.8	17.6	17.5	16.8	16.9	17.3	17.9	17.9
Tmean	21.2	21.3	21.4	21.6	21.5	21.3	21.2	21.1	21.3	21.5	21.6	21.3

Month

- Zone V

In Zone V, Fig.4.6 shows the temperature conditions at the altitude 1250 m above from the sea level , where the conditions temperature as follows;

Fig.4.6 Monthly Average Temperature from 1994 until 2010



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmax	23.0	23.0	23.3	23.7	23.7	23.5	23.4	23.9	24.2	24.2	23.8	23.2
Tmin	16.5	16.6	16.6	16.7	16.5	16.3	16.2	15.5	15.5	15.9	16.5	16.5
Tmean	19.8	19.8	20.0	20.2	20.1	19.9	19.8	19.7	19.9	20.0	20.1	19.9

Month

The daily arithmetic mean of Tmax and Tmin provide what is commonly called the average daily. Mean period and monthly values can be computed by;

$$T_{mean} = \frac{1}{2}\left(\frac{\sum T_{max}}{n} + \frac{\sum T_{min}}{n}\right) \quad \text{or} \quad \frac{\left(\sum T_{max} + \sum T_{min}\right)}{2n}$$

where n is the number of days in the period or the month. Where Tmean = 30^0C is hot ; when Tmean is 15^0C is Cool. In this study area , the mean temperature is 20.24 for the altitude 1250 m above from sea level and 26.04^0C for the altitude 250 m above from sea level .

4.2 RELATIVE HUMIDITY

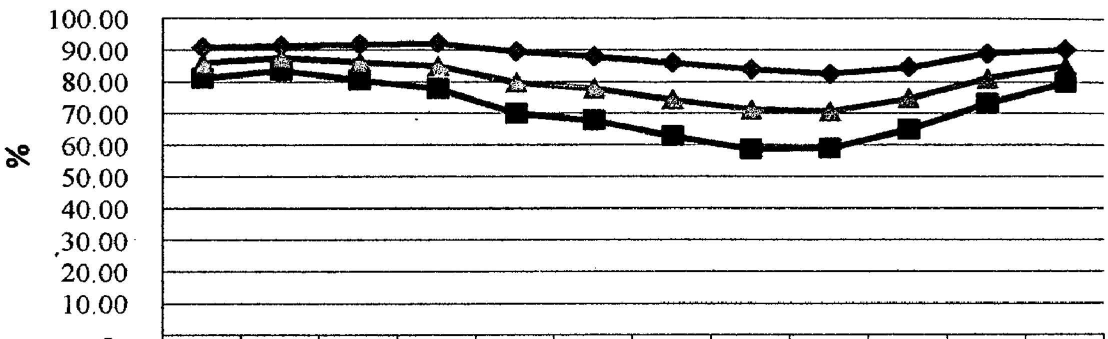
Air humidity is frequently expressed in percentage. A direct measure of relative humidity is obtained by the hair hygrograph. From the hygrograph charts, a direct reading of daily maximum and daily minimum can be made after an eventual correction base on the morning psychrometer observation. Mean relative Humidity is normally obtained by based on RHmin and RH mean weather defined is as fallows :

$$RH\ mean = \frac{(RH\ max + RH\ min)}{2}$$

Relative humidity classified as follows:

RH min	RH mean	
20	40	Low
20-50	40-70	Medium
50	70	High

Fig 4.7 Monthly Average Relative Humidity from 1994 until 2010



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RHmax	90.	91.	91.	92.	89.	88.	86.	84.	82.	84.	89.	90.
RHmin	81.	83.	80.	77.	70.	67.	62.	58.	59.	65.	73.	79.
RHmean	86.	87.	86.	85.	79.	77.	74.	71.	70.	74.	81.	85.

Month

Fig. 4.7 show the average relative humidity is high, the range for 70.8% to 87.6%. this recorded from observation station at the altitude 1070 m above from sea level.

4.3 WIND VELOCITY

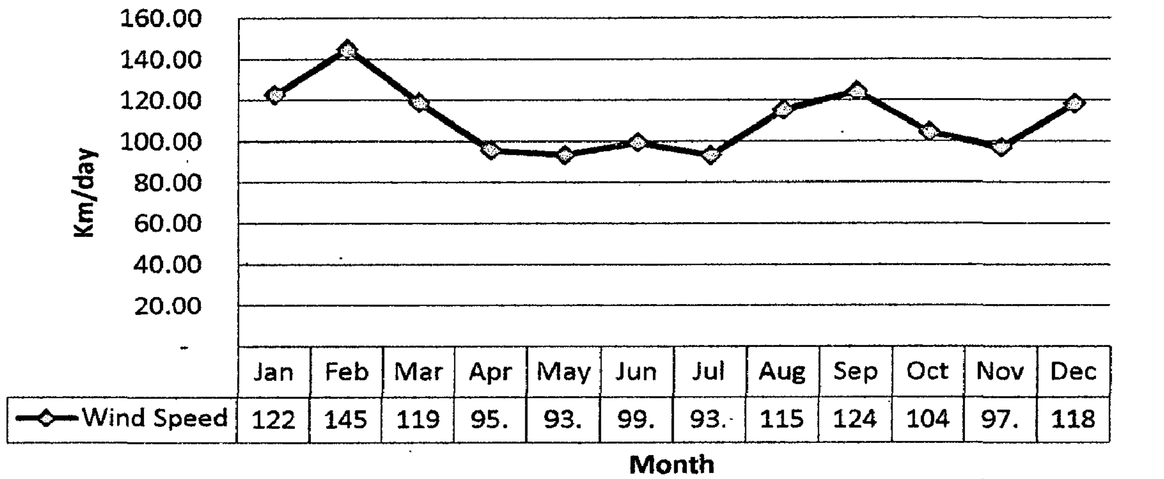
Wind speed and direction can vary considerably with time and distance. Wind is usually at minimum around sunrise and at a maximum in the noon. Where air pressure difference occur, daily variation in wind direction is frequent. Wind speed varies with the height above ground. For Agricultural use of data, it should be measured at 2.0 m above ground and expressed in Km/day.

Fig. 4.8 show the wind speed in this study area , the classified is light, maximum 145 km/day in February and minimum 93.3 Km/day in July. this recorded from observation station at the altitude 1070 m above from sea level.

Wind speed classified as follows:

Wind Speed (Km/day)	
< 175	Light
175 - 455	Mod
425 - 700	Storng
>700	Very Strong

Fiq. 4.8 Monthly Average Wind Speed from 1994 until 2010



4.4 ACTUAL SHINE

Sunshine recorder data can be given only approximate measure of radiation, depending on the data needed, the duration of bright sunshine can be used directly or converted into radiation data. In the later case the empirically derived relationship between sunshine duration and radiation are used.

The effect of radiation on evapotranspiration is best expressed in terms of net radiation (Rn). Net radiation is the difference between all incoming and outgoing radiation and can be calculated by the formula:

$$R_n = (1- \alpha) R_s - R_{nl}$$

Where,

$(1-\alpha)\ R_s$ = net short wave radiation (R_{ns}).

R_s = incoming shortwave radiation.

α = reflection coefficient .e 0.05 for water and 0.25 for green crop.

R_{nl} = net long wave radiation.

The value of shortwave radiation (R_s) can computed from the relation n/N ; where n is actual bright sunshine duration and N is the maximum possible sunshine duration at the top of the atmosphere (R_a).

Not all radiation received at the top of the atmosphere reaches the earth's surface since part of it is scattered and absorbed. Thus the relation between incoming shortwave radiation (R_s), Ra and n/N is given as follows:

$$R_s = (a + b\ n/N)\ R_a$$

where, a and b vary somewhat with latitude and season, and preferably locally determined values should be applied. Approximately a = 0.25 and b = 0.50. Net longwave radiation (R_{nl}) is dependent on temperature, humidity and duration of bright sunshine.

Fig.4.9 Monthly Average Actual Sunshine from 1994 until 2010

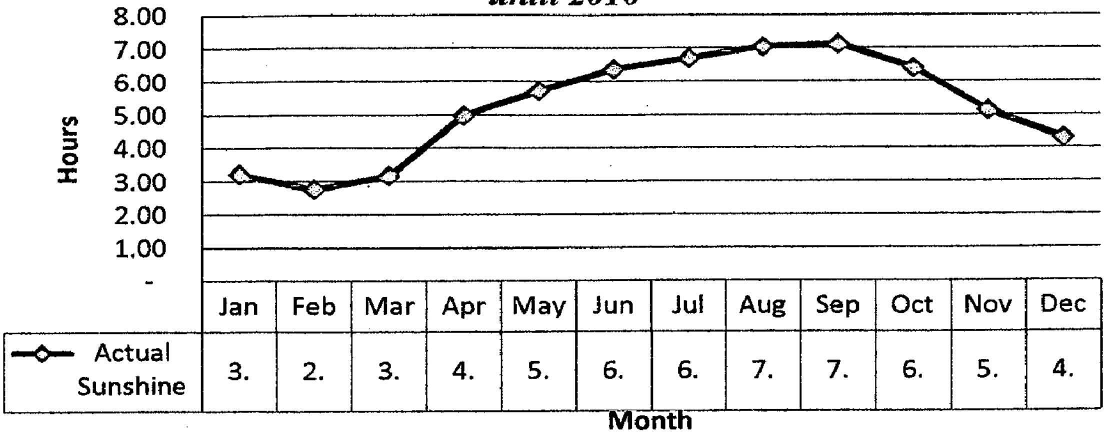
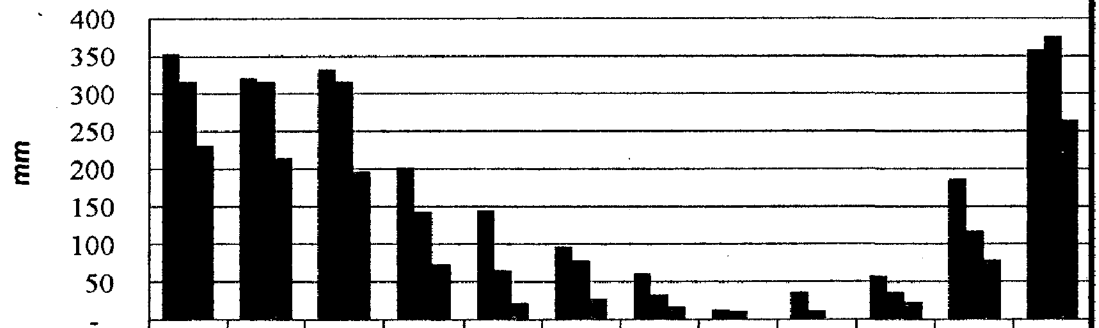


Fig. 4.9 show the actual sunshine in this study area , the maximum actual sunshine occurring is 7.1 hours on August and the minimum is 2.7 hours on February.

4.5 RAINFALL

Rainfall is the parent source of water availability in a geographical region. Storage in reservoir and soil moisture saturation needs depend upon the behavior of rainfall pattern. By shah (1990) the range and frequency distribution of various amounts about mean are necessary in planning land use and crop cultivation. The annual normal rainfall of the area is 2,165 mm, of which 1840 mm (85%) occurs from November until may or monsoon season and post monsoon occurs June until October is 267 mm (15 %). Actually only two season in this area. The monthwise distribution of rainfall is shown in Fig.4.10

Fig.4.10 Mean Monthly Rainfall in Ngada District from 1994 until 2009



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
■ Normal rainfall	353	321	332	202	145	97	62	13	37	58	187	358
■ 50% dependable	316	316	316	144	66	79	33	11	12	37	118	376
■ 75 % dependable	231	214	197	74	23	29	18	-	-	24	80	266

Frequency in deficit of annual rainfall has been computed according IMD criteria. The number of years and percentage of years when the annual rainfall is less than normal and less than 75 % dependable shown here.

1. Normal annual rainfall : 2,165 mm
2. 75% dependable : 1,152 mm
3. Total number of years : 14
4. Number of years having rainfall less than normal : 10 nos 71%
5. Number of year having rainfall less than 75% dependable : -

CHAPTER V

ACREAGE AND PRODUCTION OF CROPS.

The agricultural land of Ngada District is 26.495,00 ha or 16.35 % of total Ngada District area. The land of agricultural composed from lowland area is 18.748 ha or 11.57% which consist of irrigated area 4.259 ha or 2.63% and rainfed land / unirrigated area 14.489 ha or 8.94%, and Upland area is 7.747 ha or 4.78%.

According to this first paragraph above, obviously the definition of Lowland area or sawah land is the land within bunded fields in which rice is grown under flooded condition (but in which upland or secondary crops, such as soybean,maize,cassava,etc. The sawah land can be subdivided into :

- Irrigated sawah land : the term "irrigated" should be considered to include any form of supplement water in addition to direct rainfall
- Rainfed sawah land: no other supplemental of water; swamp sawah land.

Upland is the agricultural area can be separated into :

- House compounds
- Perennial crops around the farm
- Woodland and forest within the farmed area
- Temporary fallow land
- Land used for shifting cultivation
- Other unidentified land
- Upland fields,cultivated for secondary crops

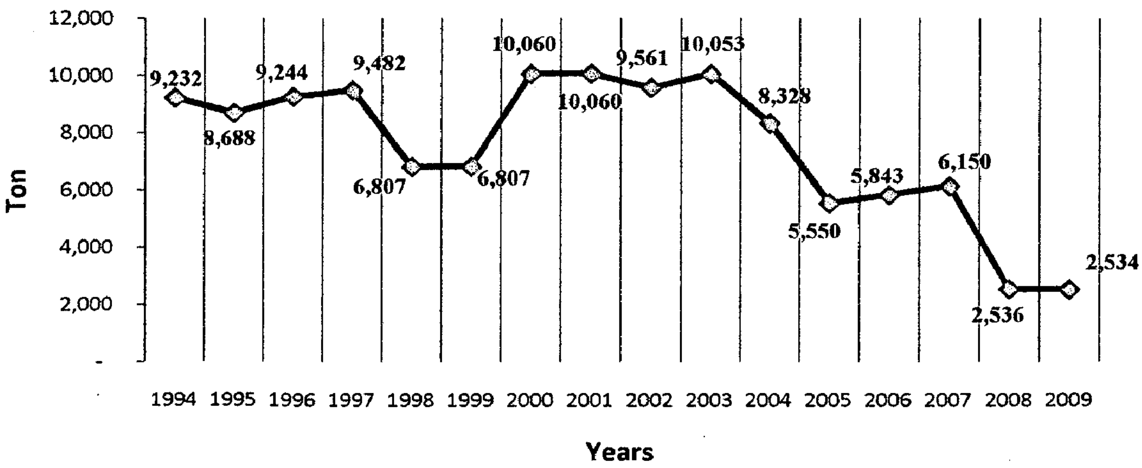
5.1 PADDY / RICE

The total rice production in Ngada district as quated in the BPS, Ngada in figures 1994 – 2009 , refers to the annual production of rice from wetland rice (also called paddy land or sawah land) as well as from dryland rice areas (also called upland rice).

5.1.1 Upland Paddy

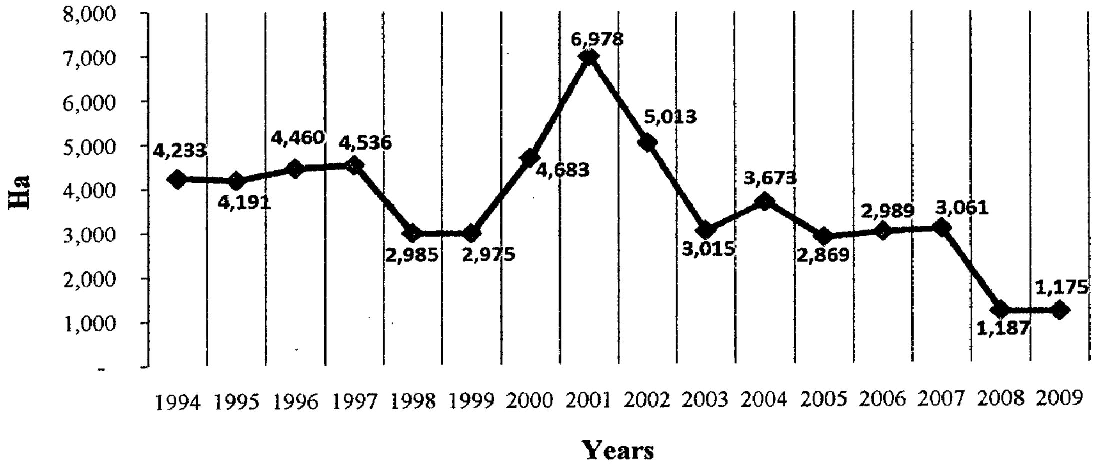
In the fig.5.1 shows the historic trends of annual paddy upland production from 1994 to 2009 are given. In this 16 years paddy upland production is decreased, and sharply decreased from 2003 to 2009. The decreased in upland paddy production during 16 years was mainly the result of decreasing of annual harvested area (Fig 5.2) , but the productivity is adequate stable (Fig 5.3). The average of production in 16 years was 7,558 ton, the average harvested area is 3626 ha, and the productivity is 21.24 ku/ha.

Fig.5.1 Paddy Upland Production in District Ngada from 1994 until 2009



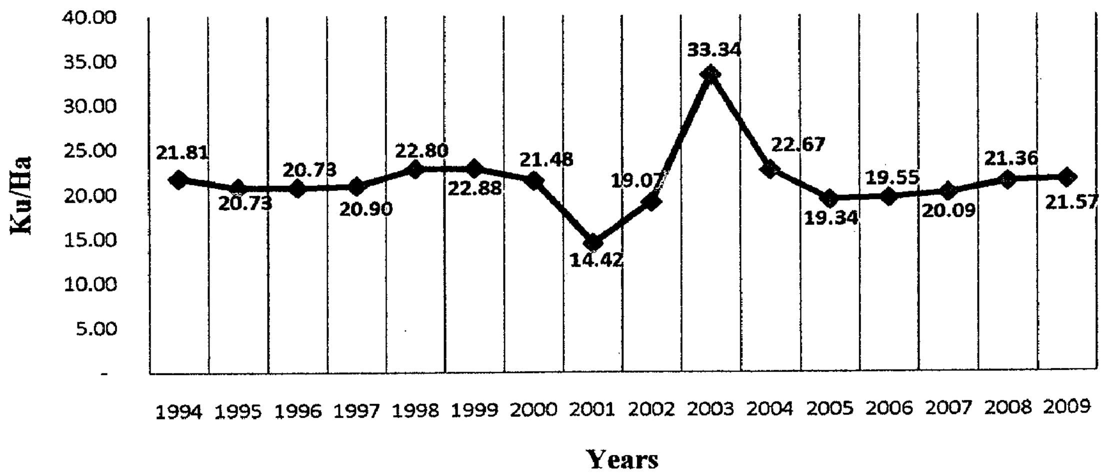
Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.2 Harvested Area of Paddy Upland in Ngada District from 1994 until 2009



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.3 Productivity of Upland Paddy in Ngada District from 1994 until 2009

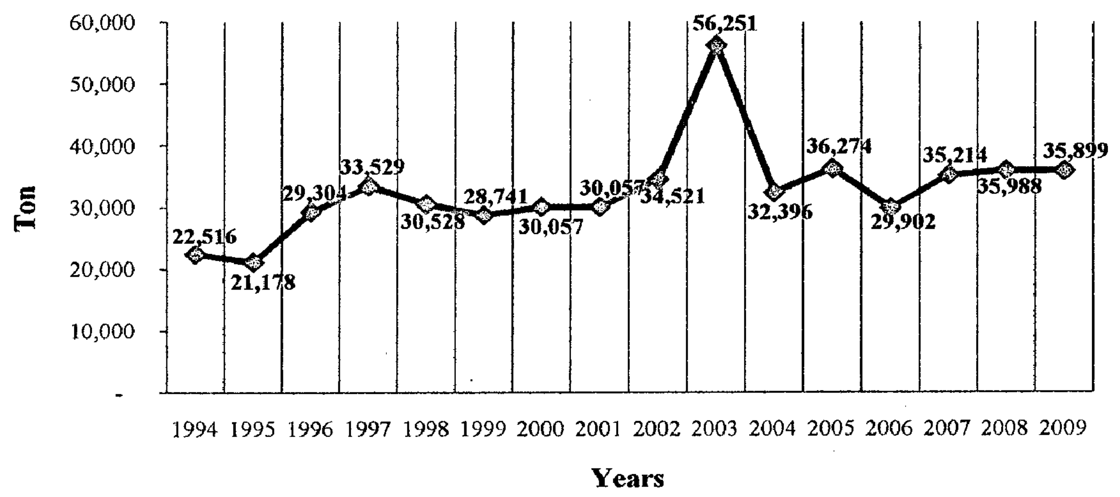


Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

5.1.2 Lowland Paddy

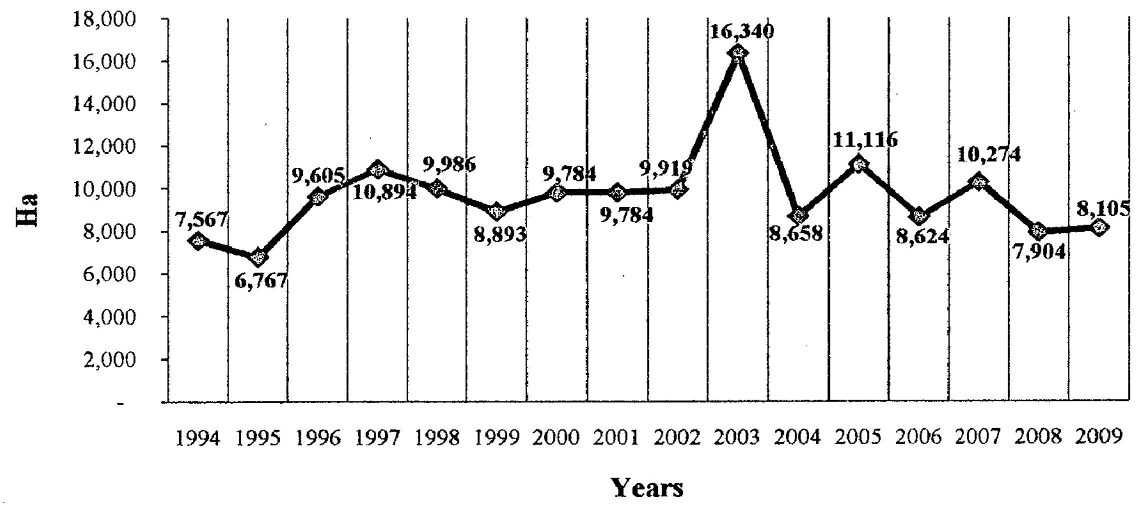
In the fig.5.4 shows the historic trends of annual paddy lowland production from 1994 to 2009 are given. In this 16 years paddy lowland production is slightly increased , and sharply in 2003. The increased in lowland paddy production during 16 years was mainly the result of increased of annual harvested area (Fig 5.5) ,because the correlation is 0.86 but the productivity is adequate stable (Fig 5.6). The average of production in 16 years was 32,647 ton, harvested of area was 9,639 ha, and the productivity was 34.04 ku/ha.

Fig.5.4 Paddy Lowland Production in Ngada District from 1994 until 2009



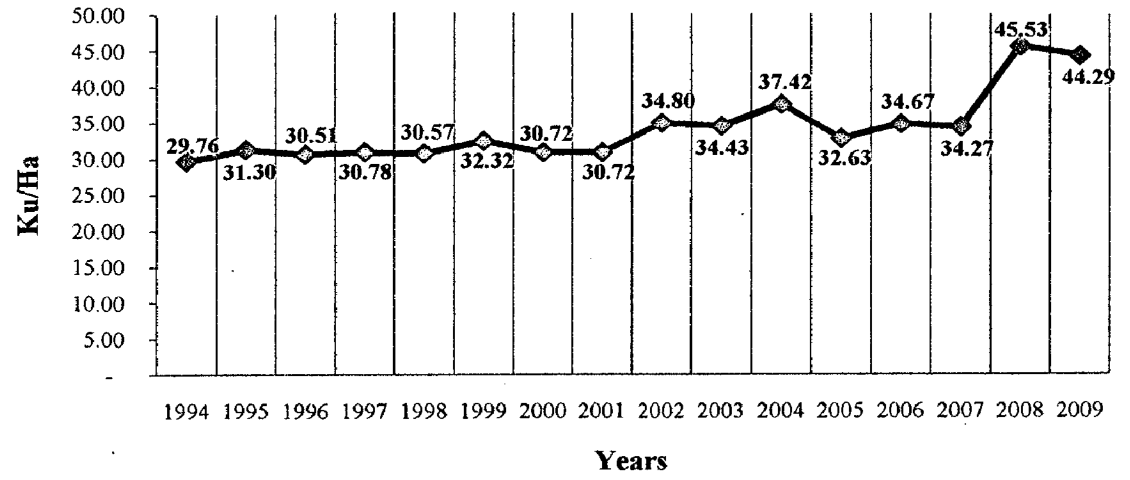
Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.5 Harvested Area of Paddy Lowland in Ngada District from 1994 until 2009



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.6 Productivity of lowland paddy in Ngada District from 1994 until 2009

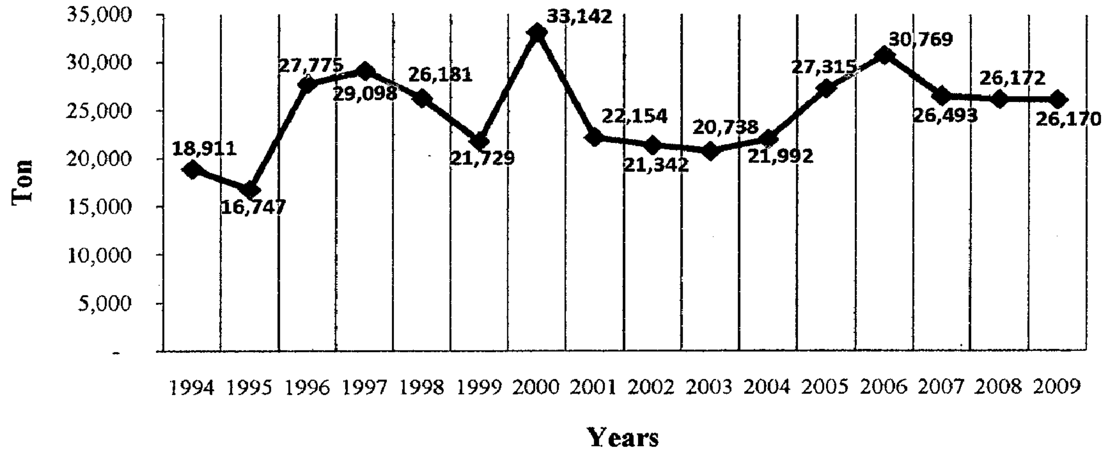


Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

5.2 MAIZE

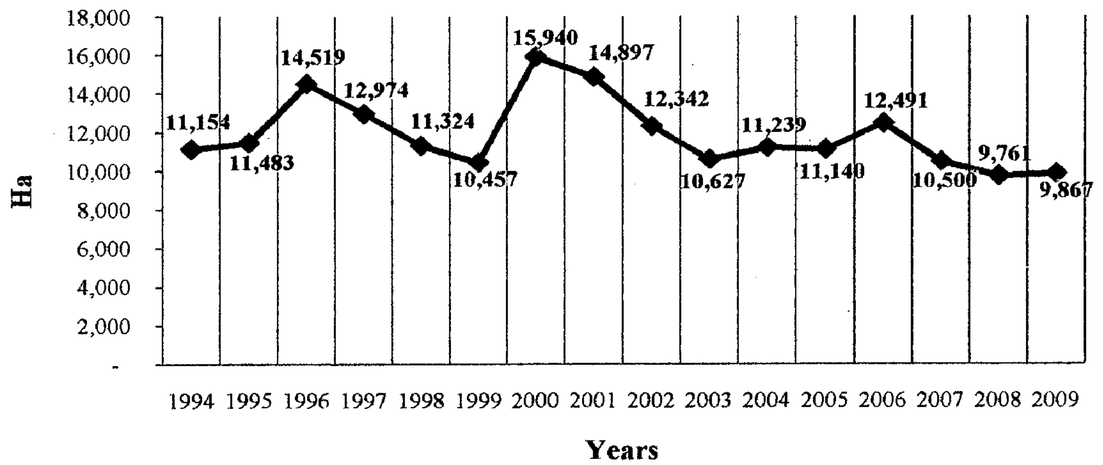
In the fig.5.7 shows the historic trends of annual maize production from 1994 to 2009 are given. In this 16 years maize production is slightly increased , and the top in 2000. The increased in maize production during 10 years back mainly the result of improved the variety from local variety to composite variety after that using the hybrid variety, because the potential production of varying variety are 23,51 ku/ha, 32,50 ku/ha and 45,25 ku/ha respectively. This we can see in fig.5.9 and fig 5.8 shows the increase in productivity despite the drop in harvested area . The average of production in 16 years was 24,796 ton, harvested of area was 11,920 ha, and the productivity was 21.05 ku/ha.

Fig.5.7 Production of Maize in Ngada District from 1994 until 2009



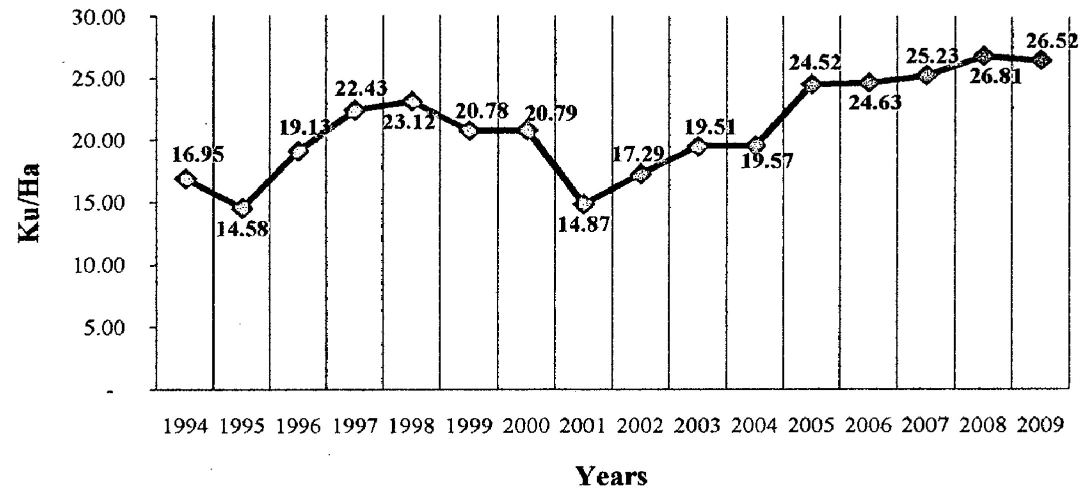
Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.8 Harvested Area of Maize in Ngada District from 1994 until 2009



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.9 Productivity of Maize in Ngada District from 1994 until 2009



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

5.3 SOYBEAN

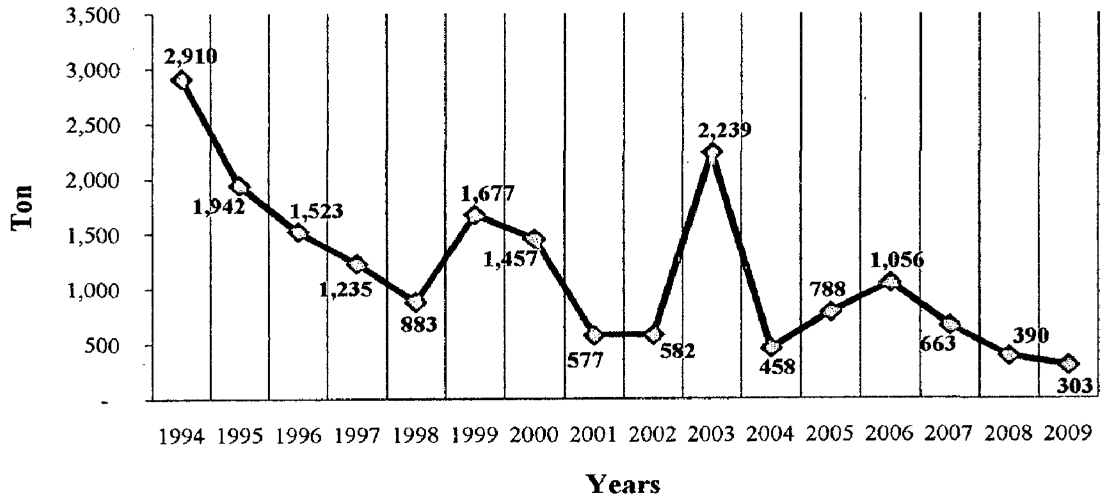
Soybean is one crop that fits these dry conditions. It needs only 70 days from planting until harvesting. Soybean technology currently used by farmers is either monoculture or a sequential rotation. In the monoculture pattern, farmers cultivate soybean only on dry land, once a year starting in March. Before March, this dry land is not used because of a lack of labor.

There is no tradition of hiring migrant labor from other parts of the Province. Family labor is used to cultivate the rain-fed paddy fields. There is little chance to hire labor in the wet season because farmers who own no land prefer to work as tenant farmers rather than as hired laborers. Many farmers cannot utilize all of their owned land. In the wet season, farmers work on their own land or within farmer groups.

In the fig.5.10 shows the historic trends of annual Soybean production from 1994 to 2009 are given. In this 16 years Soybean production is sharply decreased.

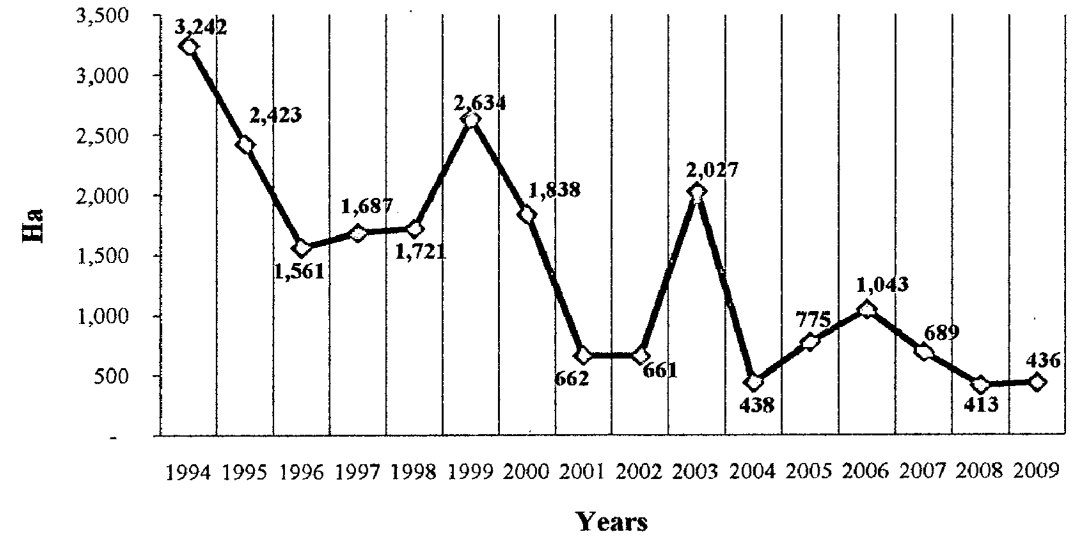
The decreased in soybean mainly the result of decreased of harvested area in fig. 5.11, but the productivity is stable and the average of production in 16 years was 1,168 ton, harvested of area was 1391 ha, and the productivity was 8.68 ku/ha.

Fig.5.10 Production of Soybean in Ngada District from 1994 until 2009



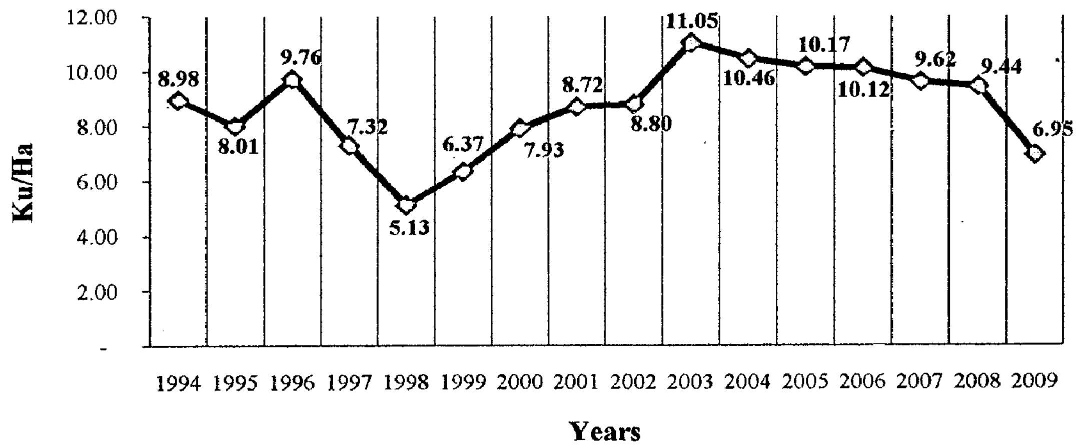
Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.11 Harvested Area of Soybean in District Ngada from 1994 until 2009



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.12 Productivity of Soybean in Ngada District from 1994 until 2009



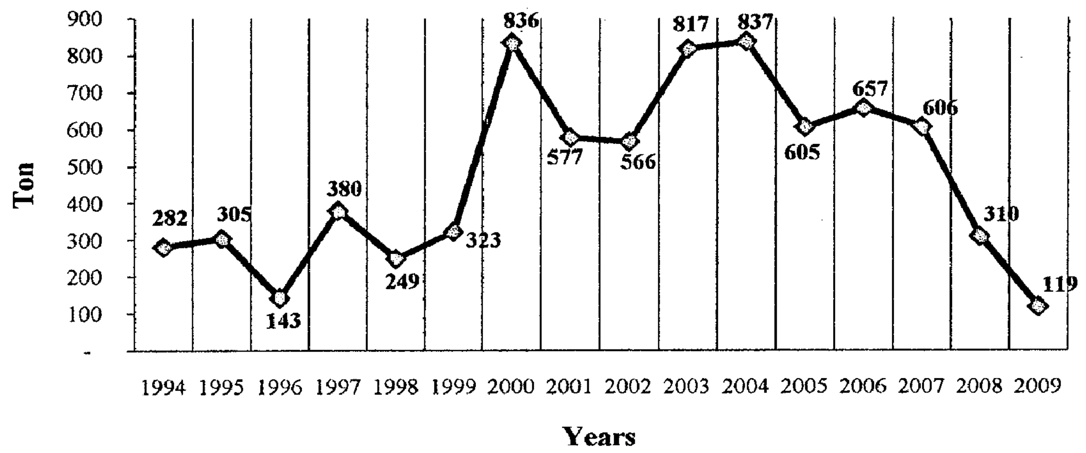
Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

5.4 GROUNDNUT

Peanut is an important commercial agricultural commodity which is highly competitive to other food crops since it offered more benefit to the farmers. Besides it has high lipid and protein content. The average peanut productivity in

Ngada District is still low, therefore it could not fulfill the domestic demand. Improvement of peanut production need to be done through crop intensification, which are focused on the lowland, upland, and acidic soil area.

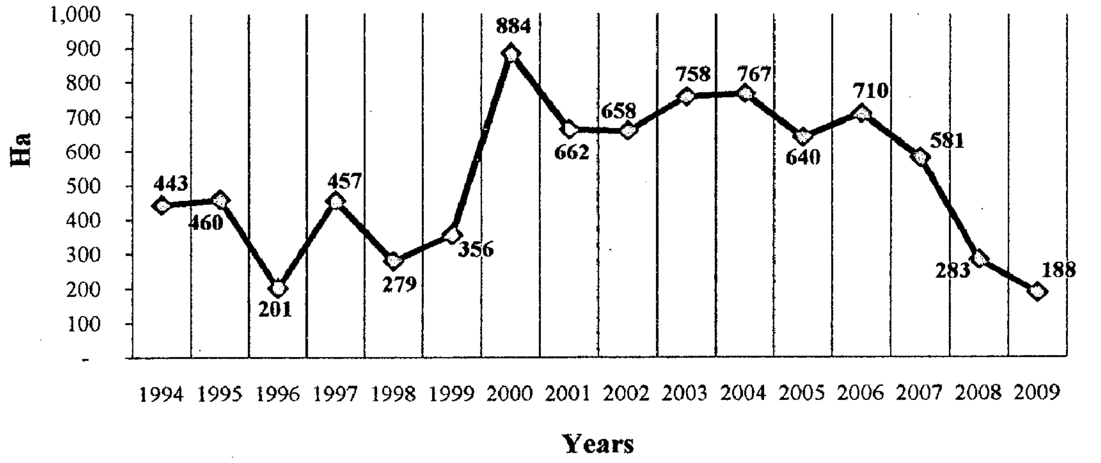
Fig.5.13 Production of Groundnut in Ngada District from 1994 until 2009



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

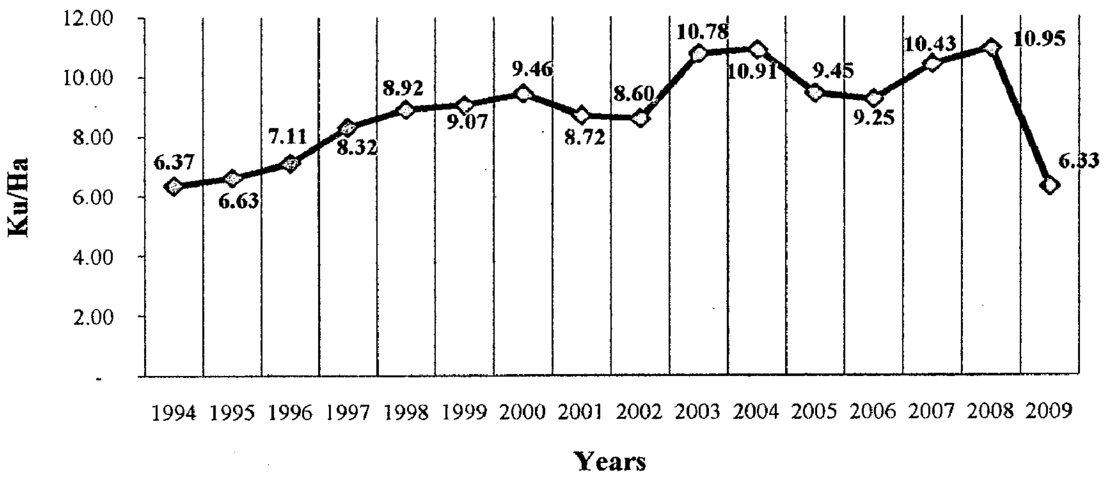
In the fig.5.13 shows the historic trends of annual maize production from 1994 to 2009 are given. In period from 1994 to 2000 groundnut production is significant increased , but from 2000 – 2009 the production decreased sharply. This fluctuation mainly the result of harvested area fluctuation also. The average of production in 16 years was 476 ton, harvested of area was 520 ha, and the productivity was 8.83 ku/ha.

Fig.5.14 Harvested Area of Groundnut in Ngada District from 1994 until 2009



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig. 5.15 Productivity of Groundnut in Ngada District from 1994 until 2009



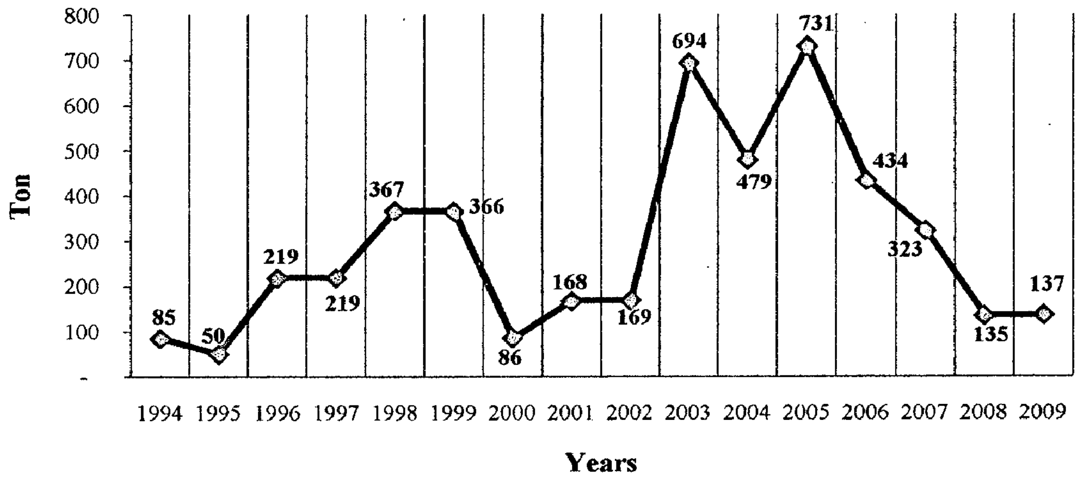
Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

5.5 GREENGRAM/ MUNGBEAN

Mungbean still received less attention, although this plant has a high nutritional value and good prices. Compared with other legume crops, green beans better in either agronomic aspect or economic such as: (a) more drought resistant, (b) fewer pest attacks, (c) can be harvested at the age of 55-60 days, (d) can be grown on less fertile soil, and cultivation practise is easy. Thus, green beans have a high potential for developed. To increase the production, availability of seed with high yield variety is the priority beside the availability of fertilizer.

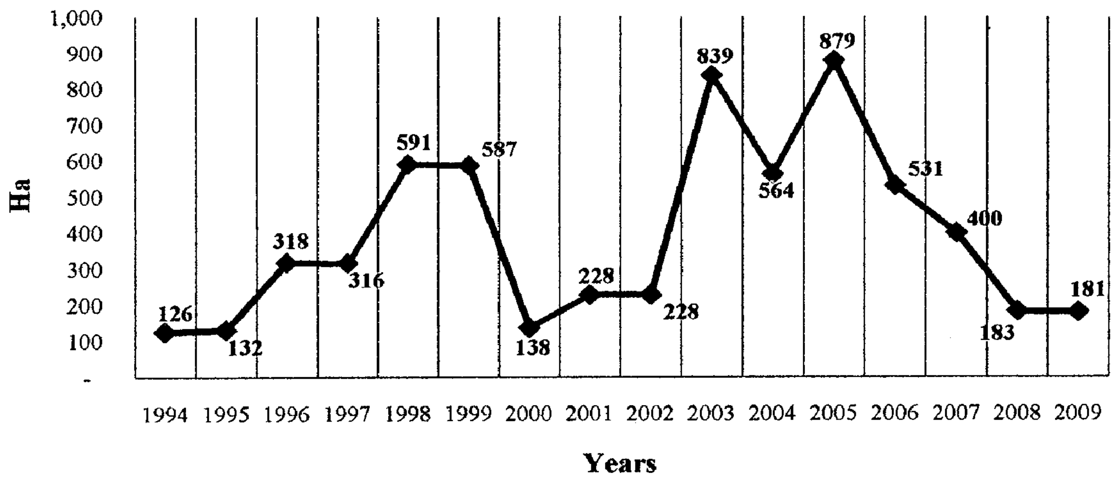
In the fig.5.16 shows the historic trends of annual mungbean production from 1994 to 2009 are given. In period from 1994 to 2005 mungbean production is increased , but from 2005 – 2009 the production decreased sharply. This fluctuation parallel with harvested area fluctuation also (see fig.5.17). The average of production in 16 years was 291 ton, harvested of area was 390 ha, and the productivity was 7.13 ku/ha.

Fig.5.16 Production of Greegram in Ngada District from 1994 until 2009



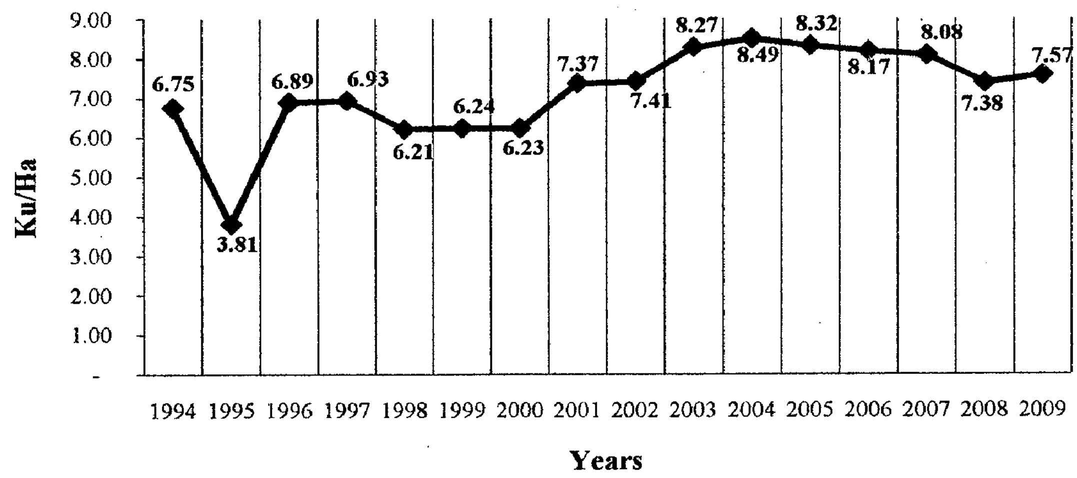
Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.17 Harvested Area of Greengram in Ngada District from 1994 until 2009



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

Fig.5.18 Productivity of Greengram in Ngada District from 1994 until 2009



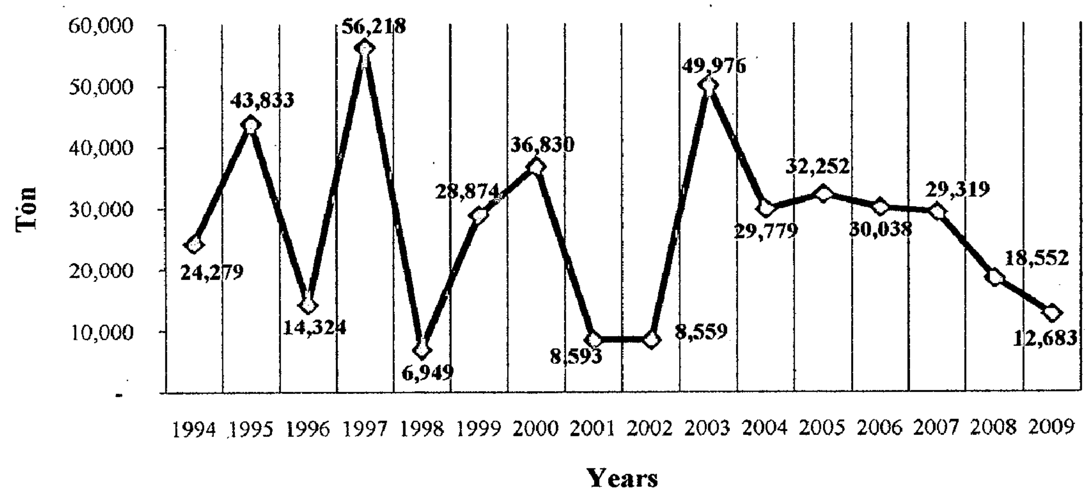
Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

5.6 CASSAVA

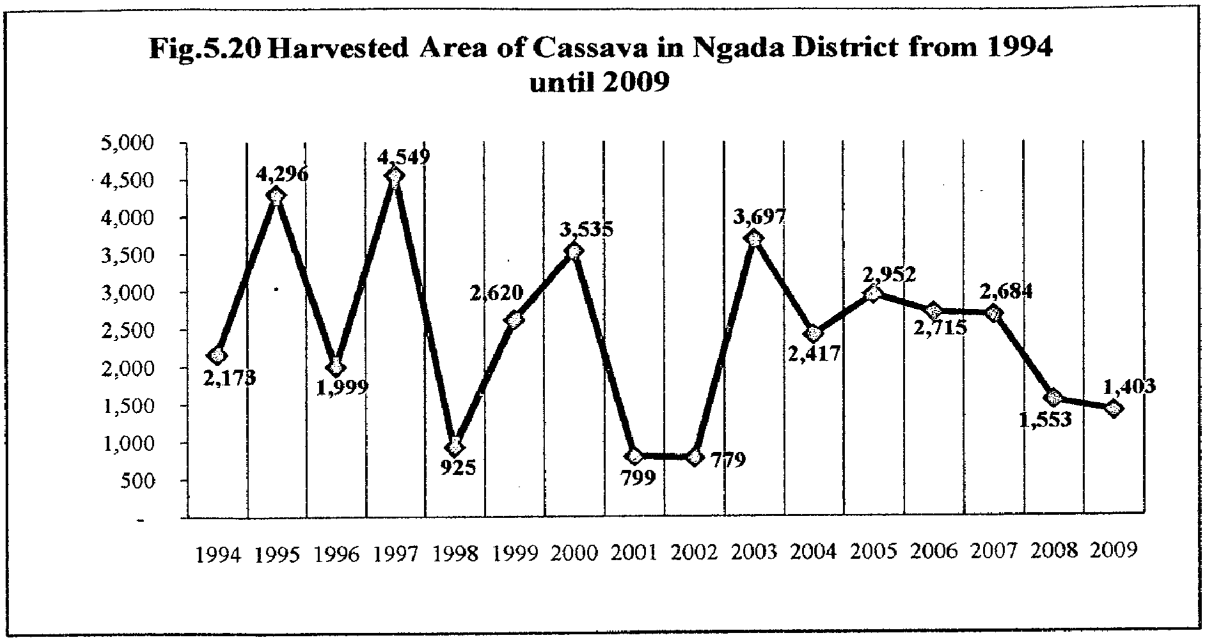
Casava (*manihot esculenta crantz*) is an important foodstuff in Indonesia after rice and maize. Approximately 60 % of cassava production in Indonesia is used as a food ingredient 32% is used as an ingredient of domestic industries, and 8 % are exported in the form of dried cassava.

Cassava can be grown as single crop (monoculture), as the fence plant, or together with other crops (intercropping or overlap-insert). For farmers who give priority to the results of cassava, but want to earn extra income from beans, rice, or corn, it can use a double row cultivation techniques (double row). With double-row planting arrangement is possible to plant twice as legumes, without reducing crop cassava. With this technique, farmers' cash more quickly get results from the harvest of beans while waiting for crops to be harvested cassava

Fig.5.19 Production of Cassava in Ngada District from 1994 until 2009

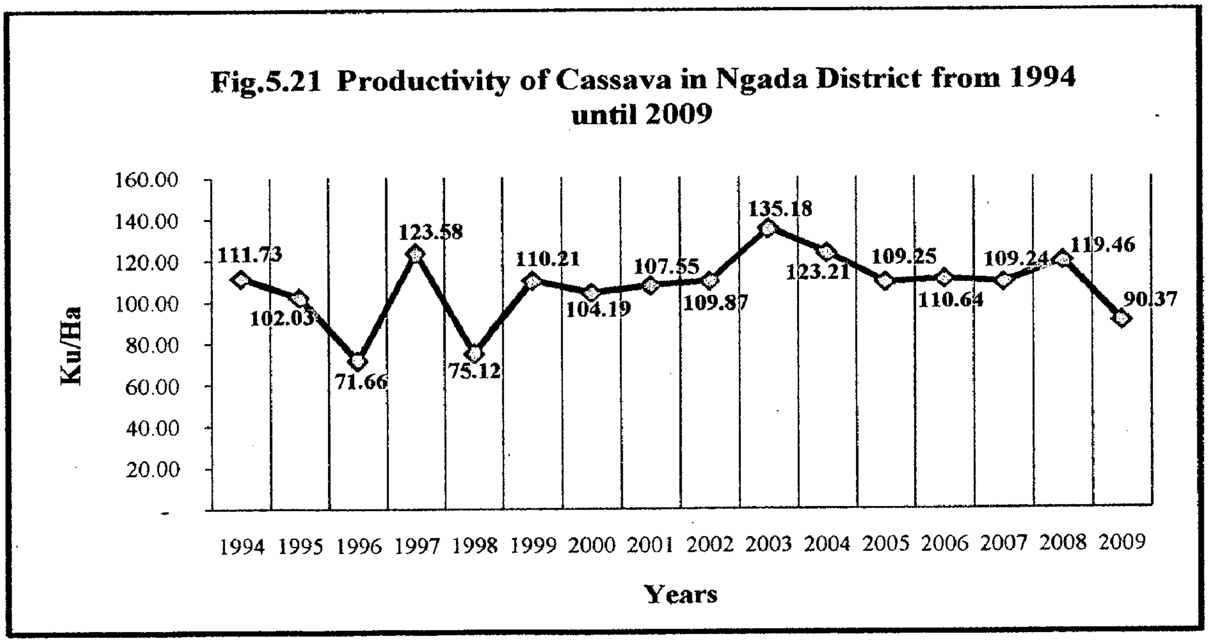


Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

In the fig.5.19 shows the historic trends of annual cassava production from 1994 to 2009 are given in Ngada District. In period from 1994 to 2003cassava production is fluctuation , but from 2003 – 2009 the production decreased sharply. This fluctuation parallel with harvested area fluctuation also (see fig.5.20). The average of production in 16 years was 26,941 ton, harvested of area was 2,444 ha, and the productivity was 107.08 ku/ha.



Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada)

CHAPTER VI

SOIL AND IRRIGATION SYSTEM OF NGADA DISTRICTS

Ngada District, with a total area of 162,041 ha is one of the districts in East Nusa Tenggara Province. The soil condition of Ngada district is dominated by volcanic landform, a few of them are still active.

6.1 SOIL CLASSIFICATION

Tabel 6.1 Soil Classification of Ngada District according to Land of Area

No	Types of Soil	Ha	% of total area
1	Mediteranean Soil	88,494.00	54.61
2	Latosol Soil	35,325.00	21.80
3	Lithosol Soil	35,450.00	21.88
4	Alluvial Soil	2,772.00	1.71
	Total	**162,041.0**	**100.00**

Source : BPS, Ngada in Figures 1994 - 2009(District Statistical Officer, Ngada

Soils are classified following taxonomic systems. They are usually group into taxonomic categories according to the morphometric soil profile properties, reflecting the kinds stage of their development (paedogenic classification). Soil classification serves two purpose :

- To make the regional distribution of variations in soil condition understandable, seen in the light of development as a result of various soil farming factors.

- To supply a basis for worldwide comparision of soil the have developed under similar conditions.

The Classification of soil in the Ngada district (table 6.1) are as follows;

1. **Mediterranean soil**, also known as **terra rossa** (italian for "red soil") is a soil classification that has been formally superseded by the formal classifications of systems such as the FAO soil classification, but that is still in common use. The terra rossa classification was still, as of 1997, a part of the national soil classifications of countries such as Israel and Italy. The UNESCO/FAO World map equivalents are the chromic luvisols (a sub-order of the luvisols), and the USDA soil taxonomy equivalent is the rhodustalfs (a sub-order of the ustalfs). The classification denotes red-coloured soils (sometimes called "red rendzinas") that develop in or on the karstic landscape of the limestones of the Miocene and earlier periods, as well as calcretes in regions where the modern Mediterranean climate is predominant. Red Mediterranean soils developed most vigorously from the Miocene to the Late Pleistocene, because those that the periods where the climate fluctuated the most. Terra rossa occurs in areas where heavy rainfall causes carbonation out of the calcium carbonate parent rock and silicates are leached out of the soil to leave residual deposits that are rich in iron hydroxides, the cause of the red colour. Such areas are usually depressions within the limestone, or areas where the vegetation is garrigue.
2. **Latosol soil** , is a name given to soils found under tropical rainforests. They are red or yellowish-red in colour throughout and they do not have distinct horizons like a podsol. The red colour comes from the oxides of

iron and aluminium which remain in the soil. They are deep soils, often 20-30m deep whereas podsols are 1-2m deep.

3. **Lythosol soil,** In USDA soil taxonomy, **Orthents** are defined as Entisols that lack horizon development due to either steep slopes or parent materials that contain no permanent weatherable minerals (such as ironstone). Typically, Orthents are exceedingly shallow soils. They are often referred to as **"skeletal soils"** or, in the FAO soil classification, as **Lithosols**. The basic requirement for recognition of an orthent is that any former soil has been either completely removed or so truncated that the diagnostic horizons typical of all orders other than Entisols are absent. Most Orthents are found in very steep, *mountainous* regions where erodible material is so rapidly removed by erosion that a permanent covering of deep soil cannot establish itself. Such conditions occur in almost all regions of the world where steep slopes are prevalent. In Australia and a few regions of Africa, Orthents occur in flat terrain because the parent rock contains *absolutely no weatherable minerals except short-lived additions from rainfall*, so that there is no breaking down of the minerals (chiefly iron oxides) in the rock.The steepness of most Orthents causes the flora on them to be sparse shrubs or grassland. In those on ancient, flat terrain, dry grassland, savanna, or, *very rarely*, rainforest can prevail.Because of their extreme shallowness and, usually, steepness and consequent high erosion hazard, Orthents are not suitable for arable farming. The flora typically supported on them is generally of very poor nutritive value for grazing, so that typically only low stocking rates are practicable. Many Orthents are very important as habitat for wildlife.

4. **Alluvium Soil**, (from the Latin, *alluvius*, from *alluere*, "to wash against") is loose, unconsolidated (not cemented together into a solid rock), soil or sediments, eroded, deposited, and reshaped by water in some form in a non-marine setting.[1][2] Alluvium is typically made up of a variety of materials, including fine particles of silt and clay and larger particles of sand and gravel. When this loose alluvial material is deposited or cemented into a lithological unit, or lithified, it would be called an **alluvial deposit**. The term "alluvium" is not typically used in situations where the formation of the sediment can clearly be attributed to another geologic process that is well described. This includes (but is not limited to): lake sediments (lacustrine), river sediments (fluvial), or glacially-derived sediments (glacial till). Sediments that are formed and/or deposited in a perennial stream or river are typically *not* referred to as alluvial. Most, if not all, alluvium is very young (Quaternary in age), and is often referred to as "cover" because these sediments obscure the underlying bedrock. Most sedimentary material that fills a basin ("basin fill") that is not lithified is typically lumped together in the term alluvial. Alluvium can contain valuable ores such as gold and platinum and a wide variety of gemstones. Such concentrations of valuable ores is termed a placer deposit.

6.2 PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

Texture classes are defined by relative contents of three major soil separates; sand, silt and clay ; present in the soil that has been passed through a 2 mm sieve; for the removal of all coarser particles. Such a sieved soil is called " fine earth " and is called either the particle size distribution or mechanical composition. According to studied by Agriculture, Estate, and Livestock Service of Ngada, physical of soil and chemical properties of soil (table 6.2 and table 6.3).

Tabel 6.2 Physical and Chemical Properties of Soil of District Ngada

(The particle size distribution,PH,Phosphate (P) retention,P2O5 and K2O-25%HCL of Ngada District)

Horizon Depth (cm)	Particle size distribution (%)			Textural Class/PSC	Silt/Clay ratio	PH		P-rentention	Org. C	HCL 25 % extract	
	Sand	Slit	Clay			H_20	NaF	%	%	P_2O_5	K_2O
Pedon K-1 (>1200 m asl)											
0-25	72.1	19.6	8.3	SiCl/Colo	2.36	5.7	11.2	78	3.61	52	39
25-51	67.9	25.1	7.0	SiL/Colo	3.59	5.8	11.3	79	2.62	34	35
51-112	66.2	26.0	7.8	SiL/Colo	3.33	6.0	10.9	65	1.40	-	-
112-150	20.0	70.5	9.5	SiL/Colo	7.43	5.8	10.7	74	3.95	-	-
150-180	34.9	29.6	35.5	SiC/Fine	0.83	6.1	9.5	50	1.46	-	-
Pedon K-2 (500-1000 m asl)											
0-16	55.4	26.2	18.4	SiL/Filo	1.42	5.9	9.2	31	1.90	50	62
16-42	52.7	28.6	18.7	SiL/Filo	1.53	6.1	9.4	36	1.62	42	88
42-70	55.8	24.3	19.9	SiCL/Filo	1.22	6.4	9.3	33	1.47	41	83
70-90	54.6	29.3	15.9	SiCL/Colo	1.86	6.5	9.3	30	0.81	-	-
90-130	51.1	30.5	18.4	SiCL/Filo	1.66	6.6	9.3	32	0.62	-	-
Pedon K-3 (0-500 m asl)											
0-15	43.6	27.1	29.3	L/Filo	0.92	6.3	9.4	36	2.01	7	51
15-45	17.1	29.7	53.2	C/Fine	0.56	6.4	8.9	28	1.04	5	24
45-78	15.3	36.3	48.4	C/Fine	0.75	6.5	9.0	29	0.82	6	16
78-108	23.7	41.0	35.3	CL/Fine	1.15	6.6	9.3	33	0.72	-	-
108-153	29.1	39.9	31.0	CL/Filo	1.23	6.7	9.4	35	0.70	-	-

Source : Agriculture, Estate, and Livestock Service of Ngada

Soil toposequence of Ngada District showed that elevation significantly influenced soil properties. With the lower elevation, the degree of soil weathering increased as reflected by increasing clay content. Soil pH, exchangeable cations, and base saturation also increased. On the contrary, contents of organic carbon, amorphous material, and P retention decreased. Soil physical properties tend to change, as shown by increasing bulk density and decreasing values of total pore space and available moisture content.

Table 6.2 Physical and Chemical Properties of Soil of District Ngada

(Exchangeable cations, CEC, acid ammonium oxalate extractable Al and Fe, and physical properties of Ngada District)

Horizon Depth (cm)	Exchangeable Cations ....(cmol (+) kg^{-1})........					NH4OAc PH 7.0 ext.		Acid amm.oxalate extr.			Physical Property		
	Ca	Mg	K	Na	Total	Soil-CEC	BS	Al_o	Fe_o	Al_o+ 0.5 Fe_o)	BD	TPS	AMC
	.........(cmol (+) kg^{-1})........						%	..............%................			g.cm^{-3}	...%......	
Pedon K-1 (>1200 m asl)													
0-25	11.4	1.55	0.30	0.11	13.37	13	100	1.40	0.67	1.7	1.01	62	19.1
25-51	6.32	1.16	0.31	0.09	7.88	11	75	1.29	0.57	1.6	-	-	-
51-112	5.92	0.97	0.31	0.15	7.35	8	96	1.18	0.65	1.5	-	-	-
112-150	20.6	2.37	1.13	0.36	24.54	28	89	1.19	0.68	1.5	-	-	-
150-180	13.3	2.24	1.92	0.48	17.93	18	100	0.44	0.82	0.8	-	-	-
Pedon K-2 (500-1000 m asl)													
0-16	10.3	2.45	0.72	0.12	13.63	14	100	0.34	0.69	0.7	1.14	57	10.4
16-42	9.8	2.66	0.83	0.13	13.39	13	95	0.36	0.74	0.7	-	-	-
42-70	10.5	3.34	0.85	0.18	14.87	15	100	0.41	0.79	0.8	1.18	55	6.8
70-90	9.55	3.21	0.73	0.21	13.70	14	100	0.33	0.66	0.7	-	-	-
90-130	11.4	4.12	0.65	0.27	16.40	16	100	0.22	0.34	0.4	-	-	-
Pedon K-3 (0-500 m asl)													
0-15	14.6	4.34	0.65	0.19	19.75	21	94	0.34	-	-	-	-	-
15-45	21.6	6.12	0.17	0.76	28.68	36	81	0.21	-	-	-	-	-
45-78	22.7	6.36	0.11	0.95	30.11	38	79	0.23	-	-	-	-	-
78-108	22.8	6.49	0.09	1.01	30.35	38	80	0.29	-	-	-	-	-
108-153	21.9	6.62	0.09	0.93	29.62	38	77	0.32	-	-	-	-	-

Source : Source : Agriculture, Estate, and Livestock Service of Ngada

The soils were developed from andesitic volcanic materials, with high amount (54-73%) of weatherable minerals. Soils developed from Andisols (Typic Hapludands) at 1,200-1,000 m asl, and Mollisols (Typic Hapludolls) at 550 m asl. Soils between 1,200 and 1,000 m asl are potentially developed for food crops, highland vegetables, and estate crops. Soils at lower elevation is generally fertile and suitable for growing food crops and estate crops.

6.3 IRRIGATION SYSTEM THEIR STORAGE

Irrigation has important bearing on agricultural production. Modernization of agricultural has given further boost to its importance. People of this area since time long are used to irrigate their lands whenever and wherever possible.

Generally in Indonesia, irrigation system are classified into four types : technical , semi-technical, simple and village managed. (i)Technical system have permanent canals and control structures. The Government control of water distribution is up to the tertiary level. (ii) Semi technical system have only few permanent control or distribution structures and are managed by the farmers . (iii) Simple system have only few permanent control or distribution structures and are managed by the farmers. (iv) Village managed irrigation system are developed and managed by farmers.

Table 6.3 show the potential irrigated land and the functional of the land by irrigation system. The amount of area has applied by irrigation system is 4,259 ha of land area in the district Ngada, and the remaining is 2,256 ha rainfed area.

Irrigation method used in most of the District Ngada using surface irrigation, water taken from the river using a intake building. So the dependence on rainfall is very high, because it does not use a reservoir that is usually used as a reserve of water for use during the dry season. This method is usually for lowland areas / sawah , but for upland areas rely solely on rain.

Table 6.3 The functional of the land by the Irrigation System							
No	**Sub District**	**Low land (Ha)**					
		Technical	**Semi technical**	**Simple**	**Village Managed**	**Rain fed Land**	
1	Aimere	-	-	-	12.00	-	12.00
2	Jerebuu	-	-	-	28.00	-	28.00
3	Bajawa	-	-	30.00	29.00	-	59.00
4	Golewa	-	270.00	90.00	346.00	288.00	994.00
5	Bajawa Utara	-	51.00	50.00	325.00	-	426.00
6	Soa	-	1,378.00	85.00	1,029.00	252.00	2,744.00
7	Riung	-	-	30.00	-	520.00	550.00
8	Riung Barat	-	136.00	50.00	270.00	696.00	1,152.00
9	Wolomeze	-	50.00	-	-	500.00	550.00
	Total	-	**1,885.00**	**335.00**	**2,039.00**	**2,256.00**	**6,515.00**

Source : BPS, Ngada in Figures 2009(District Statistical Officer, Ngada)

6.4 COMMANDED AREA PERFORMANCE

6.4.1 Land area availability and utilization

The availability of agricultural land in the district is 26,495 ha or 16.4% total area of Ngada District , which is divided into two, namely Lowland/Wetland and Upland. Fig. 2.3 show the amount of lowland area is 6,515 ha or 4.02% total area of Ngada District ; in the lowland area divided into irrigated area is 4,259 ha and rainfed area 2,256 ha and the amount of upland area is 19,980.04 ha or 12.33% total area of Ngada District.

Farmers in Ngada District using the irrigated area and rainfed area only for paddy plants but in upland area , they are may be using for upland paddy or "gogo rancah" , maize, cassava and legumes. In table 6.4 show the utilization of land by the farmers for cultivation of different crops in one season/rainy season.

Table 6.4 Area occupied by crops under existing cropping pattern of Ngada District							
No	Crops	Irrigated Area 4,259 ha	%	Rainfed Area 2,256 ha	%	Upland Area 19,980 ha	%
1	Paddy Lowland	4,259.00	100.0	2,256 ha	100		
2	Paddy Upland					3,626.44	18.15
3	Maize					11,919.69	59.66
4	Soybean					1,390.63	6.06
5	Groundnut					520.44	2.60
6	Mungbean					390.06	1.95
7	Cassava					2,443.53	12.2

Source : Source : Agriculture, Estate, and Livestock Service of Ngada

6.4.2 Total Water Availability

Dry land and a dry climate (8 months dry, 4 months rainy) in dependable 75 % are common characteristics of Ngada. Although there is semi-technical irrigation in some parts of Ngada, water availability for plantations is limited. Farmers plant drought-tolerant food crops that need little water after the paddy crop has been harvested.

Besides rainfall, canal water from the Aesesa river is the major sources of water irrigation in the command area, flowing from center to north, which irrigates the Bajawa, Soa, Golewa, and Riung Barat sub district . Total command area of the Ngada district is about 4,259 ha or 2.63 % total area of the Ngada district. The discharge at the head in the main canal is 3.15 m3/s and length of the main canal is 10.3 km, whereas the length of distribution canals is about 65.17 km. The canal starts the supply of water from the first week of January to end of March at a rate of 3.15 m3/s. Thereafter, it supplies at 1.58 m3/s, i.e., at 50% of discharge during April, May, and June. In July and Agustus , the supply decreases to 0.8 m3/s, and from September, October to end of November, it supplies water at a rate of 1.2 m3/s. The detail regarding allocation and availability of water from on this commanded area project are given in table 6.5

Table 6.5 Allocation and availability of canal water in irrigated area

No	Months	Discharge (m^3/s)	Volume of water Allocated (ha.m)	Seepage Losses from Main Canal (ha.m)	Volume of Water available (ha.m)
1	January	3.15	843.70	168.74	674.96
2	February	3.15	762.05	152.41	609.64
3	March	3.15	843.70	168.74	674.96
4	April	1.58	409.54	81.91	327.63
5	May	1.58	423.19	84.64	338.55
6	June	1.58	409.54	81.91	327.63
7	July	0.80	214.27	42.85	171.42
8	August	0.80	214.27	42.85	171.42
9	September	1.20	321.41	64.28	257.13
10	October	1.20	321.41	64.28	257.13
11	Nopember	1.20	321.41	64.28	257.13
12	December	3.15	843.70	168.74	674.96

Total alocation during the year (average)	5,928.16 ha m
Total losses in main canal	1,185.63 ha m
Water available at outlet head	4,742.53 ha m

Source : Source : Agriculture, Estate, and Livestock Service of Ngada

According to the study of the Water Resources & River Regional II Bureau, Nusa Tenggara , Ministry of Public Works, Republic of Indonesia, groundwater Potential in the watershed Aesesa is 13,602 ha.m per year, but this water source has not been used by farmers for agriculture but only for drinking water in the region coast.

For Rainfed and Upland area, just rely on rainwater for agriculture and one growing season, for this purpose we have find effective rainfall every month;

- If P (normal rainfall) > 75 mm, so Pe (effective rainfall) = 0.8*P-25
- If P (normal rainfall) < 75 mm, so Pe (effective rainfall) = 0.6*P-10

The detail regarding allocation and availability of water from on this comammded area project are given in table 6.6

Table 6.6 Allocation and availability of Rainfed area and Upland Area

No	Months	Normal Monthly Rainfall (mm)	Effective Rainfall (mm)	Rainfed Area (2,256 ha)	Upland Area (19,980.04 ha)
1	January	353.21	257.56	581.05	5146.06
2	Pebruary	321.13	231.90	523.17	4633.37
3	March	332.01	240.61	542.82	4808.40
4	April	202.06	136.65	308.28	6159.45
5	May	144.94	90.95	205.18	1817.18
6	June	96.92	52.54	118.53	1049.75
7	July	61.78	27.07	61.07	540.85
8	August	13.35	-	-	-
9	September	36.96	12.18	27.47	243.36
10	October	58.20	24.92	56.22	497.90
11	Nopember	187.28	124.83	281.62	2494.11
12	December	357.66	261.13	589.12	5217.39
Total water available during the year				3,294.53 ha m	32,607.82 ha m

6.5 Cost of Cultivation and Benefit Parameters

The Cost of cultivation of various crops in this study area is different each others that is depending upon the agricultural practice, such as; land preparation, seed & sowing, transplanting, weeding after planting, fertilizer, plant protection, harvesting, threshing. Transplanting is only for paddy crops. The wage unit price or rental of equipment and materials based on local prices are set by the district government Ngada. The price of each unit of work for each type of crops is different, depending on the level of difficulty. Detailed calculation for cost cultivation in different crops are given in Annexure D. Based on the agricultural inputs and produced crops in the study area, net benefits per hectare for various crops are given in table 6.7.

Table 6.7 Net benefit for various crops							
Sl No.	Crops	Grain yield (Kg/ha)	Unit prices (Rs/ha)	Total receipts (Rs/ha)	Cost of cultivation (Rs/ha)	Income tax 2.5 % grain yield	Net benefit (Rs/ha)
1	Paddy Lowland	3,404.49	13,85	47,139.08	27,075.51	1,178.48	18,885.09
2	Paddy Upland	2,142.24	13.85	29,661.75	19,572.95	741.54	9,347.26
3	Maize	2,104.71	14.36	30,221.43	14,638.46	755.54	14,827.43
4	Soybean	867.65	33.33	28,921.59	17,216.41	723.04	10,982.14
5	Groundnut	883.19	46.15	40,762.52	16,956.92	1,019.06	22,786.53
6	Mungbean	713.18	43.59	31,087.41	16,956.92	777.19	13,353.30
7	Cassava	10,708.01	6.15	65,895.45	18,914.36	1,647.39	45,333.71

CHAPTER VII

WATER REQUIREMENTS OF CROPS

7.1 CALCULATION OF ETO BY DIFFERENT METHODS

Four different methods viz. (i) the Blaney Criddle (ii) the Radiation Method (iii) the Modified penman and (iv) the Penman Monteith were used to calculate the ETo. The comparative analysis of ETo using USWB Pan Evaporation, Blaney Criddel, Radiation, Modified Penman and Penman Moteith methods are presented in Table 7.1

Table 7.1 Comparative Analysis of ETo calculated using different methods

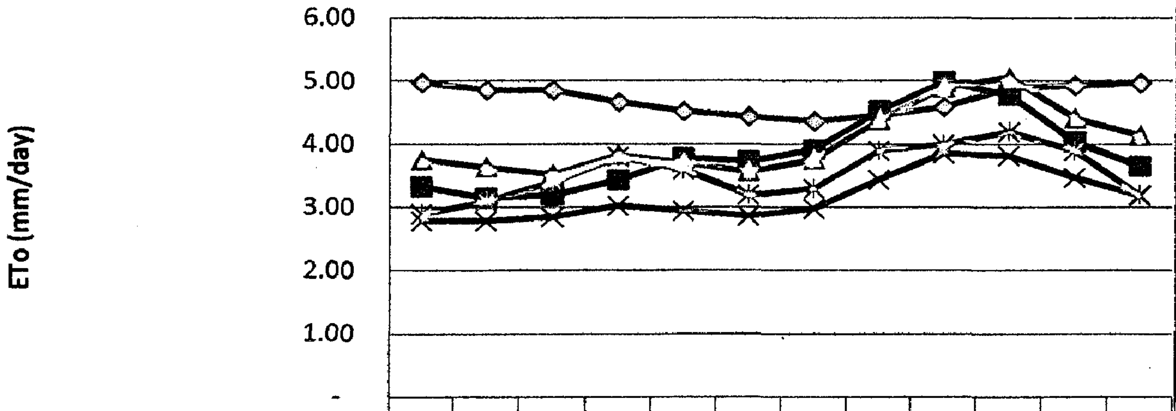
Month	Monthly Average ETo (mm/day)				Ep. USWB Pan
	Blaney Criddle	Radiation	Modified Penman	Penman Monteith	
January	4.97	3.32	3.80	2.79	2.90
February	4.86	3.15	3.66	2.79	3.10
March	4.85	3.19	3.60	2.85	3.40
April	4.66	3.43	3.77	3.02	3.80
May	4.52	3.78	3.77	2.95	3.60
June	4.44	3.73	3.67	2.87	3.20
July	4.37	3.91	3.84	2.98	3.30
August	4.45	4.53	4.39	3.44	3.90
September	4.59	4.99	5.02	3.86	4.00
October	4.89	4.78	4.95	3.82	4.20
November	4.93	4.04	4.41	3.48	3.90
December	4.97	3.65	4.11	3.19	3.20
Average	4.71	3.88	4.08	3.17	3.54

Ep: Pan evaporation by USWB Pan

The obtained result are compared with the measured USWB pan evaporation data to find out the most suitable method for this region in the section 3.2 in previous chapter. The average annual of ETo obtained by Blaney Criddle, Radiation, Modified Penman, and Penman monteith methods are 4.71, 3.88, 4.08, 3.17 mm/day respectively. Table 7.1 shows that the highest average value is obtained from Blaney Criddle Method, and the lowest average value obtained from Penman Monteith method, among all four methods taken for the comparative analysis. The values obtained from Penman Monteith Method and USWB Pan evaporation values are closer to each other.

By the correlation in every months values of ETo shown the the values of Penman Monteith method and USWB Pan evaporation are 0.848. The Penman monteith method is more realistic than other methods compared with USWB Pan evaporation. Thus we can use the Penman Monteith method to calculate ETo values are used further for computing ET crops values for determine crop water requirement. All the methods show peak values in the month april and October (Fig.7.2). Detailed calculation for ETo in different methods and PET are given in Annexure B.

Fig.7.2 ETo in different Methods of Ngada District from 2009 until 2009



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Blaney-Criddle Method	4.9	4.8	4.8	4.6	4.5	4.4	4.3	4.4	4.5	4.8	4.9	4.9
Radiation Method	3.3	3.1	3.1	3.4	3.7	3.7	3.9	4.5	4.9	4.7	4.0	3.6
Modified Penman Method	3.7	3.6	3.5	3.8	3.7	3.5	3.7	4.3	4.9	5.0	4.4	4.1
Penman Monteith Method	2.7	2.7	2.8	3.0	2.9	2.8	2.9	3.4	3.8	3.8	3.4	3.1
Ep. USWB Pan	2.9	3.1	3.4	3.8	3.6	3.2	3.3	3.9	4.0	4.2	3.9	3.2

7.2 AGROCLIMATIC CLASSIFICATION OF DISTRICT NGADA

The are four accepted methods available for climatic classification and suitability of crop.

7.2.1 Thornthwaite's Classification

With 75 % probability level of annual rainfall the Moisture Availability Index (MAI) for Thornthwaite's classification is given by :

MAI = 100 (P/PET – 1)

Where,

P = annual precipitation at 75 % dependable level

PET = annual potential evapotranspiration per month

For Ngada district , P =1152 mm from Fig.4.10 ; and PET = 900.2 mm (Annexure B).

= 100 (1152/900 – 1)

= 28

The MAI value is 28, thus according thornwathwaite's classification the climatic moisture condition is Humid.

7.2.2 Hargreaves Classification

Hargreaves has classified the moisture condition in a different way. He has developed Moisture Adequacy Index (MAI) using Thornthwaite's potential evaporation.

MAI = P/PET

Where P is 74 % dependable rainfall.

For this study area, MAI = 1152/900.2

= 1.28

The MAI value is 1.28 , thus the category is Adequate moisture.

7.2.3 Schmidt – Ferguson Classification

Schmidt – ferguson classified based on Q value, it is comparison between dry month (DM) and wet month (WM), and multiple 100%

Q = (DM/WM)* 100%

Where, DM = number of dry month with rainfall magnitudes in 75 % dependable per month are less than 60 mm , WM= number of wet month with rainfall magnitudes in 75 % dependable per month are bigger than 100 mm. In this study area DM are 6 months and WM are 4 ;

= (6/4) * 100

= 150

The Q value is 150 , thus the category is Somewhat dry climate, savanna forest. The Classification of Schmidt-Ferguson climate have utilized in forest and estates areas in Indonesia

7.2.4 Oldeman Classification

According to Oldeman classification criteria, Ngada district has wet months consecutively with rainfall magnitudes in 75 % dependable per month are 4 months; by this category mean the type is D and dry months are 8 months : mean the subdivision is 4 . Thus the classification is D4, this means Only rice field 1 times or 1 times secondary crop in farming system or the cropping pattern is rice field – secondary crop.

75 % dependable rainfall of Ngada district is given in table 7.2 according to it, there is no rainfall from August and September, very little May, June, July and April, November is little , thus very good in December, January, February and March.

Table 7.2 Mean Monthly Rainfall at Ngada District

Probability	January	February	March	April	May	June	July	August	September	October	November	December	Annual
90%	188.6	155.0	88.4	68.8	18.00	3.20	0.00	0.00	0.00	13.60	36.60	194.4	766.6
75%	231.2	214.0	196.5	73.5	22.50	28.75	17.50	0.00	0.00	23.50	79.50	265.5	1152.5
50%	316.0	316.0	316.0	144.0	66.00	79.00	33.00	11.00	12.00	37.00	118.0	376.0	1824.0
10%	601.8	449.3	538.6	446.0	500.3	241.6	200.5	42.40	118.9	146.3	400.4	510.2	4196.2
Mean (X)	353.2	321.1	332.0	202.1	144.9	96.9	61.8	13.4	37.0	58.2	187.3	357.7	2,165.5
S.D	152.8	106.4	168.0	143.6	172.0	90.8	65.2	17.4	70.9	53.3	133.3	112.9	639.3
C.V	0.43	0.33	0.51	0.71	1.19	0.94	1.06	1.30	1.92	0.92	0.71	0.32	0.30

7.3 CROP SELECTION AND GROWING SEASON

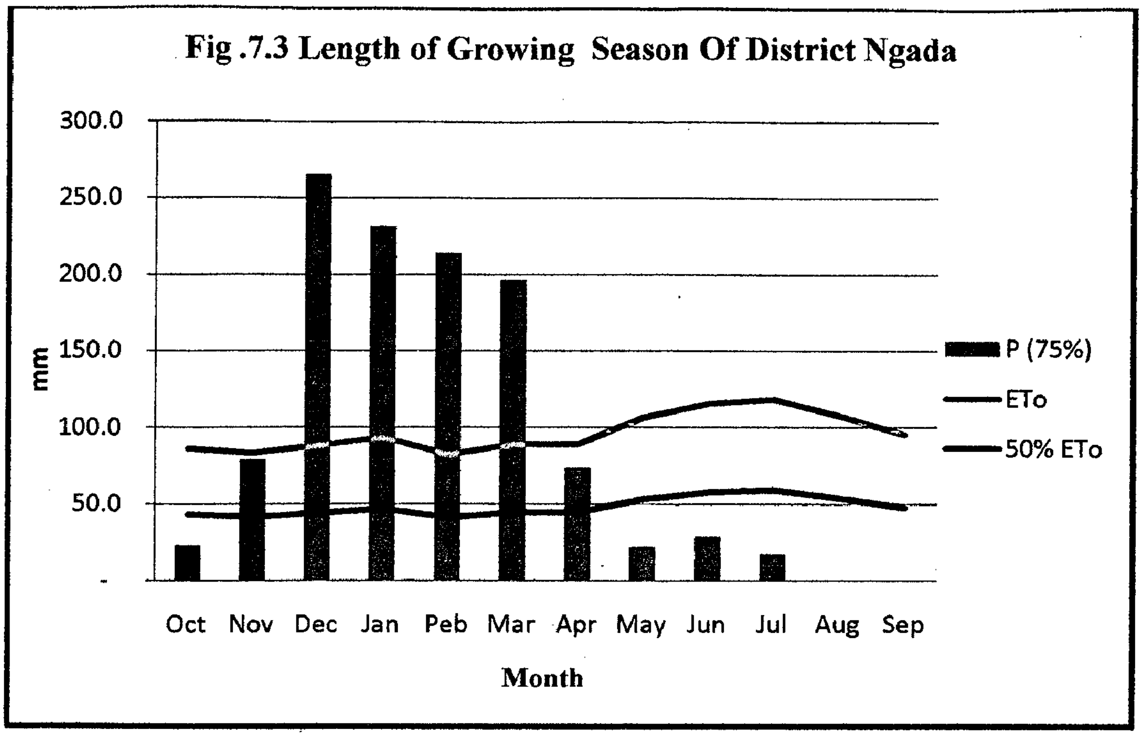
Beside the water availability, other important factors to consider in crop selection are prevailing climatic conditions and soils, the farmer preference and marketing potentials. These affect the choice of crops and crop varieties and the planting time. Table 7.3 shows that attribute of climatic and edaphic adaptability of some crops compares with the local climate in the study area.

In the figure 7.3 shown the length growing season of Ngada district according the occurring of rainfall consecutively in dependable 75 %.

Table 7.3 Attribute of climatic and edaphic adaptability of some crops

Attribute of Climate	Rice/ Paddy	Maize	Soybean Groundnut Greengram	Cassava	Local Climate and Soil Condition
Climatic Adaptability					
Optimum Temperature (^{0}C)	22-30	20-24	25-30	20-30	19-26
Radiation intensity at Max PS (Cal/cm2/min)	1.0	1.0	0.3-0.8	1	0.27 (annual average)
Length of growing season (days)	90-120	152 (L) 148 (M) 126-137(S)	150-180(L) 105-135(S)		180
Suitable thermal Climate for Rainfed production	Warm	Warm	Warm	Warm	Warm (Humid)
Edaphic Adaptability					
Slope % (optimum)	0-8	0-8	0-8	0-8	0-25% (50% from total area)
Texture (optimum)	C-CL	L	L	L	0-15 cm =L,SiL,SiCl 15-50cm =C,SiL,SiCl 50-100cm=Cl,SiCl,SiL
(Marginal)	Kaolinite clay				
Depth (cm)	50			100	100
pH	5.5-6	5	5.2-5.8	4.5-8	0-15 cm = 5.7- 6.3 15-50cm =5.8-6.4 50-100cm=6.1- 6.7

Sources : After Kassam, et.al, 1980)



7.4 CALCULATION CROP WATER REQUIREMENT

The estimation of crop water requirement is one of the basic needs for crop planning on the fram and for the planning of any irrigation project. The crop water need (Etc) is defined as depth (amount) of water needed to meet the water loss through evaporation. In other words, it is the amount of water needed by various crops to grow optimally. The crop water requirement mainly depends on :

- The climate : in sunny and hot climate crop needs more water than in cloudy and cool water
- The crops types: crops like maize or sugarcane need more water than crops like millet or sorghum
- The growth stage of the crops : fully grown crops need more water than crop that have just been planted.
- The length of growing periode : crops are long growing period needs more water than crops are short growing period.

The influence of climate is given by the reference crop evapotranspiration (ETo) and the influence of crops is expressed in the crop factor (K_c). Here for ETo calculation four methods have been selected that is already discussed in section 7.1. Mainly seven crops have selected on this study area and all these seven crops are the food crops of people in Ngada district.

In previous chapters we have known the suitability between these seven crops and the variable of weather and climate in this study area. General information i.e crop duration, growing period, and K_c value for these crops are given in table 7.4. Detailed calculation for ETc and Net Irrigation Need for all these crops according to their planting dates are given in Annexure C.

Table 7.4 General information i.e crop duration, growing period, Planting date and K_c, CU, and NIR value for these crops

No	Types of Crops	Crops Duration	Growing Season	Planting date	Kc				Consump-tive Use	NIR	Land of Cultivation
					initial	devolpment	mid	Late			
1	Paddy Lowland	150 days [a)]	November - April	Des 1	0.9	1.2	1.2	0.8	1,302.6 mm	304.7 mm	Irrigated area / Rainfed area
2	Paddy Upland	120 days		Des 1	0.9	1.12	1.2	0.7	360.1 mm	-	Upland
3	Maize	130 days		Nov 10	0.4	0.8	1.2	0.7	304.7 mm	-	Upland
4	Soybean	135 days		Nov 10	0.4	0.8	1.1	0.6	333.7 mm	-	Upland
5	Groundnut	130 days		Nov 5	0.5	0.8	1.1	0.7	276 mm	-	Upland
6	Green gram	75 days		Jan 15	0.4	0.7	1.1	0.9	173.1 mm	-	Upland
7	Cassava	210 days		Nov 1	0.3	0.8	0.8	0.3	369.5 mm	-	Upland

a) including nursery : 30 days in November

CHAPTER VIII

OPTIMAL CROPPING PATTERN IN NGADA DISTRICT

8.1 INTRODUCTION

To fulfill the high demand for food, fiber and fuel due to the increasing population, it is necessary to bring more area under cultivation or to increase production per unit area of available land and water resources. For increasing of the additional area under cultivation is difficult due to urbanization and a reluctance to disturb natural environments. Also, the allocation of water for irrigation will probably decrease from the present level by 90 to 75-80% over *the* next *10-15* years (Sivanappan, 1995). Therefore, *it is* important to optimize *the* available land and water resources to achieving maximum returns. The existing cropping pattern has been the same for many years and may not utilize resources at maximum economic efficiency. Diversification of cropping pattern could maximize the net return per unit quantity of land and water available from different sources.

In this research, we consider the crop planning problem. Generally, the farmland and water allocation are limited or might be decrease from year to year, for this reason as an agricultural manager or a farmer who wants to earn as much as possible income should using the farmland effectively. Then, the crop planning problem decides the planting ratio which maximizes farmer's income. The crop planning problem is usually formulated as a linear programming problem.

Linear programming models can handle a large number of constraints and thus, are an effective tool to aid in the optimization process. Hall and Dracup (1970) proposed a linear programming model to maximize net return and select an optimal cropping pattern. Panda et al. (1983) applied linear programming models for conjunctive use of surface and groundwater to a canal command area of Punjab and observed considerable improvement in both the economic return as well as utilization of land and water resources by adopting an optimal cropping pattern. The present study was conducted with the objective of finding the optimal cropping pattern giving the maximum net return at different water availability levels.

8.2 AREA ALLOCATION MODEL

The model was run at 100, 75 and 65 % of total water availability levels subject to the constraints of water availability for one year growing season, land area constraints in different seasons, especially for the secondary season, for this purpose we introduction the new cropping pattern only for irrigated and rainfed area and we should try to introduction the new cropping pattern. In table 6.4 previous chapter we have shown the area occupied by the crops under exiting cropping pattern, 100 % both two land cultivation panted by paddy. Thus by this optimization according allocation of water and land for this constraints we keep paddy good production for supporting demand in food for Ngada people.

constraints in different seasons.

The model used is a linear programming model consisting of three parts: (i) a linear objective function for maximization of *net return;* (ii) a set of linear constraints; and (iii) a set of non-negativity constraints. The model was formulated to allocate the land area between various crops in order to maximize the net return from the command area. It was subject to the availability of canal water or water from rainfall, land area limitations under different crops and in different seasons of the year. The model (Singh et al., 1997) used was as follows ;

1. **The objective function:**

   Maximize $Z = \sum C_i X_i;\ \ for\ i = 1,2,3, \ldots ,N$ (8.1)

   where Z is the total net return from all the crops (Rs.), N the number of crops, C_i the net return from i_{th} crop (Rs./ha), X_i the crop area under i^{th} crop (a decision variable) (ha). The objective function was subject to linearity and non-negativity constraints. (***see table 6.7 net benefit for various crops***)

2. **The linearity constraints**

   - Water availability constraints:

     $\sum W_i X_i \le W_t$ (8.2)

     where W_i is the water requirement for i^{th} crop (m), Wt the total water available from *canal* and ground water (ha m). The allocation of water from canal outlet is calculated from December until July, this is based on the growing season in the rainy season and the next crop planning problem decides the planting ratio which maximizes farmer's income. The crop planning problem is usually formulated as a linear programming problem.

Linear programming models can handle a large number of constraints and thus, are an effective tool to aid in the optimization process. Hall and Dracup (1970) proposed a linear programming model to maximize net return and select an optimal cropping pattern. Panda et al. (1983) applied linear programming models for conjunctive use of surface and groundwater to a canal command area of Punjab and observed considerable improvement in both the economic return as well as utilization of land and water resources by adopting an optimal cropping pattern. The present study was conducted with the objective of finding the optimal cropping pattern giving the maximum net return at different water availability levels.

8.2 AREA ALLOCATION MODEL

The model was run at 100, 75 and 65 % of total water availability levels subject to the constraints of water availability for one year growing season, land area constraints in different seasons, especially for the secondary season, for this purpose we introduction the new cropping pattern only for irrigated and rainfed area and we should try to introduction the new cropping pattern. In table 6.4 previous chapter we have shown the area occupied by the crops under exiting cropping pattern, 100 % both two land cultivation panted by paddy. Thus by this optimization according allocation of water and land for this constraints we keep paddy good production for supporting demand in food for Ngada people.

The population of Ngada people is 138,050 inhabitants according district Statistical Officer,Ngada in table 2.1. Thus demand of rice is 30,232.95 ton per year, because rice is staple food of people in Ngada district , this assumption if one person need 0.6 kg rice in day. Thus the contribution of paddy production from lowland area is 30,232.95 ton – 7,558 ton = 22,050 ton per year.

We have know the production and area allocation for legumes crops is very low in Upland area if we compare with Maize and Cassava, but according to the table 7.3 attribute of climate and edaphic of some crops the legumes crops like ; Soybean, Groundnut, Greengram is suitable for this area and the price of this tree kinds of crops adequate high in the market. As this reason we try to introduction this new cropping pattern in Irrigated area and Rainfed Area and make Optimization follow as by this some condition:

1. This Optimization only for Irrigated Area and Rainfed area considering their water and area potential ; water supply and ground water in rainy season and dry season
2. We should keep the paddy lowland area for equal or not less 5,255.5 ha
3. We introduction the the legumes crops in lowland area (Irrigated amd Rainfed area Fig 8.1.
4. In the lowland area we should try in to two season planting.
5. This model was run at 100, 75 and 65 % of total water availability levels subject to the constraints of water availability, land area

constraints in different seasons.

The model used is a linear programming model consisting of three parts: (i) a linear objective function for maximization of *net return;* (ii) a set of linear constraints; and (iii) a set of non-negativity constraints. The model was formulated to allocate the land area between various crops in order to maximize the net return from the command area. It was subject to the availability of canal water or water from rainfall, land area limitations under different crops and in different seasons of the year. The model (Singh et a1., 1997) used was as follows ;

1. **The objective function:**

   Maximize $Z = \sum C_i X_i$; *for* $i = 1,2,3, \ldots ,N$ (8.1)

   where Z is the total net return from all the crops (Rs.), N the number of crops, C_i the net return from i_{th} crop (Rs./ha), X_i the crop area under i^{th} crop (a decision variable) (ha). The objective function was subject to linearity and non-negativity constraints. (***see table 6.7 net benefit for various crops***)

2. **The linearity constraints**

   - Water availability constraints:

     $\sum W_i X_i \leq W_t$ (8.2)

     where W_i is the water requirement for i^{th} crop (m), Wt the total water available from *canal* and ground water (ha m). The allocation of water from canal outlet is calculated from December until July, this is based on the growing season in the rainy season and the next secondary crops so the total is 2469.83 ha.m

- Land area constraints in different seasons:

$$\sum X_i \leq A_k \tag{8.3}$$

where A_k is the area available for cultivation in different seasons of a year : i = 1- 4 for paddy, soybean, groundnut, greengram, and the same also for second season $(k = 2)$; i= 1 – 4 for paddy, soybean, groundnut, greengram. Thus for this reason the land area availability is twice of first season as; 2 x 13.030 ha.

- Food production constraints to fulfill the demand for rice and wheat to the population in the area:

$$\sum Y_i X_i \geq F_j \tag{8.4}$$

where Y_i is the yield of ith crop (quintals/ha), Fj the total food requirement of ith crop (ton), $i = 1, j = 1$ for paddy. The total food requirement is 22,050 ton per year.

- Crop area constraints:

$$E_i \leq X_i \geq Mi \tag{8.5}$$

where E_i is the existing area under ith crop (ha), M_i the maximum area which may be kept under cultivation of ith crop (ha), i = 1- 4 for paddy, soybean, groundnut, greengram respectively.

3. Non-negativity constraints:

$$Xi \geq 0 \tag{8.6}$$

The Lingo13 optimization package has been used to solve the linear optimization model. The Lingo 13 package is capable of solving linear, integer, and quadratic optimization models. The Lingo 13 uses the revised simplex method to solve the linear optimization models. The Detailed of Lingo 13 Operation as shown in Annexure E

The optimal cropping pattern resulting from this area allocation model at different water availability is given in Table 8.1. The area under Paddy is stable because we keep the requirement; there was no change even at reduced water availability levels, but groundnut and greengram reduced from 6544 ha at 100% to 5112 ha at 75% and 0 ha at 65 % water availability level and also greengram 0 ha at 100% to 1432 at 75% and 5542 ha at 65 % water availability level.

Table 8.1 Net return received and area allocated under crops at different water availability levels

No	Crops	Area allocated at water availability (ha)		
		100 %	75%	65%
1	Paddy	6485	6485	6485
2	Soybean	00	00	00
3	Groundnut	6544	5112	00
4	Greengram	00	1432	5542
Net return (Rs)*		3,91,859.5	3,88,193.6	3,31,404

*) Rupees

CHAPTER IX

SUMMARY AND CONCLUSION

9.1 SUMMARY

The present study " **Crop Planning Under Variable Weather Condition in Indonesia**" , has been aimed to make analysis of agro climatic characteristic of the Ngada district area and selecting the local variety of crops. Thus analysis of changes in cropping pattern in irrigation area and rainfed area. Ngada district lies between 8^0- 9^0 South Latitude and 120^045'- 121^050' East Longitude is part Nusa Tenggara Timur Province – Indonesia is the area of study.

In the first step was determined the average variable of weather form the data during 1994 until 2009 such as; Temperature, Relative Humidity, Actual Shines, Rainfall. The local agroclimate classification in this study area should be finding by five methods (Koppen Classification, Thornthwaite's Classification, Hargreeves Classification, Schmidt – Ferguson Classification, and Oldeman Classification) and the purpose is to make the suitability between the food crops and the local soil and climate condition. The last result was conducted with the objective of finding the optimal cropping pattern giving the maximum net return at different water availability levels.

9.2 CONCLUSIONS

Based on the present study the following conclusion can be asserted :

1. The agroclimate classification in Ngada district is humid tropic with 4 wet months consecutively, 8 dry months so by Oldeman make this category the farming system in this study area is only rice field 1 times or 1 times secondary crop.
2. The Length of Growing Season by 50% ETo is 6 months, started from November and finish in April
3. The food crops are suitable for this area are ; Paddy, Maize, Soybean, Ground nut, Greengram, Cassava.
4. In Ngada district the land of cultivation consist of two ; lowland area (irrigated area and rainfed area)
5. The Optimization developed new cropping pattern for this study area especially for in lowland area (irrigated and rainfed Area) which before only one season , namely in rainy season to develop for second season with optimal cropping pattern consist of the crops such as ; paddy, groundnut, and green gram
6. With this optimization depends on the selection of crops, if the available water is 100%, depending on the preference of the benefits of planting food crops per kg of food crop prices high, but preference will move to food plants that requirement low water, if water is available.

REFERENCES

[1]. BPS Kabupaten Ngada, Ngada in Figures, 2009.

[2]. J.K Kakde , Agricultural Climatology, Metropolitan Book Co.Pvt. Ltd ,1985

[3]. Nanthachai Kantanantha, Cropping Decision Planning Under Yield and Prices Uncertainties, Georgia Institute of Technology, August 2007

[4]. Planning of Crop and Water Management Practices Using Weekly Rainfall Data, National Institute of Hydrology, Roorkee,1999-2000

[5]. F.H.S. Chiew , N.N. Kamaladasa, H.M. Malano, T.A. McMahon, Penman-Monteith, FAO-24 reference crops evapotranspiration and class-A pan data in Australia, 10 Nopember 1995

[6]. FAO Irrigation and Drainage Paper No. 56

[7]. FAO Irrigation and Drainage Paper No. 27

[8]. S.K. Tripathi, Manual on Agronomy for Engineers, Water use management by National Bank For Agriculture and Rural Development Bombay,November 1994

[9]. FAO/UNESCO/WMO Interagency Project On Agroclimatology, Technical Report ; A Study Of The Agroclimatology of The Humid Tropics of Southeast Asia

[10] D.K. Singh,C.S.Jaiswal,K.S Reddy, R.M. Singh, D.M. Bhandarkar, 2001 , Optimal Cropping pattern in a canal command area

[11] Deepak Khare,M.K. Jat, Ediwahyunan, 2006 , Assesment of Conjunctive Use Planning Options ; A case study of sapron irrigation command area of Indonesia

ANNEXURE A

A.1. Mean daily Percentage of Annual Day Time Hours for Different Latitudes (p)

Latitudes	North South	Jan Jul	Feb Aug	Mar Sep	Apr Oct	May Nov	Jun Dec	Jul Jan	Aug Feb	Sep Mar	Oct Apr	Nov May	Dec Jun
20^0		0.25	0.26	0.27	0.28	0.29	0.30	0.30	0.29	0.28	0.26	0.25	0.25
15^0		0.26	0.26	0.27	0.28	0.29	0.29	0.29	0.28	0.28	0.27	0.26	0.25
10^0		0.26	0.27	0.27	0.28	0.28	0.29	0.29	0.28	0.28	0.27	0.26	0.26
5^0		0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.27	0.27	0.27
0^0		0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27

A.2 Mean Monthly Extra-Terresterial Radiation (mm/day) (Ra)

Southern Hemiphere												
Latitudes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10^0	16.40	16.30	15.50	14.20	12.80	12.00	12.40	13.50	14.80	15.90	16.20	16.20
8^0	16.10	16.10	15.50	14.40	13.10	12.40	12.70	13.70	14.90	15.80	16.00	16.00
6^0	15.80	16.00	15.60	14.70	13.40	12.80	13.10	14.00	15.00	15.70	15.80	15.70
4^0	15.50	15.80	15.60	14.90	13.80	13.20	13.40	14.30	15.10	15.60	15.50	15.40
2^0	15.30	15.70	15.70	15.10	14.10	13.50	13.70	14.50	15.20	15.50	15.30	15.10
0^0	15.00	15.50	15.70	15.30	14.40	13.90	14.10	14.80	15.30	15.40	15.10	14.80

ANNEXURE A

A.3 Wind Correction (data are not collected at 2 m)

Measurement height, m	1.0	1.5	2.0	3.0	4.0	5.0	6.0	10.0
Correction factor	1.35	1.15	1.06	1	0.93	0.88	0.85	0.83

A.4 Saturation Vapour pressure $\mathbf{e_a}$ in mbar as function of mean air temperature t in ^{0}C

Temperature (^{0}C)	18	19	20	21	22	23	24	25	26
$\mathbf{e_a}$ (mbar)	20.6	22	23.4	24.9	26.4	28.1	29.8	31.7	33.6

A.5 Values of Weighting factor (1- W) for the effect of wind and humidity of ETo at different temperature and altitudes

Temperature (^{0}C)		18	20	22	24	26
(1-W) at altitude	m					
	0	0.34	0.32	0.29	0.27	0.25
	500	0.33	0.3	0.28	0.26	0.24
	1000	0.31	0.29	0.27	0.25	0.23
	2000	0.29	0.27	0.25	0.23	0.21

A.6 Values of Weighting factor (1- W) for the effect of wind and humidity of ETo at different temperature and altitudes

Temperature (^{0}C)		18	20	22	24	26
(1-W) at altitude	m					
	0	0.66	0.68	0.71	0.73	0.75
	500	0.67	0.70	0.72	0.74	0.76
	1000	0.69	0.71	0.73	0.75	0.77
	2000	0.71	0.73	0.75	0.77	0.79

ANNEXURE A

A.7 Conversion Factor for extra -terresterial radiation to net solar radiation Rns for a given reflection α of 25 % and different ratios of actual to maximun sunshine hours (1-α) (0.25 + 0.5 n/N)

n/N	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
(1-α) (0.25 + 0.5 n/N)	0.26	0.28	0.30	0.32	0.34	0.36	0.34	0.39	0.41

A.8 Mean daily maximun duration of bright sunshine hours N for difference in months and latitudes

	Southern Hemiphere											
Latitudes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20^0	13.20	12.80	12.30	11.70	11.20	10.90	11.00	11.50	12.00	12.60	13.10	13.30
15^0	12.90	12.60	12.20	11.80	11.40	11.20	11.30	11.60	12.00	12.50	12.80	13.00
10^0	12.60	12.40	12.10	11.80	11.60	11.50	11.60	11.80	12.00	12.30	12.60	12.70
5^0	12.30	12.30	12.10	12.00	11.90	11.80	11.80	11.90	12.00	12.20	12.30	12.40

A.9 Correction for temperature f (t) on long-wave radiation R_{nl}

Temperature (^{0}C)	18	20	22	24	26
f (t) = 0 Tk^4	14.2	14.6	15	15.4	15.9

A.10 Correction for Vapour pressure f (ed) on long-wave radiation R_{nl}

ed m bar	14	18	20	22	24
f (ed) = 0.34 - 0.444/√ed	0.18	0.15	0.14	0.13	0.12

ANNEXURE A

A.11 Correction for the ratio of actual and maximun bright sunshine hours f(n/N) on long-wave radiation R_{nl}

n/N	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
f(n/N)=0.1+ 0.9 n/N	0.28	0.33	0.37	0.42	0.46	0.51	0.55	0.60	0.64

A.12 Slope of saturation vapour pressure curve (Δ) for different air temperatures (T)

T mean (^{0}C)	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5
Δ = (kPa/^{0}C)	0.13	0.133	0.137	0.141	0.145	0.149	0.153	0.157	0.161	0.165

A.13 Psychometric Constant (γ) for different altitudes

Altitudes (m)	500	600	700	800	900	1000	1100	1200	1300
γ = (kPa/^{0}C)	0.064	0.063	0.062	0.061	0.061	0.06	0.059	0.058	0.058

A.14 Saturation vapour pressure (e^0) for different temperature (T)

T mean (^{0}C)	12	12.5	13	13.5	14	14.5	15	15.5	16	16.5	17	17.5
e^0 = (kPa)	1.403	1.449	1.498	1.547	1.599	1.651	1.705	1.761	1.818	1.877	1.938	2

T mean (^{0}C)	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5	23	23.5
e^0 = (kPa)	2.064	2.13	2.197	2.267	2.338	2.412	2.487	2.564	2.644	2.726	2.809	2.896

T mean (^{0}C)	24	24.5	25	25.5	26	26.5	27
e^0 = (kPa)	2.984	3.075	3.168	3.263	3.361	3.462	3.565

ANNEXURE A

A.15 Daily extraterresterial radiation (Ra) for different Latitudes in Southern Hemisphere for 15 day of the month

	Southern Hemiphere values in (MJ/m^2 per day)											
Latitudes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10^0	39.50	39.30	37.80	34.60	31.10	29.10	29.80	32.80	36.60	38.50	39.30	39.40
8^0	38.90	39.00	37.90	35.10	31.90	30.00	30.70	33.40	36.60	38.40	38.80	38.70
6^0	38.30	38.70	38.00	35.60	32.70	30.90	31.50	34.00	36.80	38.20	38.20	38.00
4^0	37.60	38.30	38.00	36.00	33.40	31.80	32.30	34.60	37.00	38.00	37.60	37.20
2^0	36.90	37.90	38.00	36.40	34.10	32.60	33.10	35.20	37.10	37.70	37.00	36.40
0^0	36.20	37.50	37.90	36.80	34.80	33.40	33.90	35.70	37.20	37.40	36.30	35.60

A.16 Mean dailight hours (N) for different Latitudes in the Southern for The 15th day month

	Southern Hemiphere values in (hours)											
Latitudes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10^0	12.50	12.30	12.10	11.80	11.50	11.40	11.50	11.70	11.90	12.20	12.50	12.60
8^0	12.40	12.30	12.10	11.80	11.60	11.50	11.60	11.70	12.00	12.20	12.40	12.50
6^0	12.30	12.20	12.00	11.90	11.70	11.70	11.70	11.80	12.00	12.10	12.30	12.30
4^0	12.20	12.10	12.00	11.90	11.80	11.80	11.80	11.90	12.00	12.10	12.20	12.20
2^0	12.10	12.10	12.00	12.00	11.90	11.90	11.90	11.90	12.00	12.00	12.10	12.10
0^0	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00

ANNEXURE A

A.17 σ (Tk) 4 Values at different temperatures

T mean (^{0}C)	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5
$\sigma(Tk)^4$= (kPa)MJ/m^2 per day	32.4	32.7	32.9	33.1	33.3	33.6	33.8	34.0	34.3	34.5	34.8	35.0

T mean (^{0}C)	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5
$\sigma(Tk)^4$= (kPa)MJ/m^2 per day	35.2	35.5	35.7	36.0	36.2	36.5	36.7	37.0	37.2	37.5	37.7	38.0

T mean (^{0}C)	24.0	24.5	25.0	25.5	26.0	26.5	27.0
$\sigma(Tk)^4$= (kPa)MJ/m^2 per day	38.2	38.5	38.8	39.0	39.3	39.5	39.8

A.18 Correction factors for length and number of days in a month, for use in the thornthwaite formula.

Southern Hemiphere												
Latitudes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15^0	1.12	0.98	1.05	0.98	0.98	0.94	0.97	1.00	1.00	1.07	1.07	1.12
10^0	1.08	0.97	1.05	0.99	1.01	0.96	1.00	1.01	1.00	1.06	1.05	1.10
5^0	1.06	0.95	1.04	1.00	1.02	0.99	1.02	1.03	1.00	1.05	1.03	1.06

ANNEXURE B

B.1. BLANEY - CRIDDLE METHODE CALCULATIONS

Give : Station name : Bajawa
Latitude : 8.5^0 South Longitudinal : 121^0 East
Altitude : 1250 m.

A. Equation :

$$Eto = p\ (0.46\ T\ mean + 8)$$

Eto = Reference crop evaporation (mm/day) as an average for a period of 1 month
Tmean = mean daily temperature (0C)
p = mean daily percentage of annual day time hours for different latitudes (**Annexure A.1**)

B. Data

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Tmax	24.2	23.6	24.4	24.8	25.0	24.5	24.4	24.7	25.8	26.2	25.8	24.2	
Tmin	16.8	17.0	16.2	15.6	14.4	13.5	12.5	12.2	13.3	15.0	15.9	16.8	
p	0.29	0.28	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.28	0.28	0.29	
T mean	20.54	20.32	20.28	20.15	19.71	19.02	18.44	18.48	19.58	20.61	20.89	20.51	
0.46 Tmean	9.45	9.35	9.33	9.27	9.07	8.75	8.48	8.50	9.00	9.48	9.61	9.43	
0.46 Tmean + 8	17.45	17.35	17.33	17.27	17.07	16.75	16.48	16.50	17.00	17.48	17.61	17.43	
ETo	**4.97**	**4.86**	**4.85**	**4.66**	**4.52**	**4.44**	**4.37**	**4.45**	**4.59**	**4.89**	**4.93**	**4.97**	

ANNEXURE B

B.2 RADIATION METHODE CALCULATIONS

Give :

Station name	:	Bajawa					
Latitude	:	8.5^0	South	Longitudinal	:	121^0	East
Altitude	:	1250	m.				

A. Equation :

$Eto = c (W * Rs)$

Eto = Reference crop evaporation (mm/day) as an average for a period considered

c = adjustment factor, which depends on mean humidity and day time wind conditions

W = weighting factor, which is a function of the temperature and altitude (**Annexure A.6**)

Rs = solar radiation at the ground level, expressed in equivalent evaporation in mm/day

$Rs = [(a_s +(b_s * n/N)] R_a$

Ra = Mean Monthly extra-terresterial radiation (mm/day) (**Anexure A.2**)

a_s 0.25 b_s 0.50

B. Data

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Ra	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0	
n	3.2	2.8	3.2	5.0	5.7	6.4	6.7	7.1	7.1	6.4	5.1	4.3	
N	12.25	12.35	12.10	12.60	11.70	11.70	11.75	11.85	12.00	12.25	12.50	12.50	
Tmax	24.25	23.61	24.35	24.75	24.98	24.50	24.37	24.72	25.81	26.17	25.83	24.23	
Tmin	16.83	17.04	16.20	15.55	14.44	13.54	12.51	12.24	13.35	15.04	15.94	16.79	
Tmean	20.54	20.32	20.28	20.15	19.71	19.02	18.44	18.48	19.58	20.61	20.89	20.51	
W	0.73	0.73	0.73	0.72	0.72	0.71	0.71	0.71	0.72	0.73	0.73	0.73	
Vwind	1.42	1.68	1.38	1.11	1.08	1.15	1.08	1.34	1.44	1.21	1.12	1.37	
RHmean	86.09	87.62	86.21	85.06	79.87	77.92	74.49	71.35	70.81	74.81	81.15	85.13	
c	0.74	0.74	0.74	0.74	0.81	0.81	0.81	0.85	0.85	0.81	0.76	0.74	

n/N	0.26	0.22	0.26	0.40	0.49	0.55	0.57	0.60	0.59	0.52	0.41	0.34	
(as + (bs*n/N))	0.38	0.36	0.38	0.45	0.50	0.52	0.54	0.55	0.55	0.51	0.46	0.42	
Rs	6.15	5.83	5.91	6.45	6.49	6.48	6.80	7.50	8.16	8.09	7.29	6.76	
ETo	**3.32**	**3.15**	**3.19**	**3.43**	**3.78**	**3.73**	**3.91**	**4.53**	**4.99**	**4.78**	**4.04**	**3.65**	

ANNEXURE B

B.3 MODIFIED PENMAN METHODE CALCULATIONS

Give :				
	Station name	:	Bajawa	
	Latitude	:	8.5^0 South	Longitudinal : 121^0 East
	Altitude	:	1250 m.	

A.Equation : Eto = c [W.Rn + (I - W) . f (u). (ea - ed)]

Eto	=	Reference crop evapotranspiration (mm/day)
e_a	=	Saturation vapuor pressure in mbar at the mean air temperatur in ^{0}C (**Annexure A.4**)
e_d	=	mean actual vapour pressure of the air in mbar
		e_a (RH mean / 100), RH = Relative Humadity.
u1	=	Wind speed at 4 m measurement height
u2	=	(U2 = c . U1) c = Wind Correction (**Annexure A.3**)
f (u2)	=	0.27 (1 + u2/100)
(1-W)	=	a temperature and elevation related weigthting factor for the effect of wind and humidity on Eto (**Annexure A.5**)
W	=	a temperature and elevation related weigthing factor for the effect of radiation on Eto (**Annexure A.6**)
Rn	=	net Radiation (same as $Qn=R_{ns} - R_{nl}$)
In Which,		
Rns	=	the net incoming shortwave solar radiation = $R_a(1-\alpha)(0.25 + 0.50\ n/N)$
		Values $(1-\alpha)(0.25+0.50\ n/N)$ in (**Annexure A.7**)
		in which R_a is same as QA or extraterresterial radiation, expressed in equivalent evaporation in mm/day
		(values of Ra in **Annexure A.2**)
		n/N is the ratio between actual and the possible hours of bright sunshine (Values of N in **Annexure A.8**)
Rnl	=	the net long wave radiation = f(t).f(ed).f(n/N), the values of which are given in (**Annexure A.9, A.10,A.11** , respectively)
c	=	adjusment factor to compensate for the effect to day and night weather conditions (Approxiamate values) for different areas given by Doorinbos and Pruit (FAO,1975) take values 1.09

B. Data

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Tmean	20.5	20.3	20.3	20.2	19.7	19.0	18.4	18.5	19.6	20.6	20.9	20.5	
RHmean	86.1	87.6	86.2	85.1	79.9	77.9	74.5	71.4	70.8	74.8	81.1	85.1	
n	3.23	2.77	3.18	4.98	5.73	6.38	6.71	7.06	7.14	6.42	5.14	4.31	
N	12.45	12.35	12.10	11.90	11.75	11.75	11.70	11.85	12.00	12.25	12.40	12.45	
n/N	0.26	0.22	0.26	0.42	0.49	0.54	0.57	0.60	0.59	0.52	0.41	0.35	
Ra	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0	
u_1	122.91	145.03	119.05	95.81	93.55	99.62	93.39	115.47	124.49	104.61	97.08	118.45	
u_2	114.31	134.87	110.72	89.10	87.00	92.65	86.86	107.39	115.78	97.29	90.29	110.16	
(0.25 +0.5n/N)	0.28	0.27	0.28	0.35	0.37	0.38	0.40	0.41	0.40	0.39	0.34	0.32	

C. Solving For Aerodynamic Term (1-W)* f(u)*(e_a - e_d)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
e_a	26.4	26.4	25.7	25.7	24.9	23.4	22.7	22.7	24.9	26.4	26.4	26.4	
e_d	22.7	23.1	22.2	21.9	19.9	18.2	16.9	16.2	17.6	19.8	21.4	22.5	
$e_a - e_d$	3.67	3.27	3.54	3.84	5.01	5.17	5.79	6.50	7.27	6.65	4.98	3.92	
$f(u_2)$	0.58	0.63	0.57	0.51	0.50	0.52	0.50	0.56	0.58	0.53	0.51	0.57	
(1-W)	0.28	0.27	0.27	0.28	0.28	0.29	0.29	0.29	0.28	0.27	0.27	0.27	
-W).f(u).(ea-ed)	0.6	0.6	0.5	0.5	0.7	0.8	0.8	1.1	1.2	1.0	0.7	0.6	

D. Solving For Radiation Term $W*R_n = W*(R_{ns} - R_{nl})$

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR

R_{ns}	4.5	4.3	4.3	5.0	4.8	4.7	5.0	5.6	6.0	6.2	5.5	5.1
f(t)	15.0	15.0	15.0	14.9	14.8	14.6	14.6	14.6	14.8	15.0	15.0	15.0
$f(e_d)$	0.12	0.12	0.13	0.13	0.13	0.14	0.15	0.16	0.15	0.14	0.13	0.12
f(n/N)	0.33	0.30	0.34	0.48	0.54	0.59	0.62	0.64	0.64	0.57	0.47	0.41
Rnl	0.60	0.54	0.66	0.92	1.04	1.20	1.35	1.44	1.36	1.16	0.89	0.74
Rn	3.9	3.8	3.7	4.1	3.7	3.5	3.7	4.2	4.6	5.1	4.6	4.4
W	0.73	0.73	0.73	0.72	0.72	0.71	0.71	0.71	0.72	0.73	0.73	0.73
ETo	**3.76**	**3.64**	**3.53**	**3.83**	**3.71**	**3.57**	**3.76**	**4.38**	**4.90**	**5.06**	**4.41**	**4.14**

ANNEXURE B

B. 4 PENMAN-MONTEITH METHODE CALCULATIONS

Give :

Station name	:	Bajawa				
Latitude	:	8.5^0	South	Longitudinal	:	121^0 East
Altitude	:	1250	m.			

A.Equation

$$ETo = \frac{0.408\,\Delta\,(Rn - G) + \gamma\,\frac{900}{T + 273}\,u2\,(es - ea)}{\Delta + \gamma\,(1 + 0.34\,u2)}$$

Where:

ETo	=	Reference evapotranspiration (mm/day)
Rn	=	Net radiation at the crop surface (MJ/m2 per day)
G	=	Soil heat flux density (MJ/m2 per day)
T	=	Mean daily air temperature at 2 m height (°C)
u2	=	Wind speed at 2 m height (m/sec)
es	=	Saturation vapour pressure (kPa)
ea	=	Actual vapour pressure (kPa)
es - ea	=	Saturation vapour pressure deficit (kPa)
Δ	=	Slope of saturation vapour pressure curve at temperature T (kPa/°C)
γ	=	Psychrometric constant (kPa/°C)

B. Data

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Tmax	24.2	23.6	24.4	24.8	25.0	24.5	24.4	24.7	25.8	26.2	25.8	24.2	
Tmin	16.8	17.0	16.2	15.6	14.4	13.5	12.5	12.2	13.3	15.0	15.9	16.8	
Tmean	20.5	20.3	20.3	20.2	19.7	19.0	18.4	18.5	19.6	20.6	20.9	20.5	
RHmean	86	88	86	85	80	78	74	71	71	75	81	85	
Rhmax	91	92	92	92	90	88	86	84	83	85	89	90	
RHmin	81	84	81	78	70	68	63	59	59	65	73	80	
Wind (km/d)	1.42	1.68	1.38	1.11	1.08	1.15	1.08	1.34	1.44	1.21	1.12	1.37	
Sunhours	3.23	2.77	3.18	4.98	5.73	6.38	6.71	7.06	7.14	6.42	5.14	4.31	
Tmean	20.54	20.32	20.28	20.15	19.71	19.02	18.44	18.48	19.58	20.61	20.89	20.51	
Δ (**Annexure A.12**)	0.15	0.15	0.15	0.15	0.14	0.14	0.13	0.13	0.14	0.15	0.15	0.15	
γ (**Annexure A.13**)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	
$(1+0.34u_2)$	1.48	1.57	1.47	1.38	1.37	1.39	1.37	1.45	1.49	1.41	1.38	1.47	
Δ/[Δ + γ (1+0.34u2)]	0.63	0.62	0.63	0.65	0.64	0.63	0.63	0.61	0.62	0.65	0.65	0.64	
γ/[Δ+γ (1+0.34u2)]	0.25	0.24	0.25	0.26	0.26	0.27	0.27	0.27	0.25	0.25	0.25	0.25	
[900/(Tmean+273)]u2	4.36	5.15	4.23	3.40	3.33	3.55	3.34	4.13	4.43	3.71	3.44	4.20	

C.Vapour pressure deficit												
$e^{0(Tmax)}$ (**Annexura A.14**)	3.00	2.89	3.02	3.09	3.13	3.05	3.02	3.09	3.29	3.36	3.30	3.00
$e^{0(Tmin)}$ (**Annexura A.14**)	1.90	1.93	1.83	1.76	1.64	1.54	1.44	1.42	1.52	1.70	1.80	1.90
e_s (saturation vapour pressure)	2.45	2.41	2.42	2.42	2.38	2.29	2.23	2.25	2.41	2.53	2.55	2.45
e_a derived from maximun and minimun relative humidity												
e^0(Tmin)Rhmax/100	1.73	1.77	1.68	1.62	1.47	1.36	1.24	1.19	1.26	1.44	1.60	1.72
e^0(Tmax)Rhmin/100	2.44	2.42	2.43	2.41	2.19	2.06	1.90	1.81	1.94	2.19	2.41	2.39
e_a	2.08	2.09	2.06	2.01	1.83	1.71	1.57	1.50	1.60	1.81	2.01	2.06
Vapour deficit (e_s-e_a)	0.37	0.32	0.37	0.41	0.55	0.58	0.66	0.75	0.81	0.72	0.54	0.39
D .Radiation												
Ra (**Annexure A.15**)	38.90	39.00	37.90	35.10	31.90	30.00	30.70	33.40	36.60	38.40	38.80	38.70
N (**Annexure A.16**)	12.40	12.30	12.10	11.80	11.60	11.50	11.60	11.70	12.00	12.20	12.30	12.30
n/N	26%	22%	26%	42%	49%	55%	58%	60%	59%	53%	42%	35%
Rs=(0.25+0.5n/N)Ra	14.79	14.13	14.45	16.18	15.86	15.82	16.56	18.42	20.04	19.71	17.80	16.46
Rso=[0.75+2(alt)/10^5]Ra	30.15	30.23	29.37	27.20	24.72	23.25	23.79	25.89	28.37	29.76	30.07	29.99
Rs/Rso	0.49	0.47	0.49	0.59	0.64	0.68	0.70	0.71	0.71	0.66	0.59	0.55
Rns=0.77*Rso	11.39	10.88	11.13	12.46	12.21	12.18	12.75	14.19	15.43	15.17	13.71	12.67
σTmax (**Annexure A.17**)	39.27	38.75	39.27	39.53	39.53	39.27	39.27	39.53	40.80	40.33	40.06	39.27
σTmin (**Annexure A.17**)	35.24	35.24	34.75	34.52	34.04	33.57	33.11	32.88	33.34	34.28	34.75	35.24
(σTmax+σTmin)/2	37.26	37.00	37.01	37.03	36.79	36.42	36.19	36.21	37.07	37.31	37.41	37.26
(0.34-0.14$\sqrt{e_a}$)	0.14	0.14	0.14	0.14	0.15	0.16	0.16	0.17	0.16	0.15	0.14	0.14
(1.35Rs/Ro-0.35)	0.31	0.28	0.31	0.45	0.52	0.57	0.59	0.61	0.60	0.54	0.45	0.39
Rnl	1.61	1.43	1.62	2.37	2.86	3.25	3.51	3.73	3.65	3.07	2.38	2.03
Rn=Rns-Rnl	9.79	9.45	9.51	10.09	9.35	8.93	9.24	10.46	11.78	12.10	11.33	10.64
Gday =0.14												
Gmonth=0.14(Tm-Tm-1)	0.52	-0.03	-0.01	-0.02	-0.06	-0.10	-0.08	0.00	0.15	0.14	0.04	-0.05
Rn-G	9.26	9.48	9.51	10.11	9.42	9.03	9.32	10.46	11.63	11.95	11.29	10.70
0.408(Rn-G)	3.78	3.87	3.88	4.12	3.84	3.68	3.80	4.27	4.74	4.88	4.61	4.36
E.Grass reference evaporation												
Δ/[Δ + γ (1+0.34u2)][0.408(Rn-G)]	2.40	2.39	2.46	2.66	2.47	2.32	2.38	2.61	2.95	3.15	3.01	2.78
γ/[Δ+γ (1+0.34u2)][900/(Tmean+273)]u2 (es-ea)	0.40	0.40	0.39	0.36	0.48	0.55	0.60	0.83	0.91	0.67	0.46	0.41
ETo	**2.79**	**2.79**	**2.85**	**3.02**	**2.95**	**2.87**	**2.98**	**3.44**	**3.86**	**3.82**	**3.48**	**3.19**

ANNEXURE C

C.1 Paddy Lowland / Rice

SI No	Description of Items.	Months								Total
		Novembe	December		January		Pebruary	March		
1	Numbers of days	30.0		31.0		31.0	28.0	30.0		150.0
2	Eto (mm/day)	3.2		2.8		2.8	3.0	3.0		
	Eto (mm)	95.6		86.5		86.4	84.7	90.7		
3	Nursery	30.0								
			Initial	**Development**		**Mid Season**		**Late Season**		
			30.0	**1.0**	**29.0**	**2.0**	**28.0**	**30.0**		**120.0**
4	Crop Coefficient (Kc)		0.9	1.2	1.2	1.2	1.2	0.8		
				1.1		1.2	1.2	0.8		
5	Consumptive Use Etc = Eto x Kc (mm)			91.3		107.2	101.6	72.6		
6	Land preparation,Puddling&Saturation	350.0		-		-	-	-		
7	Seepage & Percolation (5mm/day)	-		155.0		155.0	140.0			
8	Ponding	-		100.0		-	-	-		
	Total Consumtipve Use (mm)	**380.0**		**346.3**		**262.2**	**241.6**	**72.6**		**1,302.6**
9	Normal Monthly Rainfall,P (mm)	187.3		357.7		353.2	321.1	332.0		1,219.3
10	Effective Rainfall,Pe (mm)	124.8		261.1		257.6	231.9	240.6		875.4
11	**Net Irrigation Requirement (NIR) (mm)**	**255.2**		**85.2**		**4.6**	**9.7**			**354.6**
12	Field Irrigation Requirement (FIR) (mm)	340.2		113.6		6.1	12.9			472.8
13	Project Irrigation Requirement (PIR)(mm)	425.3		142.0		7.7	16.2			591.1

C.2 Paddy Upland

SI No	Description of Items	Months								Total
		Novembe	December		January		Pebruary	March		
1	Numbers of days			31.0		31.0	28.0	30.0		120.0
2	Eto (mm/day)			2.8		2.8	3.0	3.0		
	Eto (mm)			86.5		86.4	84.7	90.7		
3	Nursery									
			Initial	**Development**		**Mid Season**		**Late Season**		
			30.0	**1.0**	**29.0**	**2.0**	**28.0**	**30.0**		**120.0**
4	Crop Coefficient (Kc)		0.9	1.2	1.2	1.2	1.2	0.7		
				1.1		1.2	1.2	0.7		
5	Consumptive Use Etc = Eto x Kc (mm)			91.3		103.7	101.6	63.5		
6	Land preparation,Puddling&Saturation			-		-	-	-		
7	Seepage & Percolation (5mm/day)									
8	Ponding									
	Total Consumtipve Use (mm)			**91.3**		**103.7**	**101.6**	**63.5**		**360.1**
9	Normal Monthly Rainfall,P (mm)			357.7		353.2	321.1	332.0		1,032.0
10	Effective Rainfall,Pe (mm)			261.1		257.6	231.9	240.6		750.6
11	**Net Irrigation Requirement (NIR) (mm)**									-
12	Field Irrigation Requirement (FIR) (mm)									-
13	Project Irrigation Requirement (PIR)(mm)									-

ANNEXURE C

C.3. Maize

SI No	Description of Items	Months									Total
		Novembe	December		January		Pebruary		March		
1	Numbers of days	20.0		31.0		31.0		28.0	20.0		130.0
2	Eto (mm/day)	3.5		3.2		2.8		2.8	2.9		
	Eto (mm)	69.6		98.8		86.5		78.1	59.0		
3	Nursery	-		-		-		-	-		
		Initial	**Development**			**Mid Season**		**Late Season**			
		20.0	**10.0**	**21.0**	**4.0**	**27.0**	**18.0**	**10.0**	**20.0**		**130.0**
4	Crop Coefficient (Kc)	0.4	0.8	0.8	0.8	1.2	1.2	0.7	0.7		
		0.4		0.8		1.0		0.9	0.7		
5	Consumptive Use Etc = Eto x Kc (mm)	27.8		79.0		84.4		72.2	41.3		
6	Land preparation,Puddling&Saturation	-		-		-		-	-		
7	Seepage & Percolation (5mm/day)	-		-		-		-	-		
8	Ponding	-		-		-		-	-		
	Total Consumtipve Use (mm)	**27.8**		**79.0**		**84.4**		**72.2**	**41.3**		**304.7**
9	Normal Monthly Rainfall,P (mm)	187.3		357.7		353.2		321.1	332.0		**1,551.3**
10	Effective Rainfall,Pe (mm)	124.8		261.1		257.6		231.9	240.6		**1,116.0**
11	**Net Irrigation Requirement (NIR) (mm)**	No Need Irrigation									
12	Field Irrigation Requirement (FIR) (mm)										
13	Project Irrigation Requirement (PIR)(mm)										

C.4. Soybean

SI No	Description of Items	Months									Total
		Novembe	December			January	Pebruary	March			
1	Numbers of days	20.0			31.0	31.0	28.0	25.0			135.0
2	Eto (mm/day)	3.5			3.2	2.8	2.8	2.8			
	Eto (mm)	69.6			98.8	86.5	78.1	71.2			
3	Nursery	-			-	-	-	-			
		Initial	**Development**		**Mid Season**			**Late Season**			
		20.0	**10.0**	**20.0**	**1.0**	**31.0**	**28.0**	**25.0**			**135.0**
4	Crop Coefficient (Kc)	0.4	0.8	0.8	1.1	1.1	1.1	0.6			
		0.4			0.9	1.1	1.1	0.6			
5	Consumptive Use Etc = Eto x Kc (mm)	24.3			85.6	95.2	85.9	42.7			
6	Land preparation,Puddling&Saturation	-			-	-	-	-			
7	Seepage & Percolation (5mm/day)	-			-	-	-	-			
8	Ponding	-			-	-	-	-			
	Total Consumtipve Use (mm)	**24.3**			**85.6**	**95.2**	**85.9**	**42.7**			**333.7**
9	Normal Monthly Rainfall,P (mm)	187.3			357.7	353.2	321.1	332.0			1,551.3
10	Effective Rainfall,Pe (mm)	124.8			261.1	353.2	231.9	240.6			1,211.7
11	Net Irrigation Requirement (NIR) (mm)	No Need Irrigation									
12	Field Irrigation Requirement (FIR) (mm)										
13	Project Irrigation Requirement (PIR)(mm)										

ANNEXURE C

C.5 Groundnut

SI No	Description of Items	Months									Total
		Novembe	Decem	January		Pebruary		March			
1	Numbers of days	25.0	31.0		31.0		28.0	15.0			130.0
2	Eto (mm/day)	3.5	3.2		2.8		2.8	2.8			
	Eto (mm)	87.0	98.8		86.5		78.1	42.7			
3	Nursery	-	-				-	-			
		Initial	Development		Mid Season		Late Season				
		25.0	**31.0**	**4.0**	**27.0**	**18.0**	**10.0**	**15.0**			**130.0**
4	Crop Coefficient (Kc)	0.5	0.8	0.8	1.1	1.1	0.7	0.7			
		0.5	0.8		0.8		0.9	0.7			
5	Consumptive Use Etc = Eto x Kc (mm)	39.1	74.1		64.9		68.3	29.9			
6	Land preparation,Puddling&Saturation	-	-		-		-	-			
7	Seepage & Percolation (5mm/day)	-	-		-		-	-			
8	Ponding	-	-		-		-	-			
	Total Consumtipve Use (mm)	**39.1**	**74.1**		**64.9**		**68.3**	**29.9**			**276.3**
9	Normal Monthly Rainfall,P (mm)	187.3	357.7		353.2		321.1	332.0			1,551.3
10	Effective Rainfall,Pe (mm)	124.8	261.1		257.6		231.9	240.6			1,116.0
11	Net Irrigation Requirement (NIR) (mm)										
12	Field Irrigation Requirement (FIR) (mm)	**No Need Irrigation**									
13	Project Irrigation Requirement (PIR)(mm)										

C.6 Greengram

SI No	Description of Items	Months								Total
		January	Pebruary		March					
1	Numbers of days	15.0		28.0		31.0				74.0
2	Eto (mm/day)	2.8		2.8		2.8				
	Eto (mm)	41.9		78.1		88.2				
3	Nursery	-		-		-				
		Initial	Development	Mid Season		Late Season				
		15.0	**25.0**	**3.0**	**22.0**	**9.0**				**74.0**
4	Crop Coefficient (Kc)	0.4	0.7	1.1	1.1	0.9				
				0.9		1.0				
5	Consumptive Use Etc = Eto x Kc (mm)	14.7		70.2		88.2				
6	Land preparation,Puddling&Saturation	-		-		-				
7	Seepage & Percolation (5mm/day)	-		-		-				
8	Ponding	-		-		-				
	Total Consumtipve Use (mm)	**14.7**		**70.2**		**88.2**				**173.1**
9	Normal Monthly Rainfall,P (mm)	202.1		144.9		96.9				443.9
10	Effective Rainfall,Pe (mm)	353.2		321.1		332.0				1,006.3
11	Net Irrigation Requirement (NIR) (mm)									
12	Field Irrigation Requirement (FIR) (mm)	No Need Irrigation								
13	Project Irrigation Requirement (PIR)(mm)									

ANNEXURE C

C.7 Casava

SI No	Description of Items	Months										Total
		November		December		January	Pebruary	March		April	May	
1	Numbers of days		30.0		31.0	31.0	28.0		31.0	30.0	29.0	210.0
2	Eto (mm/day)		3.5		3.2	2.8	2.8		2.8	3.0	2.9	
	Eto (mm)		104.3		98.8	86.5	78.1		88.2	90.7	85.5	
3	Nursery											
		Initial	**Development**		**Mid Season**				**Late Season**			
		20.0	10.0	30.0	1.0	31.0	28.0	30.0	1.0	30.0	29.0	**210.0**
4	Crop Coefficient (Kc)	0.3	0.8	0.8	0.8	0.8	0.8	0.8	0.3	0.3	0.3	
			0.6		0.8	0.8	0.8		0.6	0.3	0.3	
5	Consumptive Use Etc = Eto x Kc (mm)		57.4		79.0	69.2	62.4		48.5	27.2	25.7	
6	Land preparation,Puddling&Saturation		-		-	-	-		-	-	-	
7	Seepage & Percolation (5mm/day)		-		-	-	-		-	-	-	
8	Ponding		-		-	-	-		-	-	-	
	Total Consumtipve Use (mm)		**57.4**		**79.0**	**69.2**	**62.4**		**48.5**	**27.2**	**25.7**	**369.5**
9	Normal Monthly Rainfall,P (mm)		187.3		357.7	353.2	321.1		**332.0**	202.1	144.9	1,898.3
10	Effective Rainfall,Pe (mm)		124.8		261.1	257.6	231.9		240.6	136.7	90.9	1,343.6
11	Net Irrigation Requirement (NIR) (mm)											
12	Field Irrigation Requirement (FIR) (mm)											
13	Project Irrigation Requirement (PIR)(mm)	No Need Irrigation										

ANNEXURE C

C.8. Maize (second season)

SI No	Description of Items	Months								Total
		April	May		June		July		August	
1	Numbers of days	20.0		31.0		30.0		31.0	18.0	130.0
2	Eto (mm/day)	3.0		2.9		2.9		3.0	3.4	
	Eto (mm)	60.5		91.4		86.1		92.5	61.9	
3	Nursery	-		-		-		-	-	
		Initial	Development			Mid Season		Late Season		
		20.0	10.0	21.0	4.0	26.0	15.0	16.0	18.0	130.0
4	Crop Coefficient (Kc)	0.4	0.8	0.8	0.8	1.2	1.2	0.7	0.7	
		0.4		0.8		1.0		0.9	0.7	
5	Consumptive Use Etc = Eto x Kc (mm)	24.2		73.1		84.0		85.6	43.3	
6	Land preparation,Puddling&Saturation	-		-		-		-	-	
7	Seepage & Percolation (5mm/day)	-		-		-		-	-	
8	Ponding	-		-		-		-	-	
	Total Consumtipve Use (mm)	**24.2**		**73.1**		**84.0**		**85.6**	**43.3**	**310.2**
9	Normal Monthly Rainfall,P (mm)	202.1		144.9		96.9		61.8	13.4	519.1
10	Effective Rainfall,Pe (mm)	136.7		90.9		52.5		27.1	(2.0)	305.2
11	**Net Irrigation Requirement (NIR) (mm)**	**-112.46**		**-17.80**		**31.43**		**58.52**	**45.30**	**135.26**
12	Field Irrigation Requirement (FIR) (mm)					41.91		78.03	60.40	180.35
13	Project Irrigation Requirement (PIR)(mm)					52.39		97.54	75.50	225.44

C.9. Soybean (second season)

SI No	Description of Items	Months								Total
		April	May			June	July		August	
1	Numbers of days	20.0			31.0	30.0		31.0	23.0	135.0
2	Eto (mm/day)	3.0			2.9	2.9		3.0	3.4	
	Eto (mm)	60.5			91.4	86.1		92.5	79.1	
3	Nursery	-			-	-		-	-	
		Initial	Development		Mid Season			Late Season	Late Season	
		20.0	10.0	20.0	1.0	30.0	29.0	2.0	23.0	135.0
4	Crop Coefficient (Kc)	0.4	0.8	0.8	1.1	1.1	1.1	0.6	0.6	
		0.4			0.9	1.1		0.9	0.6	
5	Consumptive Use Etc = Eto x Kc (mm)	21.2			79.2	94.7		78.7	47.4	
6	Land preparation,Puddling&Saturation	-			-	-		-	-	
7	Seepage & Percolation (5mm/day)	-			-	-		-	-	
8	Ponding	-			-	-		-	-	
	Total Consumtipve Use (mm)	**21.2**			**79.2**	**94.7**		**78.7**	**47.4**	**321.2**
9	Normal Monthly Rainfall,P (mm)	202.1			144.9	96.9		61.8	13.4	519.1
10	Effective Rainfall,Pe (mm)	136.7			90.9	52.5		24.4	(2.0)	302.6
11	**Net Irrigation Requirement (NIR) (mm)**	**No Need Irrigation**				**42.20**		**54.23**	**49.43**	**145.86**
12	Field Irrigation Requirement (FIR) (mm)					60.29		77.47	70.61	208.37
13	Project Irrigation Requirement (PIR)(mm)					75.36		96.83	88.26	260.46

ANNEXURE C

C.10 Groundnut (second season)

SI No	Description of Items	Months									Total
		April	May	June		July		August			
1	Numbers of days	25.0	31.0	30.0		31.0		13.0			130.0
2	Eto (mm/day)	3.0	2.9	2.9		3.0		3.4			
	Eto (mm)	75.6	91.4	86.1		92.5		44.7			
3	Nursery	-	-			-		-			
		Initial	Development		Mid Season		Late Season				
		25.0	31.0	4.0	26.0	19.0	12.0	13.0			130.0
4	Crop Coefficient (Kc)	0.5	0.8	0.8	1.1	1.1	0.7	0.7			
		0.5	0.8	0.8		0.9		0.7			
5	Consumptive Use Etc = Eto x Kc (mm)	34.0	68.6	64.6		81.0		31.3			
6	Land preparation,Puddling&Saturation	-	-	-		-		-			
7	Seepage & Percolation (5mm/day)	-	-	-		-		-			
8	Ponding	-	-	-		-		-			
	Total Consumtipve Use (mm)	**34.0**	**68.6**	**64.6**		**81.0**		**31.3**			**279.4**
9	Normal Monthly Rainfall,P (mm)	202.1	144.9	96.9		61.8		13.4			519.1
10	Effective Rainfall,Pe (mm)	136.7	90.9	52.5		27.1		(2.0)			305.2
11	Net Irrigation Requirement (NIR) (mm)	**No Need Irrigation**		**12.06**		**53.90**		**33.27**			**99.2**
12	Field Irrigation Requirement (FIR) (mm)			16.07		71.86		44.36			132.3
13	Project Irrigation Requirement (PIR)(mm)			20.09		89.83		55.45			165.4

C.11 Greengram (second season)

SI No	Description of Items	Months								Total
		April	May		June					
1	Numbers of days	15.0	31.0		29.0					75.0
2	Eto (mm/day)	3.0	2.9		2.9					
	Eto (mm)	45.4	91.4		83.3					
3	Nursery	-	-		-					
		Initial	Development	Mid Season		Late Season				
		15.0	25.0	6.0	19.0	10.0				75.0
4	Crop Coefficient (Kc)	0.4	0.7	1.1	1.1	0.9				
			0.9		1.0					
5	Consumptive Use Etc = Eto x Kc (mm)	15.9	82.3		83.3					
6	Land preparation,Puddling&Saturation	-	-		-					
7	Seepage & Percolation (5mm/day)	-	-		-					
8	Ponding	-	-		-					
	Total Consumtipve Use (mm)	**15.9**	**82.3**		**83.3**					**181.4**
9	Normal Monthly Rainfall,P (mm)	202.1	144.9		96.9					443.9
10	Effective Rainfall,Pe (mm)	136.7	90.9		52.5					280.1
11	Net Irrigation Requirement (NIR) (mm)	No Need Irrigation			30.7					30.7
12	Field Irrigation Requirement (FIR) (mm)				41.0					41.0
13	Project Irrigation Requirement (PIR)(mm)				51.2					51.2

ANNEXURE D

Cost Cultivation of Paddy
Ngada District Province Nusa Tenggara Timur - Indonesia

Sl. No.	Items of Cost	Lowland Paddy	Upland Paddy	Maize	Soybean	Groundnut	Mungbean	Casava
					(Rupiah/ha)			
1	Land Preparation	1,800,000	560,000	560,000.00	560,000.00	560,000.00	560,000.00	560,000.00
2	Seed & Sowing	250,000	450,000	450,000.00	450,000.00	450,000.00	450,000.00	450,000.00
3	Transplanting	420,000						
4	Weeding after planting	210,000	560,000	560,000.00	1,120,000.00	1,120,000.00	1,120,000.00	560,000.00
5	Fertilizer (Urea,KCL,SP)	625,000	405,000	405,000	302,000	256,000	256,000	663,000
6	Plant Protection	120,000	120,000	120,000.00	120,000.00	120,000.00	120,000.00	120,000.00
7	Harvesting	360,000	360,000	360,000.00	360,000.00	360,000.00	360,000.00	1,000,000.00
9	Threshing	1,014,750	1,014,750	140,000.00	140,000.00	140,000.00	140,000.00	
8	Others	479,975.00	346,975.00	259,500.00	305,200.00	300,600.00	300,600.00	335,300.00
	Total Cost in Rp/ha	**5,279,725.00**	**3,816,725.00**	**2,854,500.00**	**3,357,200.00**	**3,306,600.00**	**3,306,600.00**	**3,688,300.00**
	Total Cost in Rs/ha	**27,075.51**	**19,572.95**	**14,638.46**	**17,216.41**	**16,956.92**	**16,956.92**	**18,914.36**

Benefit of Cost

Price per Kg (Rs)	13.85	13.85	14.36	33.33	46.15	43.59	6.15
Productivity (kg/ha)	3,404.49	2,142.24	2,104.71	867.65	883.19	713.18	10,708.01
Income per ha (Rp)	47,152.18	29,669.99	30,223.58	28,918.70	40,759.12	31,087.59	65,854.27
Profit (Rp)	20,076.66	10,097.04	15,585.12	11,702.29	23,802.20	14,130.67	46,939.91
BC	**1.74**	**1.52**	**2.06**	**1.68**	**2.40**	**1.83**	**3.48**

ANNEXURE E

DETAILED OF LINEAR PROGRAMING OPTOMIZING BY LINGO 13

I . Water Availability 100%

```
MODEL:
MAX =    13.85* X1 + 33.3*X2+ 46.15*X3 + 43.59*X4;

         0.3546*X1 + 0.146*X2 + 0.099*X3 + 0.0307*X4 <= 3799.74 ;
         X1+X2+X3+X4          <= 13030;
         3.4*X1               >= 22050;
         X1                   >= 0;
         X2                   >= 0;
         X3                   >= 0;
         X4                   >= 0;

END

Global optimal solution found.
  Objective value:                              391859.5
  Infeasibilities:                              0.000000
  Total solver iterations:                             1

  Model Class:                                        LP

  Total variables:                  4
  Nonlinear variables:              0
  Integer variables:                0

  Total constraints:                8
  Nonlinear constraints:            0

  Total nonzeros:                  17
  Nonlinear nonzeros:               0

                                Variable           Value        Reduced
Cost
                                      X1        6485.294
0.000000
                                      X2        0.000000
12.85000
                                      X3        6544.706
0.000000
                                      X4        0.000000
2.560000
```

```
                                   Row     Slack or Surplus       Dual
Price
                                    1          391859.5
1.000000
                                    2          852.1288
0.000000
                                    3          0.000000
46.15000
                                    4          0.000000             -
9.500000
                                    5          6485.294
0.000000
                                    6          0.000000
0.000000
                                    7          6544.706
0.000000
                                    8          0.000000
0.000000
```

II. Water Availability 75 %

```
MODEL:
MAX =    13.85* X1 + 33.3*X2+ 46.15*X3 + 43.59*X4;

        0.3546*X1 + 0.146*X2 + 0.099*X3 + 0.0307*X4 <= 2849.805;
        X1+X2+X3+X4          <= 13030;
        3.4*X1               >= 22050;
        X1                   >= 0;
        X2                   >= 0;
        X3                   >= 0;
        X4                   >= 0;

END
```

```
Global optimal solution found.
  Objective value:                              388193.6
  Infeasibilities:                              0.000000
  Total solver iterations:                             2

  Model Class:                                        LP
  Total variables:                    4
  Nonlinear variables:                0
  Integer variables:                  0

  Total constraints:                  8
  Nonlinear constraints:              0

  Total nonzeros:                    17
  Nonlinear nonzeros:                 0
```

```
                              Variable           Value          Reduced
 ost
                                    X1        6485.294
 .000000
                                    X2        0.000000
14.61164
                                    X3        5112.697
0.000000
                                    X4        1432.008
0.000000

                                   Row    Slack or Surplus      Dual
Price
                                     1        388193.6
1.000000
                                     2        0.000000
37.48170
                                     3        0.000000
42.43931
                                     4        0.000000            -
12.31774
                                     5        6485.294
0.000000
                                     6        0.000000
0.000000
                                     7        5112.697
0.000000
                                     8        1432.008
0.000000
```

II. Water Availability 65 %

```
MODEL:
MAX =    13.85* X1 + 33.3*X2+ 46.15*X3 + 43.59*X4;

        0.3546*X1 + 0.146*X2 + 0.099*X3 + 0.0307*X4 <= 2469.831 ;
        X1+X2+X3+X4          <= 13030;
        3.4*X1               >= 22050;
        X1                   >= 0;
        X2                   >= 0;
        X3                   >= 0;
        X4                   >= 0;

END
Global optimal solution found.
  Objective value:                              331406.1
  Infeasibilities:                              0.000000
  Total solver iterations:                             3

  Model Class:                                        LP
```

Total variables: 4
Nonlinear variables: 0
Integer variables: 0

Total constraints: 8
Nonlinear constraints: 0

Total nonzeros: 17
Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	6485.294	0.000000
X2	0.000000	174.0010
X3	0.000000	94.41710
X4	5542.205	0.000000

Row	Slack or Surplus	Dual Price
1	331406.1	1.000000
2	0.000000	1419.870
3	1002.500	0.000000
4	0.000000	144.0105
5	6485.294	0.000000
6	0.000000	0.000000
7	0.000000	0.000000
8	5542.205	0.000000

LIST OF TABLES