THE DETERMINATION OF CROP WATER REQUIREMENT OF MANGO

IN THE TRANSITIONAL ZONE OF GHANA

by

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CERTIFICATION

I, Samuel Kyei Okyereh hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person nor the material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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ABSTRACT

This study sought to determine the optimum crop water requirement of mango using meteorological data for the transitional agro-ecological zone of Ghana and make comparison of the various methods of crop water requirement determination or estimation.

The estimates could be useful in the design and management of irrigation systems. Mango production would offer or create employment for rural and urban dwellers. It would assist to minimize or reduce the rural-urban migration and supply some of the basic raw materials needed to feed fruit processing or agro-based industries in Ghana. It can be also used for afforestation and reforestation programmes in Ghana.

Meteorological data were collected from Ghana Meteorological Agency for selected locations in the transitional agro-ecological zones for the period 1976-2006. The locations were: Atebubu, Berekum, Ejura and Wenchi. The crop water requirement was estimated using Blaney-Criddle, Radiation, Penman, Thornthwaite and Pan Evaporation methods. From the results of the research, the least and highest optimum crop water requirement of mango using meteorological data were 880 mm and 1127 mm for Blaney-Criddle, 1224 mm and 1271 mm for Radiation, 1367 mm and 1446 mm for Penman, 1567 mm and 1780 mm for Thornthwaite respectively .The value of 1111 mm was for Pan Evaporation method. Also, the Thornthwaite method had the highest annual crop water requirement of mango with the values of 1694 mm in Atebubu, 1607 mm in Berekum, 1567 mm in Ejura and 1780 mm in Wenchi. However, the Blaney-Criddle method had the least values with 880 mm in Atebubu, 1021 mm in Berekum, 938 mm in Ejura and 1127 mm in Wenchi.

In conclusion, Penman is the standard or best method. It includes all the climatic factors that affect evapotranspiration. Blaney-Criddle, Radiation and Thornthwaite are temperature based methods. Blaney-Criddle and Radiation underestimate the crop water requirement. However, Thornthwaite overestimates the crop water requirement. Pan Evaporation is the direct method and shows the combined effect of the climatic factors .

TABLE OF CONTENT

PAGES

PAGES

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Mango (*Mangifera Indica L .)* belongs to the family Anacardiaceace, also known as the cashew family (Nakasone and Paull, 1999). It is a very popular and highly productive tropical fruit crop which is indigenous to tropical Asia and may have originated from India (Rice *et al*, 1990). From the Indian sub-continent it has spread to other parts of the tropical world and is one of the most popular and choicest fruits of India (Purseglove, 1987). However, it is now found in all the tropical areas, as well as many subtropical regions of the world, attesting to its wide range of adaptability. It was introduced into Ghana in the early 1920's from the Sri Lanka, India and Trinidad (Addo-Quaye *et al*,1993). The yield depends on the age and cultivar, but generally, about 500-1500 fruits per tree per year may be obtained at three to four years (Addo-Quaye *et al*, 1993).

It is highly prized as a dessert fruit (Kochhar, 1986). All parts of the mango tree, from the root to the leaf, serve some purpose to mankind. For example the leaves may be used as fodder to feed livestock and the wood is valuable for boat building. In most tropical regions, the fruit is grown only for local consumption and has been described as ‘’king of all fruits’’ (Samson, 1992). All kinds of preserve including juice and jam can be prepared from ripe fruits, while pickles and chutney are prepared from unripe fruits .It has a rich, luscious aromatic flavour and delicious taste with a blend of sweetness and acidity. The bark contains tannin which may be used for tanning leather.

The edible portion takes up 60-75 percent of the fruit weight. The flesh of a riped fruit as depicted in figure1.1 contains about 15 percent sugar, mostly sucrose, much vitamin A and a fair amount of vitamin B and C (Samson, 1992). It also contains 84 percent water and small amount of fruit acids, minerals, fats and protein (Kochhar, 1986).

Figure1.1 Ripe mango fruit (Cultivar- Zill)

Mango production would offer or create employment for rural and urban dwellers. It could also help to solve unemployment problems. A favourable and vibrant agricultural sector in Ghana is the key to poverty reduction because it employs the majority of the poor (Adu-Gyamerah, 2008). For instance, the youth could be engaged in mango production in mango plantations under the National Youth Employment Programme. In Ghana's Eastern Region, for example, cultivation of improved exportable mango has created jobs for over 5,000 people and made the area the most prominent in mango production (USAID, 2005). Mango production increased from 700 kg per acre in 2002 to 2704 kg per acre in 2005 in Ghana (USAID, 2005) .Clusters of mangoes grow from long stems attached to the main branches with each tree producing an average of 100 fruits each year. India is by far the largest producer, with an area of 16,000 km² and an annual production of 10.8 million tonnes, which accounted for 57.18% of the total world production. Within India, the southern state of Andhra Pradesh is the largest producer of Mangoes, with 350,000 hectares under cultivation (UN and FAO, 2004).

Mango production in Ghana would also assist to minimize or reduce the rural-urban migration and supply some of the basic raw materials needed to feed fruit processing or agro-based industries in Ghana. Since the crop is developing to become an industry in Ghana, we need to assist farmers to grow the fruit and take advantage of the growing world consumption. Commercially cultivated mango is relatively a new agricultural industry in Ghana. This industry is one area within the horticultural sector which, if well developed and provided with the necessary logistics and support, can easily become a major foreign exchange earner (Adu-Gyamerah, 2008). This is because the country has fertile lands for mangoes, which can easily become a top export product. According to experts in agriculture, Ghana is one of the few countries in the world with two mango seasons, major and minor season. Therefore, with the right practices, both seasons can yield fruits for the international mango market (Asamoah, 2006).

Mango is generating greater income per acre than even cocoa. For example, cocoa is today making about a ton per acre with revenue of 900 Ghana Cedis, but the same acre of land of exotic mango is making over 2,000 Ghana Cedis (Asante-Mensah, 2004). In terms of export earnings, currently yield per acre for cocoa stand more than 1,000 Ghana Cedis; citrus, 1,500 Ghana Cedis to 2,500 Ghana Cedis but mango ranges between 2,500 Ghana Cedis and 4,000 Ghana Cedis (Quartey, 2008). In 2004, the European Union imported 170,000 metric tonnes valued at more than $ 200 million. Out of this, Ghana registered only 220 metric tonnes representing one percent of the total volume of imports of the product (Asamoah, 2006). Although Ghana has been exporting mangoes over the past 15 years, the country's exports are very insignificant in the international market, as the country is not listed in the first 40 exporters of mangoes in spite of the fact that the country has a comparative advantage over the other exporters of mango (Asamoah, 2006). Recent studies have shown that, Ghana's comparative advantage in the production of fresh mangoes, especially the grafted type, has the potential to greatly turn around and transform the economy, if much attention were re-directed and focused on mass cultivation of the fruit (Quartey, 2008). In addition, current statistics on the export earnings have shown that the crop has enormous potential that could transform Ghana's economy much better than other traditional export products (Quartey, 2008).

In addition, mango can be used for afforestation and reforestation programmes in Ghana. Located in the transitional zone between the Savannah North and the Forest South, large-scale mango farms which will provide shelter, slow down desertification and contribute to save the environment (Adu-Gyamerah, 2008).

Within the tropics it has relatively wide ecological amplitude, and thrives well in the dry transitional zones (Addo-Quaye *et al*, 1993). In Ghana, it grows well across all the ecological zones, although it performs best in less humid forest-savannah transition and savannah zones (Mintah *et al*, 2002).The soil should be deep and well-drained. With the growing importance of the crop its crop water requirement data are frequently needed at short notice for forecasting and project planning. The knowledge of the crop water requirement can also assist in the cultivation and improvement in yield.

Climate is one of the most important factors that controls agriculture and rainfall in particular influences agriculture in the tropics. For instance, heavy rainfall during flowering and fruiting can cause marked reductions in pollination or washes away the pollen; reduces fruit set and maturation of fruits. Temperature affects the normal growth of crops .High temperatures during the day cause great loss of water through the process of evapotranspiration which increases with increasing temperature. High night temperatures can affect crop yield. Light energy is also very essential for the manufacturing of plant's food. Apart from photosynthesis, light intensity influences the rate of plant growth and development. Humidity alters the rate of evapotranspiration. Under low humidity, plant loses a lot of water to the atmosphere. Evaporation and transpiration decrease with increase in relative humidity but increase with decrease in relative humidity. Strong wind can do much harm to the mango trees as its wood is soft. When the storms are frequent, serious damage may be inflicted. It may cause damage to crops by causing fruits to drop from plants and sometimes breaking or even uprooting the whole plants. Plants lose more water by evaporation and transpiration in dry wind.

It is necessary to estimate crop water needs in order to calculate deficiencies in the crop water requirement caused by shortage in precipitation or soil moisture storage capacities. Irrigation systems are designed and constructed to meet water deficits and to ensure that adequate supplies of water to plant at the critical stages of growth are provided. Generally, development of farm water management programmes requires knowledge of when to irrigate and how much water should be provided in order to realize the full potential yield of the crop.

It is therefore reasonable to estimate the potential evapotranspiration for tropical mango, since evapotranspiration depends on climatic factors like temperature and humidity. An estimate of crop water requirement can be calculated from measured meteorological data and the crop water requirement of mango, may for example, begin from transplanting, maturity or establishment to harvesting. In general, dry weather and a cloudless sky during flowering and fruit-ripening are considered essential for a good crop (Kochhar, 1986).

There are a multitude of methods used to estimate or determine crop water requirement. Some of these are the Pan evaporation, Blaney-Criddle, Thornthwaite, Penman, Radiation, Jensen-Haise, Atmometer, Penman-Montieth, Bowen Ratio, CROPWAT, Priestley –Taylor and Lysimeter methods. In this study, the methods that would be used are the Pan evaporation, Blaney-Criddle, Thornthwaite, Penman and Radiation.

Concerning the accuracy of these methods, the modified Penman method would offer the best results with minimum possible error of plus or minus 10 percent in summer, and up to 20 percent under low evaporative conditions (Doorenbos and Pruitt, 1996). The Pan method can be graded next with possible error of 15 percent, depending on the location of the pan .The Radiation method, in extreme conditions, involves a possible error of up to 20 percent in the summer. The Blaney-Criddle method should only be applied for periods of one month or longer; in humid, windy, mid-latitude winter conditions and over and under prediction of up to 25 percent (Doorenbos and Pruitt, 1996). The Thornthwaite method has the largest possible error of 56 percent of ET in April and the smallest error of 22 (Shelton, 1978).

Evaporation pans provide a measurement of the integrated effect of radiation, wind, temperature and humidity on evaporation from a specific open water surface.

Blaney-Criddle Method is suggested for areas where available climatic data cover air temperature data only. Using measured temperature data as well as general levels of humidity, sunshine and wind, an improved prediction of effect of climate on evapotranspiration should be obtainable.

Radiation Method is suggested for areas where climatic data include measured of air temperature and sunshine, cloudiness or radiation but not measured wind and humidity. Knowledge of general levels of humidity and wind is required. The Penman equation (Penman Method) consists of two terms: the energy (radiation) term and aerodynamic term (wind and humidity) and varies with climatic conditions. Under calm weather conditions the aerodynamic term is usually less important than the energy term. The Thornthwaite method depends on temperature and latitude.

The prediction methods of crop water requirements are used owing to the difficulty in obtaining accurate field measurements. The methods that are often needed to be applied under climatic and agronomic conditions are very different from those under which they were originally developed. Testing the accuracy of the methods under a new set of conditions is also laborious, time-consuming and costly. Besides, little effort is sometimes put into the estimation of crop water requirements for design and the management of irrigations.

1.2 OBJECTIVES OF STUDY

The general objective of the study was to determine or estimate the crop water requirement of mango. The following are the specific objectives of the study:

1. To determine optimum crop water requirement of mango using meteorological data, and

2. To make comparison of various methods of crop water requirement determination.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 CLIMATE AND WEATHER

Weather can be described as atmospheric condition for a place for a short period of time, usually less than a year (a day, week or month). Weather changes from day to day. The elements that make up the weather include atmospheric temperature, rainfall or precipitation, humidity, sunshine, pressure and wind. Climate on the other hand may be defined as the total day to day weather conditions of a place or as the whole average atmospheric phenomena for a certain region, calculated for a period of thirty years. It is the sum total of all the elements of weather for any place for a long period of time usually more than a year.

2.1.1 CLIMATE AND AGRICULTURE

Climate is one of the most important factors in agriculture, for not only does it determine the moisture status and radiation receipts for photosynthesis and to a large extent plant growth and crop yields, but also it is the dominant factor in determining the geographic limits within which farm crops can be grown and the type of farming that can be practiced in any region. It determines the natural vegetation and nature or characteristics of the properties of the soil. The climate has an important influence on the nature of the natural vegetation and the characteristics of the soil (Tweneboah, 2000).

2.1.2 RAIN-FED AGRICULTURE

Rain-fed agriculture is entirely depended on rains. It relies on the rain calendar and on rain distribution during the rainy seasons. Rain calendar means the pattern of rainfall during the year (Tweneboah, 2000). In some regions, rain-fed farming is practised during one growing season whereas in others, two growing seasons are possible. In the case where there is only one rainy season and one dry season in the year, the rain calendar is said to be UNIMODAL. In other regions, where there are two wet seasons and two dry seasons of varying length, the rain calendar is BIMODAL and the farmer benefits from two growing seasons. Regions with bimodal rains are characterized by the fact that many plants are able to prolong their life cycles without a break throughout the year.

2.2 RAINFALL

This is the amount of rain falling within a given area in a given time. Rainfall is the natural form of water application to the soil for crop production Rain is one of the condensation forms of precipitation (Beinempaka *et al* 1990). As air rises, it cools and becomes saturated with water vapor.

Most crops require a good supply of water from the time of planting to nearly the time of harvesting (Beinempaka *et al* 1990). The root hairs, which absorb water containing plant nutrients (food), are found mainly in the top layer of soil. If these root hairs fail to absorb enough water because of low rainfalls crop yield will be reduced. In some cases, crops may fail completely due to lack of soil moisture.

Rainfall is the most essential factor that determines the distribution of vegetation and is the most important climatic factor influencing agriculture in the tropics, as it generally has the biggest effect in determining the potential of any area, the farming system which can be followed and the nature, timing and sequences of farming operations. It is the major environmental factor that determines which crops can be grown, when they are planted, and the yield. Rainfall, which greatly determines the deficit or surplus of moisture in the soil, is the major element of the climate which exerts limiting influence on the plant growth in the tropics. The agriculturist is primarily interested in rainfall as the supplier of soil moisture for crops and grassland. It still remains the predominant means by which food and other plant products are produced worldwide.

The vegetation in an area is affected by the rainfall distribution throughout the year. Areas receiving little or unreliable rainfall usually have short grass and little vegetation cover, whereas areas receiving a lot of rainfall have tall grass and thick vegetation cover (Beinempaka *et al* 1990). Sometimes the rainfall is sufficient in amount but poorly distributed. Other times the rain is inadequate; in these cases irrigation comes in as an artificial intervention to add or supplement rainfall (Beinempaka *et al* 1990).

2.2.1 Rainfall Effectiveness

Not all rainfall is effective but only the portion that contributes to evapotranspiration. It should be noted that expected effective rainfall is considered in determining the field irrigation requirement. A certain amount of rain is necessary to ensure successful growth of the vegetation in general and crop in particular. The rapid rates of evaporation and transpiration which result from high temperatures over large areas of Africa mean that both natural vegetation and crops require very large quantities of water in order to live and grow. A well-distributed, ample rainfall is necessary for successful growth of plants (Beinempaka *et al* 1990).

2.2.2 Rainfall Reliability

This is another important factor in the growth of crops. It is that of a place's mean annual rainfall at a site or place that can be expected. Using rainfall records, we can calculate the chances of rains falling. In other words, rainfall reliability refers to how sure one can be that the rains will come when they are expected to. This can help to assess the risk involved in growing a particular crop in any area in a particular year (Beinempaka *et al* 1990).

2.2.3 Rainfall Distribution

Rainfall distribution helps the farmer to decide which crops (annual or perennial) to grow and when to plant them. The distribution alters the length of the growing seasons (Beinempaka *et al* 1990).

2.2.4 Rainfall Intensity

This is a measurement of the heaviness of the rain over a given time. It is measured by recording the amount of rain that falls in a short period, such as five or ten minutes. This can be measured with a recording rain gauge. Usually, the heavier the storm, the higher the intensity. Tropical rains are characterized by short, heavy storms that lead to run-off and soil erosion, whereas temperate rains are gentle and well-distributed over time (Beinempaka *et al* 1990).

2.2.5 Rainfall Measurement

The usual method of measuring rainfall is by using a standard rain gauge which is 12.5 cm in diameter. The rainfall during the previous 24 hours is usually measured and recorded at 9:00 am each day. At the end of each month, the daily figures are added to give a monthly total. The mean rainfall often quoted for a place is an average rainfall figure over several years (Beinempaka *et al* 1990).

2.2.6 Hydrological (Water) Cycle

This is the cycle of water movement from the atmosphere to the ground, through living organisms and back to the atmosphere as shown in figure 2.1. It is the study of water as it occurs in the atmosphere as well as on and below the surface of the earth and the formation of precipitation which may occur as rain, snow or hail (Schwab *et al*, 1993).

Some of the precipitation evaporates partially or completely before reaching the ground. Precipitation reaching the ground may be intercepted by vegetation. It may infiltrate the surface of the ground; it may evaporate, or may run off the surface. Evaporation may be from the free water surfaces, or from the leaves of the plants through transpiration .A portion of the total rainfall which moves into the soil surface, is used by vegetation, becomes part of the deep groundwater supply or seeps to stream and to the oceans (Schwab *et al*, 1993).

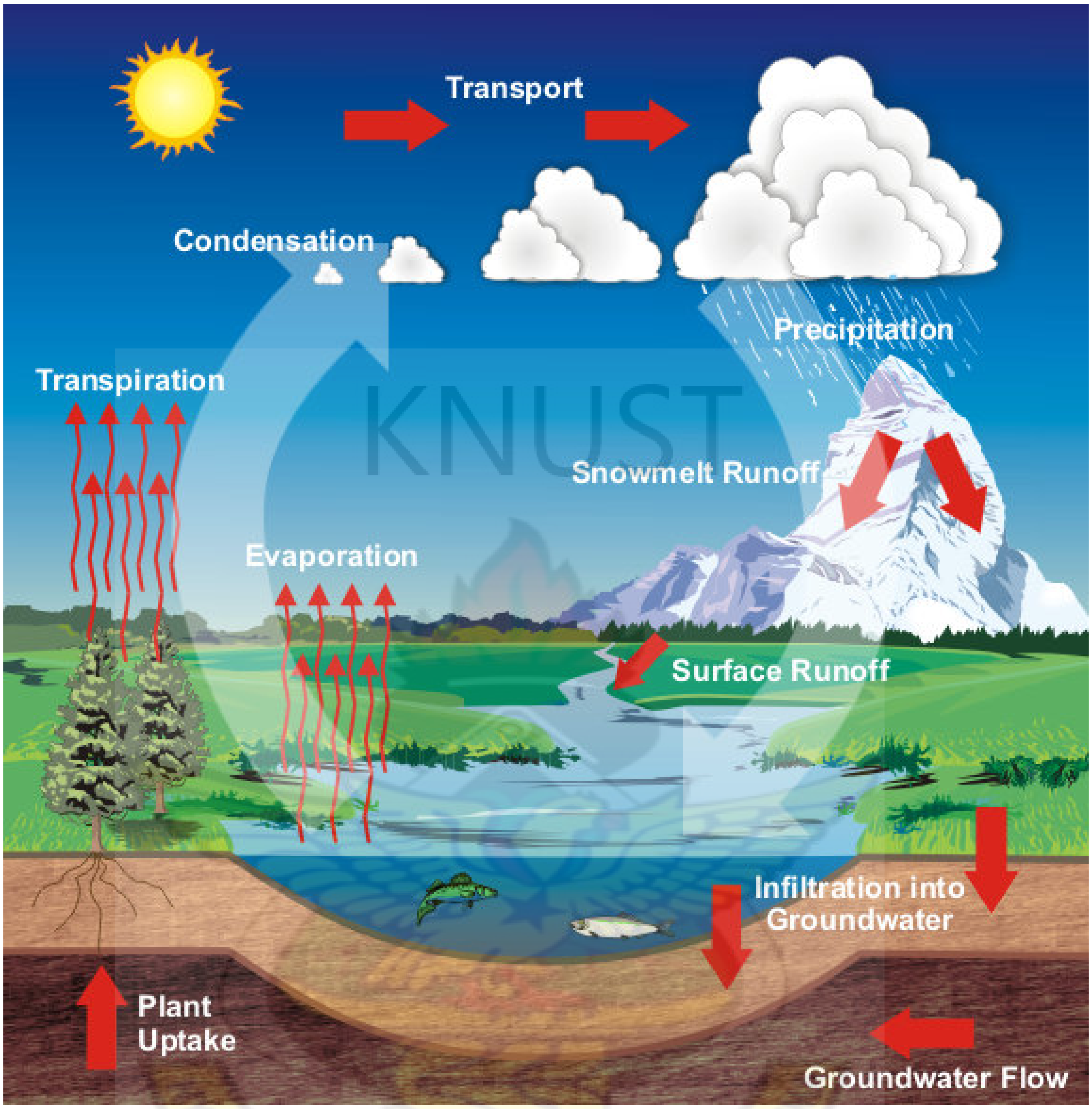

Figure 2.1 The hydrological cycle

2.2.7 Importance of water to plants

Water is very essential for plant growth and during the actively-growing phase According to Addo-Quaye *et al* (1993), some of the uses to plants are as follows:

(i) It is a medium through which plant nutrients are taken by the plant. It acts as a solvent for the nutrients. Water forms the solution of the nutrients, and this solution is absorbed by the roots. Thus, water acts as the nutrient carrier. The transpiration stream carries essential nutrients from the soil to the sites where they are needed in the shoot.

(ii) Water permits the movement of food substances produced in the leaves to other parts of the plants to support new growth or storage.

(iii) It confers mechanical strength to the plant in non-woody tissues by maintaining turgidity in the tissues. If water shortage occurs for long periods, permanent wilting and death may ensue.

(iv)The lack of water decreases the intensity of photosynthesis.

(v) Water cools the soil and atmosphere, and thus makes more favourable environment for healthy plant growth. It helps to control soil temperature and soil aeration.

(vi) Water provides a good medium for microbial activity in the soil and it satisfies the evapotranspiration requirements of plants. It supplies moisture which is essential for the life of bacteria beneficial to the plant growth.

(vii) It aids or assists in germination and development of seeds and crops.

(viii) It maintains plant's turgidity, which the sum total of the pressure is built on the cell sap against the cell wall due to the water absorbed by the root hair.

(ix) It is a constituent of plant protoplasm.

2.2. 8 Rainfall in relation to mango production

An annual rainfall of 750-1900 mm is generally desirable for mango production (Kochhar, 1986). It has a rainfall tolerance of between 250 mm and 2500 mm (Gibbon and Pain, 1988). Mango trees can tolerate a wide range of climatic conditions. The trees can survive in swampy conditions for an extended period of time, but will also survive in areas with an annual rainfall of less than 300 mm (NDA, 2000).

According to Tweneboah (2000), the transitional zone has a mean annual rainfall of 1300-1400 mm and a humid period of 180-190 days. Mango thrives in the transitional zone and has rainfall distribution of 1300 mm for a period of 180-190 days with one major season (Addo-Quaye *et al*, 1993).

An important feature of the mango is its ability to perform well in low rainfall regimes. According to Opeke (1992), a good crop can even be obtained with 750 mm per annum, if this is well distributed over eight to nine months. There exits a relatively long dry season. Such dry areas also fulfill the condition of high insulation. Where the dry season coincides with flowering, a good crop of high quality, tasty fruits are usually obtained.

It can withstand occasional flooding. According to Rice *et al* (1993), for commercial production a minimum of 635 mm is recommended. This is why mango is gradually gaining prominence in the drier northern regions of Ghana.

Heavy rainfall during flowering and fruiting can cause marked reductions in pollination or washes away the pollen, reduces fruit set and mars maturation of fruits. The mango flower is very delicate and easily injured in most weather. During rainy days, pollinating insects remain inactive and an effective pollination cannot occur. Furthermore, heavy rains at flowering can cause a high incidence of fungal infections on the inflorescences. Heavy rains during the flowering and fruit ripening periods are harmful and are fairly sensitive to frost. The best regions for commercial mango production are those with a humid rainy season alternating with a well defined dry season during the flowering period of the plants. Good rainfall distribution is crucial for flowering and fruit set, rather than total rainfall. A dry or even more effective cool period preceding flowering is necessary for reliable mango production as it promotes flower induction. Low rainfall is preferred during flowering. In areas with two wet seasons, such as parts of West Africa, flowering and fruit production may occur twice each year, but in most areas one crop per year is produced (Nakasone and Paull 1999).

Irrigation must be applied regularly to prevent water stress during early fruit development when cell division is occurring and to produce vegetative flushing after harvest. Where mangoes are produced under such low-rainfall conditions irrigation is of vital importance (NDA, 2000). Mangoes are to some extent drought resistant, but will not achieve optimum growth if they do not receive sufficient water (especially during the fruit-developing phase). Correct irrigation is very important for maximum production in most mango-producing areas of the country (NDA, 2000).

2.3 TEMPERATURE

It may be defined as the degree of hotness or coldness of the atmospheric air. It is influenced by the latitude and altitude of a place. Temperature affects growth, flowering and fruit setting in crops. Some crops are adapted to low temperature while others need high temperatures for normal growth. Of all the necessary factors for growth the most important is the temperature of the air. Soil temperatures are also important as they influence root growth and function. Temperature is the major factor controlling the crop growth rate and range of adaptation. Each crop has its own optimum temperature for growth, plus a maximum for normal development and survival.

High temperatures during the day cause great loss of water through the process of transpiration, which increase with increasing temperature (Beinempaka *et al* 1990).

Transpiration rate increases with increasing temperature. Extremely high temperature can cause heat injury. The growth of the crop will then be affected. If the ambient temperature of air and ground are high, evaporation will proceed more rapidly than if they are low since heat energy is more readily available. Extremely low temperature causes possibility of cold injury and water deficit (Yayock *et al*, 1988).

2.3.1 Temperature in relation to mango production

There must be a marked dry season. Light frost is tolerated but the minimum for growth lies above 10^0C, the optimum near 25^0C and the maximum at 42^0C. The maximum temperature during very hot weather is at 32 ^{0}C (Dickson and Benneh, 1980).

Optimum growth temperature ranges from 24^0C to 27^0C (Kochhar, 1986). According to Nakasone and Paull (1999), the air temperature in the range of 24^0C-30^0C is needed and the tree can endure up to 48^0C during fruit development if sufficient irrigation is available. The tree readily grows in all the tropic and subtropic climates with a mean temperature of 21^0C to 27^0C. The lowest temperatures tolerated by mango are 1^0C to2^0C (Opeke, 1992). The trees also survive in a temperature as high as 45 °C (NDA, 2000).

On the other hand, it can withstand very high temperatures. Certain cultivars are less tolerant to high temperatures and low humidity, and the fruit will show symptoms of sunburn (Sensation, Edward, Isis, Fascell and Keitt). Cultivars with a high tolerance include Neldica, Tommy Atkins, Irwin, Lilley, Lippens, Chené, Kent, Ceriese, Kensington, Jubilee, Palmer and Zill (NDA, 2000). Mango trees will grow and produce well in areas with very high temperatures (45 °C). However, when the maximum temperature exceeds 46 °C vegetative growth ceases, especially if it is accompanied by low humidity. For optimum growth and production, the average maximum temperature should be between $27^0$and 36 °C (NDA, 2000).

According toYayock *et al* (1988), they perform best in areas commonly known as the dry tropics where they can withstand temperature as high as 48^0C. Temperature plays a key role in mango flowering and the response varies with varieties. Some varieties can withstand frost without damage while others are severely injured. It can stand frost without damage while other crops are severely injured. Low temperature can lead to flower deformation and loss of pollen viability. Ovule abortion occurs at low temperature, which is around 14^0C. Low temperatures when the trees are in full bloom can cause the fruit to develop to approximately golf-ball size, turn yellow and then be aborted. Large numbers of these fruit result in a reduction in yield (NDA, 2000). High temperature is not as injurious as low temperature but if accompanied by low humidity and high winds it affects the tree adversely.

2.4 The effect of relative humidity on crop production

The average relative humidity is about 55% and the maximum temperature during very hot weather is at 32 ^{o}C (Dickson and Benneh, 1988). Some of the ways humidity affects crops are as follows:

(i) High humidity favours the development and spread of a number of fungal and bacterial diseases and makes the drying of crop very difficult.

(ii) The rate at which crops use water is highest under hot, dry condition and lowest when it is very humid.

(iii) The humidity of the air has an important effect on the process of flowering and fertilization. It is well known that the viability and fertility of pollen grains greatly depend on the humidity of the air (Addo-Quaye *et al*, 1993).

(iv) Daily temperature variation is greater under low humidity; high humidity exerts an effect on temperature (Addo-Quaye *et al*, 1993).

(v) Humidity affects the rate of transpiration. Under low humidity, the plant loses a lot of water to the atmosphere. Transpiration is faster in a dry or partially saturated atmosphere. Evaporation and transpiration decrease with increase in relative humidity but increase with decrease in relative humidity (Addo-Quaye *et al*, 1993). The crop is successfully cultivated under conditions which vary from very hot, very humid to cool and dry, to very hot and arid conditions (NDA, 2000).

2.5 WIND

Winds blow from centres of high pressure to centres of low pressure. These centres are usually associated with low and high temperature respectively. Wind often influences rainfall distribution. The prevailing winds in the tropical regions are caused by the heating of the earth through the heating of the sun and by the earth's rotation (Beinempaka *et al* 1990).

2.5.1 Ecological significance of wind.

According to Beinempaka *et al* (1990), ecological significance of the wind is as follows:

(i) It interferes with agricultural operations such as irrigation, spraying, dusting and broadcasting.

(ii) It helps as an agent of cross-pollination.

(iii) It may cause damage to crops by causing fruits to drop from plants and sometimes breaking and uprooting the whole plants.

(iv) Plants lose more water by evaporation and transpiration in dry wind. Transpiration is faster on windy days than on calm days.

Moreover, according to NDA (2000), the effects of wind are:

(i) Wind (even moderate winds) could cause scratch marks on fruit. Harmful fungi and bacteria can enter the fruit through these wounds. Fruit with such marks are unacceptable for marketing.

(ii) Stronger winds will cause fruit loss, resulting in lower yields. Certain cultivars, such as Zill, Haden and Kent, are prone to a greater extent to fruit loss under windy conditions than others.

Damage by wind can be minimised by:

(a) Avoiding very windy areas.

(b) Establishing windbreaks such as artificial structures or fast-growing trees on the upwind side of prevailing winds. It is advisable to establish mango orchards in such a manner that the rows run diagonally to the prevailing wind direction to avoid a funnel effect.

(c) Prune the non-bearing flower panicles as soon as it is evident that these will not bear any fruit, because when they become dry and hard, they cause scratch marks on the fruit. (NDA, 2000).

2.6 LIGHT (SOLAR RADIATION)

Solar radiation is the energy source that drives most of the processes of importance to soils and plants (Hanks, 1992). Light is the most important ecological factor for nature, because it serves as the only source of energy for majority of species. Light energy is very important for green plants, for it is necessary for the manufacture of the plant's food in the vital process of photosynthesis. Light causes the stomata to open and also increases the air temperature. The main aspects of light that are of interest in agriculture are:

(i) The day length (from sunrise to sunset) and

(ii) The cloudiness during the day, both of which determine radiation (Addo-Quaye *et al*, 1993).

It is also a component of the environment which has a large influence on the crop growth and development. Two aspects of light are important:

i. How much or the intensity.

ii. How long or the duration (day length).

2.6.1 Light Intensity

Light intensity depends on the geographical latitude of a locality and the time of the year. Tropical regions, i.e. area between the Tropic of Cancer (23.5^0N) and the Tropic of Capricorn (23.5^0S) has relatively little seasonal variation in solar intensity since the sun remains fairly high in the sky all year around (Addo-Quaye *et al*, 1993). The Sun is overhead on the Tropic of Capricorn on 22 nd December, Equator on both 23 rd March and 22 nd September and Tropics of Cancer on 21st June (Akinsanmi, 1988).

The fundamental process of photosynthesis in green plants depends on light intensity. Apart from photosynthesis, light intensity also influences the rate of plant growth and development. For example, it has a tremendous influence in regulating many processes in plant such as flowering, stem elongation, leaf expansion and seed germination.

Furthermore, light regulates and co-ordinates growing movements in plants (Addo-Quaye *et al*, 1993).

2.6.2 Day length

The length of the light period of the day is very important for plant life. The length of the day in the tropics (on the equator) all the year round is about 12 hours. The day length has a different influence on the generative development. The value of this information is to enable the farmer to select appropriate crops for his farm (Addo-Quaye *et al*, 1993).

2.7 SOIL AND TOPOGRAPHY IN RELATION TO MANGO PRODUCTION

Mango trees grow and produce well on various soil types. Mango does not make high demand on the soil. It may be sandy or loamy, lateritic or alluvial, as long as it is not waterlogged. Mango does well on sandy loam or well drained soil. Deep alluvial soils which are well drained and rich in organic matter are best for its cultivation. Mango is adapted to a wide range of soils than is very important for green plants most tropical fruit trees, provided the soil is sufficiently deep and well-drained. Mango will grow in almost any well-drained soil whether sandy, loam or clay, but avoid heavy, wet soils. The tree often develops a fairly strong taproot shortly after planting. This taproot can continue growing until it reaches the soil water-table, and under favourable conditions can penetrate the soil to a depth of 6 m. However, most of the roots responsible for nutrient uptake are found in the top 500 mm of soil, with the largest concentrations in the top 250 mm (NDA, 2000). Depending on the conditions under which the mango is grown, i.e. dryland or under irrigation, the response to the soil type will vary.

The shape of the ground in the relation to underlying rock of the earth's surface is known as Topography. It affects the rate of runoff and erosion (Iwena, 2007). Mango trees grow best on a slight slope which enables runoff of excess water and prevents waterlogging. Physical properties are important: good drainage, permeability, fair water holding capacity and ground water at a depth of 3-4 m are features of an ideal soil for mango (Samson, 1992). There should be a hard layer to limit root penetration and watertable should not be higher than 2.5 m (Nakasone and Paull 1999). A light slope is desirable as it improves drainage; but steep slopes are also unsuitable. Mango trees do not grow and produce well in soils with impermeable layers. They also do not thrive on very steep slopes because excessive drainage in this case could lead to water shortages and soil erosion. Under irrigation, mangoes grow well in soils with an unimpeded depth of more than 1 m. If irrigation scheduling is well planned, there should be no problem on soil with a depth of 750 mm, provided that any soil or rocky layers that restrict root growth to a depth of 750 mm allows excess water to drain easily (NDA, 2000). If not, a temporary shallow soil water table could develop above this layer, with resulting damage to the trees. The ideal soil texture for mango cultivation under irrigation is a sandy loam or loam (with a clay content of 15 to 25 %), but soils with a clay content of up to 50 % are also suitable (NDA, 2000). The ideal soil has a fairly loose, brittle, crumbly structure. Compact or strongly-developed soil structures prevent effective water infiltration and root penetration. These soils are normally associated with high clay content in the subsoil. Allowing the soil to dry out for 2 or 3 months before the flowering stage will promote good flower formation. This phenomenon is attributed to a simultaneous stimulation of vegetative growth during the autumn months which, in turn, influences flower formation in spring. Fruit drop as well as the size and quality of mango fruit seems to be influenced by irrigation at certain times. Irrigation during the developmental stage of the fruit is essential to prevent fruit drop and to promote the development of young fruit. Additional irrigation from fruit set to ripening results in a considerable improvement in both fruit size and quality (NDA, 2000).

In some areas moisture losses through transpiration and evaporation are so low (because of humidity, temperature and rainfall conditions) that the soil remains moist enough throughout the year to prevent wilting of the trees. Mangoes can then be grown under dryland conditions, provided the soil has the ability to retain moisture that can be available to the plants in drier periods (NDA, 2000). For good growth, mango needs a deep soil to accommodate their extensive root systems. Soils with lower or higher clay content will not be able to supply sufficient moisture to the plants. Mango trees grow best in soils with pH values of 6 to 7.2 (NDA, 2000). The P^H should be between 5.5 and 6.00 (Kochhar, 1986). According to Nakasone and Paull (1999) a flat alluvial soil with of P^H of 5.5-7.0 is also suitable. The exchangeable aluminium (Al) is not more than 30 ppm; soils with a P^H of 5.5 or higher may be used. At P^H values lower or higher than 6 to 7.2 the trees may suffer trace-element deficiencies, especially phosphate and potassium (NDA, 2000). They are somewhat tolerant of alkalinity.

2.8 ALTITUDE IN RELATION TO MANGO PRODUCTION

Although mango trees are found at elevations up to 1200 m, it is unwise to plant orchards higher than 600 m (Samson 1992).The best production occurs at elevation between 0 and 600 m (Rice *et al* 1993).According to Opeke (1992), mango may grow at up to 1200 m in the tropics, but best performance can be expected in the tropical lowlands below 600 m. In the tropical and subtropical regions, mangoes grow well at altitudes ranging from sea level to 1 200 m. However, production decreases at higher altitudes. In South Africa, it is generally accepted that mango production above altitudes of 600 m is not commercially viable (NDA, 2000).

2.9 EVAPOTRANSPIRATION

Evapotranspiration (ET) is the process by which water is released into the air by evaporation from the soil and transpiration from plant surfaces. It is a combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration. Evapotranspiration is the total movement of water vapour into the air from land which supports plant life. It includes transpiration from the plants, evaporation from damp soil and evaporation from any open water that may be present in furrows or depressions following irrigation or heavy rainfall. It is expressed in terms of depth of water (millimeters), and the rate of evapotranspiration in millimeters per hour.

Evaporation is the process whereby liquid water is converted to water vapour (vaporization) and removed from the evaporating surface (vapour removal). Water evaporates from a variety of surfaces, such as lakes, rivers, pavements, soils and wet vegetation. Transpiration consists of the vaporization of liquid water contained in plant tissues and the vapour removal to the atmosphere. Crops predominately lose their water through stomata. These are small openings on the plant leaf through which gases and water vapour pass. Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process.

2.9.1 Factors affecting crop evapotranspiration

(i) Climate

(a) Variation with time

It is common practice to use mean climatic data for determining mean ETcrop. However, due to weather changes, ETcrop will vary from year to year and for each period within the year .In areas having distinct dry and wet seasons, the transition months show significant differences from year to year depending on rains arriving early or late.

(b) Variation with distance

In calculating ETcrop, by necessity climatic data are sometimes used from station located some distance from the area under study. This is permissible in areas where the same weather extends for long distances. With the change in weather over distance consequently ETcrop may change markedly over small distances

(c) Variation with size of irrigation development, advection.

Meteorological data used are often collected prior to irrigation development in stations located in rainfed or uncultivated, or even on rooftops and airports. ETcrop will be higher in fields surrounded by dry fallow land as compared to that surrounded by extensive vegetated area.

(d) Variation with altitude

In a given climatic zone, ETcrop will vary with altitude. This is not caused by difference in altitude as such but mainly by associated changes in temperature, humidity and wind. Also radiation at high altitude may be different to that in low lying areas. For the Blaney-Criddle method, ETo may be adjusted by 10 percent for each 1000 m altitude change above sea level (Doorenbos and Pruitt, 1996).

(ii) Soil water

(a)Level of available soil water

The methods presented on ETcrop assume soil water in ample supply. As the soil dries, the rate of water transmitted through the soil will be reduced. When at some stage the rate of flow is below the rate needed to meet ETcrop, ETcrop will fall below its predicted level.

(b) Groundwater

For most crops, growth and consequently ETcrop will be affected when groundwater is shallow or the soil is waterlogged. In spring in cooler climates, wet soils warm up slowly, causing delay in germination and plant development; land preparation may be delayed resulting in later planting. Consequently, different ETcrop values apply during the remainder of the season.

(c) Salinity

ETcrop can be affected by soil salinity since the soil water uptake by plant can be drastically reduced due to higher osmotic potential of the saline groundwater. Poor crop growth may be due to adverse physical characteristics of saline soils.

(iii) Method of irrigation.

ETcrop is affected little by the method of irrigation if the system is properly designed, installed and operated. Only with widely spaced crops and young orchards will ETcrop be reduced since evaporation will be restricted to the area kept moist.

(iv) Cultural practices.

(a) Fertilizers

The use of fertilizer has only a slight effect on ETcrop unless crop growth was previously adversely affectd by low soil nutrition.

(b)Plant population

The effect of plant or plant density on ETcrop is similar to that of percentage of ground cover. When top soils are kept relatively dry, evaporation from the soil surface is sharply reduced and ETcrop will be less for low population crop than for high population crop.

(c) Tillage

Tillage produces little, if any effects on ETcrop unless a significant quantity of weed is eliminated. Rough tillage will accelerate evaporation from the plough layer; deep tillage may increase water losses when the land is fallow or when the crop cover is sparse. After the surface has dried, evaporation from the dry surface might be less than an untilled soil

(d) Mulching

In irrigated agriculture the use of mulch from crop residues to reduce ETcrop is often considered of little net benefit, except for specific purposes such as reducing erosion, preventing soil sealing and increasing infiltration.

Polyethylene and perhaps also asphalt mulches are effective in reducing ETcrop, when it covers more than 80 percent of the soil surface and crop cover is less than 50 percent of the total cultivated area (Doorenbos and Pruitt, 1996).

(e) Windbreaks

Reduced wind velocities produced by artificial and vegetative windbreaks may reduce ETcrop by about 5 percent under windy, warm dry conditions at horizontal distance equal to 25 times the height of barrier downwind from it, increasing to 10 and sometimes up to 30 percent at a distance of 10 times this height (Doorenbos and Pruitt, 1996).

2.10 CROP WATER REQUIREMENTS

Crop water requirements are defined as the depth of water needed to meet the water loss through evapotranspiration (ETcrop) of a disease - free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment (Doorenbos and Pruitt, 1996). The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. The total quantity of water required by a plant for its growth and maturity under field conditions, including that supplied by rainfall, and any irrigation and groundwater available to the plant. Crop water requirements encompass the total amount of water used in evapotranspiration. Out of the total evapotranspiration, evaporation account for about 10 percent and plant transpiration for the remaining 90 percent (Phocaides, 2001).

Successful irrigation must begin by trying to decide how much is needed and then supplying that need. To supply more water than necessary will be wasteful, but this must be adequate for crop growth. The quantity of water used by a crop depends on how much is evaporated from the leaves. This is affected by how hot and dry the air is and how much the wind blows (Hudson, 1975).

2.11 ELEMENTS TO BE CONSIDERED WHEN ESTIMATING CROP WATER REQUIREMENT

1. Effective rainfall

It is the amount of rainwater retained in the root zone and it should be deducted from the total irrigation water requirements calculated. It is that part of the precipitation falling during the growing period of a crop that is available to meet the evapotranspiration needs of the crop (Punmia and Pande, 1990).

In surface hydrology, it is the rain that produces runoff. In irrigation practice, that portion of the total precipitation which is retained by the soil so that it is available for use for crop production. In geohydrology, it is that part of the total precipitation that reaches the groundwater.

2. Groundcover

It is the percentage of the field area (ground) covered by the cultivation .A reduction factor, expressed as Kr, is applied to the conventional ETcrop calculations.

3. Crop coefficient.

Crop Coefficient, Kc, is the ability (indication) of crop response to water. It is an indication of water use. Crop Coefficient (Kc) can be obtained from:

$$Kc = \frac{ETcrop}{ETo} \qquad (2.1)$$

where, The procedures for the selection of appropriate Kc values take into account the crop characteristics, time of planting or sowing, and stages of crop development and general climatic conditions. The factors affecting the value of the crop coefficient (Kc) are mainly the crop characteristics, crop planting or sowing data, rate of crop development, length of growing season and climatic conditions.

4. Crop growing season

The crop growing season has been divided into four stages as illustrated in Table 2.1 and Figure 2.2.:

Table 2.1 CROP GROWING SEASONS.

FOUR STAGES	MONTHS	CROP COEFICIENT, Kc	Kc
1.Crop Establishment	May	0.3	Kc< 1
1.Crop Establishment	June	0.3	Kc< 1
2.Crop Development	July	0.6	Kc< 1
2.Crop Development	August	0.8	Kc< 1
3.Maturity (Critical)	September	1.2	Kc>1
3.Maturity (Critical)	October	1.2	Kc >1
3.Maturity (Critical)	November	1.2	Kc>1
3.Maturity (Critical)	December	1.2	Kc>1
3.Maturity (Critical)	January	1.2	Kc>1
4.Harvest	February	0.8	Kc< 1
4.Harvest	March	0.5	Kc< 1
4.Harvest	April	0.2	Kc< 1

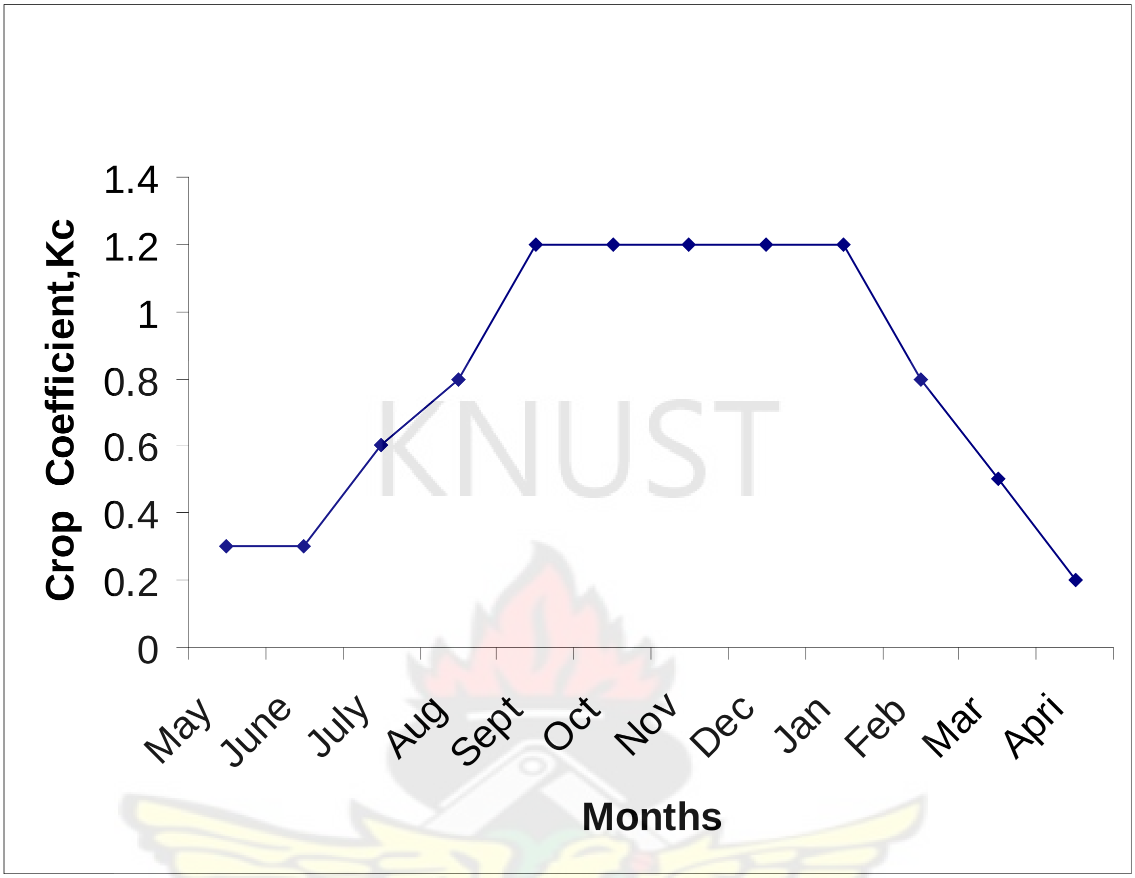

Figure 2.2. Crop Coefficient Curve for Mango

The current varieties or cultivars take about an average of three years to start bearing fruits. The seed is sown in the nursery beds which are later budded or grafted. The seedlings are then transplanted after about six to twelve months in the nursery. It is supplied with a generous amount of organic manure. The young mango plant is mulched. Pruning is done to remove dead wood and low hanging branches.

The crop can be established by three years. Table 2.1 and Figure 2.2, it depict that it is an annual cycle of flowering and fruiting and this cycle repeats itself.

The four stages of crop development are

(i) Crop establishment stage or initial period

The least amount of water is required at this stage. There is a lower demand for water. The demand for water increases gradually from this stage to the crop development stage. Kc is less than one. There is germination and early growth when the soil surface is not or is hardly covered by crop (groundcover less than10 percent).

(**ii) Crop development stage or period**

From the end of the initial stage to the time of effective full groundcover, that is 70 to 80 percent groundcover). Kc is less than one.

(iii) Mid-season or maturity stage

From the end of crop development period to the start of maturity as indicated by leaf discoloration, leaves falling off or curling and discolouring. A high or great amount of water is used for flower formation and fruiting. It is the time of the highest crop water demand. It is the most critical stage. Kc is greater than one.

(iv) Late-season or harvest stage

From the end of the mid-season stage until full maturity or harvest (Doorenbos and Pruitt, 1996), Kc is less than one.

5. Potential Evapotranspiration.

The term potential evapotranspiration is used to describe the evapotranspiration which could occur under natural conditions without irrigation, if water were freely available to the plants, which is what irrigation would provide. Potential evapotranspiration refers to the maximum rate of evapotranspiration from a large area completely and uniformly covered with growing vegetation with an unlimited moisture supply.

2.12 CURRENT PRODUCTION OF MANGO

Globally, the production of mango currently stands at about 25 million tonnes of fresh fruits as depicted in figure 2.2 and 290,000-processed mango pulp, puree and juice (Quartey, 2008). Of this Africa produces only 2.5 million tonnes, accounting for about 10 per cent of fresh fruits and 11 per cent of processed mango (Quartey, 2008). Ghana's current production is said to have increased from about 1,200 tonnes in 2007 to about 2,000 in 2008 (Quartey, 2008). The rest of global production comes from leading producers like Brazil, Mexico, Venezuela, Peru, India and U.S.A.

Figure 2.3 Mango tree with fruits.

There was a strong recommendation for the expansion of the production base of mangoes for export and the recent intervention includes; the mango mapping exercise undertaken by the Trade and Investment Programme for a Competitive Export Economy (Asamoah, 2006). Under this programme, the objective was to establish a database on current mango production and operation as a guide to interventions in the industry. The Ministry of Food and Agriculture developed the Horticultural Export Industry Initiative to help improve the country's horticultural industry capacity to compete on the international market (Asamoah, 2006). All these interventions were to propel the country's mango sector to new heights and take advantage of the growing international market of mangoes.

2.13 DEMAND FOR MANGO

The demand for mango in Ghana far exceeds the supply (Quartey, 2008). This is welcome news that must be embraced by not just individual farmers but also at the national level in order to make gains for the nation's development. The country as it stands now cannot in the short term produce enough to meet the ever-increasing demand on the European market (Quartey, 2008).

This is besides the growing demand for the fresh mango fruits from South Africa, especially during the winter months, which incidentally coincides with the harvest in Ghana (Quartey, 2008). This means, the export market for mangoes has already been created by the huge demand. This is simple but vital information that should trigger effort to supply. The SPORE Journal reports that, there is an enormous growing demand for mangoes globally. This demand has risen to an annual average of 10 per cent and is expected to rise by a further 8 per cent by the close of 2008 (Quartey, 2008). Such growth, according to the SPORE Journal could prove a golden opportunity to Africa, especially, Ghana that has comparative advantage in the cultivation of the mango fruit.

The local volume of trade for the giant fibreless hybrid mango species (Keitt and Kent) in Ghana is very small because the vast majority of Ghanaian mango eaters go in for the local type. Hybrid mangoes produced in Ghana are therefore meant for European market where there is a huge demand for it (Adu-Gyamerah, 2008).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The transitional agro-ecological zone of Ghana is so named because it is located between the forest and savannah vegetative zones of southern and northern Ghana. The zone covers an area of 10630 km^2 with a population of 544,131 in 2000. This is located mainly in the Brong-Ahafo and Ashanti regions of Ghana as shown in figure 3.1. (GSS, 2002). Some of the major urban areas in the zone are Atebubu, Berekum, Ejura, Wenchi, Techiman and Nkoranza.

The zone, which was originally forested, has lost most of its cover and is now a derived savannah, and is the leading producer of grains, cereals and tubers in Ghana. In recent times, commercial tree crops such as cashew have become popular. Variations in climatic and vegetative conditions have rendered the transitional zone and the southern part of Ghana more favourable for farming compared to the north. The transitional zone, however, experiences a double maximum rainfall regime, where there are two rainy or wet seasons. The two rainfall regimes occur from May to August and from September to October, with a mean annual rainfall of 1430mm.

Ghana has an immeasurable comparative advantage in the cultivation of grafted mango. This rests in the fact that most of the lands of the Coastal Savannah, Northern Ashanti, the transitional zones of Ashanti and Brong Ahafo Regions, the Northern Volta Region, and the whole of Northern, Upper East and Upper West Regions are suitable for mango production that meets international quality specification (Quartey, 2008).

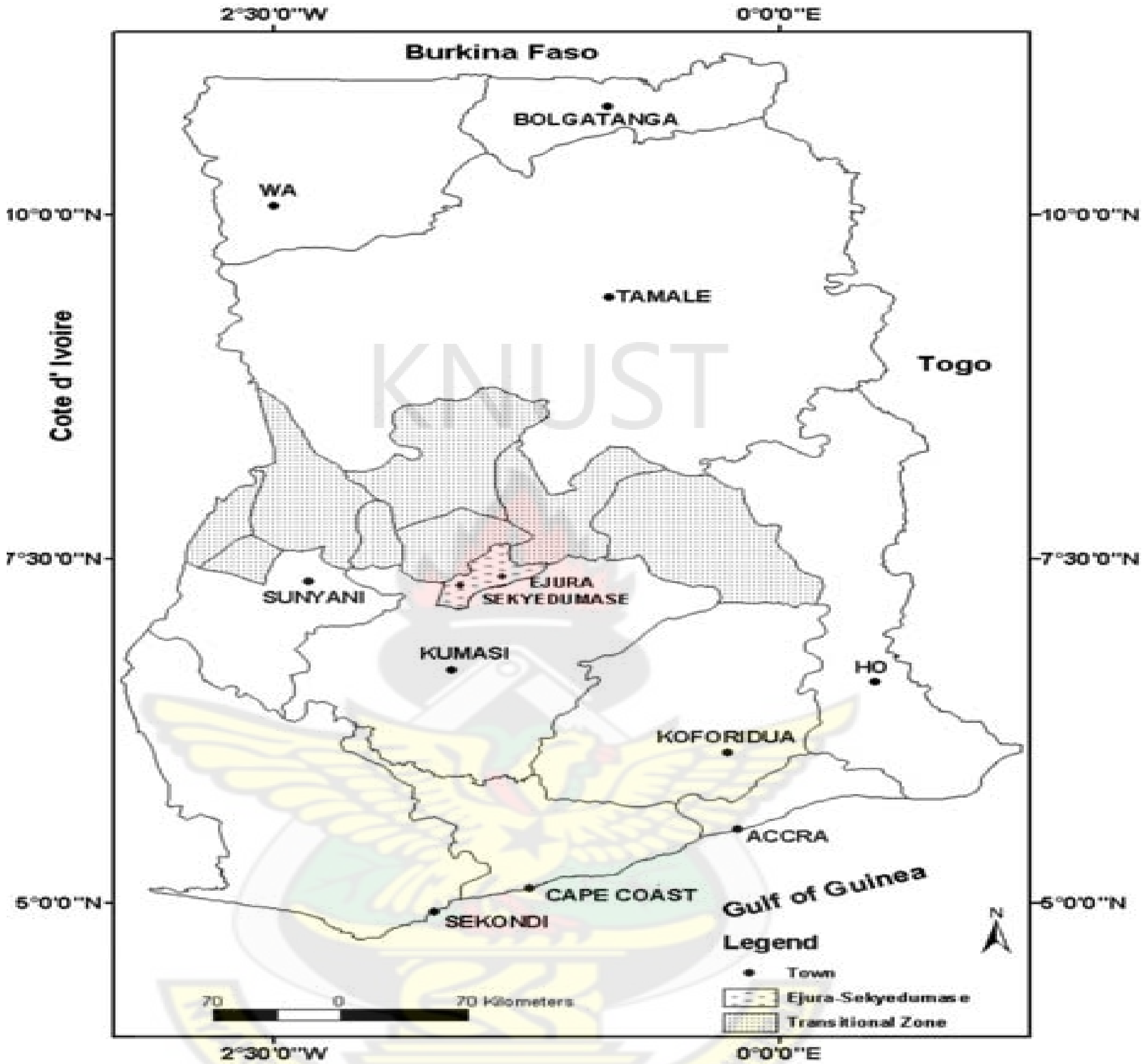

FIGURE 3.1: Map of Ghana showing the transitional agro-ecological zone.

The study was conducted in the Transitional agro-ecological zone of Ghana. Climatic or meteorological data were collected from the Ghana Meteorological Agency, Accra from 1976 to 2006. These were the mean monthly rainfall, maximum and minimum temperatures, relative humidity (0600 and 1500 hours), wind speed, sunshine hours and potential evapotranspiration. The following towns were selected in the study area:

Atebubu (7.55^0 N, 2.3^0 W), Berekum (7.45^0 N, 2.59^0 W), Ejura (7.38^0 N, 1.36^0 W), and Wenchi (7.75^0 N, 2.1 ^{0}W). The crop water requirement was computed or estimated using Pan Evaporation, Blaney-Criddle, Radiation, Penman and Thornthwaite Methods.

3.2 CALCULATION OF REFERENCE CROP EVAPOTRANSPIRATION (ETo).

1. Pan Evaporation Method.

Evaporation pans provide a measurement of the integrated effect of radiation, wind, temperature and humidity on evaporation from a specific open water surface. Reference crop evapotranspiration (ETo) can be obtained from: $ETo = KpEpan$ ……………………………………………………(3.1)

where,

$Epan = pan\ evaporation(mm/day)$

$Kp = pan\ coefficient$

Pan evaporation is a measurement that combines or integrates the effects of several climate elements: temperature, humidity, solar radiation, and wind. Evaporation is greatest on hot, windy, dry days; and is greatly reduced when air is cool, calm, and humid. Pan evaporation measurements enable farmers and ranchers to understand how much water their crops will need.

An evaporation pan is used to hold water during observations for the determination of the quantity of evaporation at a given location. Such pans are of varying sizes and shapes, the most commonly used being circular or square. The best known of the pans are the "Class A" evaporation pan as shown in figure 3.2 and the "Sunken Colorado Pan". Often the evaporation pans are automated with water level sensors and a small weather station is located nearby.

The **Class A evaporation pan**. Has a cylinder with a diameter of 47.5 in (120.7 cm), has a depth of 10 in (25 cm) (Wikipedia, 2008**)**. The pan rests on a carefully leveled, wooden base and is often enclosed by a chain link fence to prevent animals drinking from it as shown in figure3.2. Evaporation is measured daily as the depth of water (in inches) evaporates from the pan. The measurement day begins with the pan filled to exactly two inches (5 cm) from the pan top. At the end of 24 hours, the amount of water to refill the pan to exactly two inches from its top is measured.

Figure 3.2 Class A evaporation pan

If precipitation occurs in the 24-hour period, it is taken into account in calculating the evaporation. Sometimes precipitation is greater than evaporation, and measured increments of water must be dipped from the pan. Evaporation cannot be measured in a Class A pan when the pan's water surface is frozen.

The Class A Evaporation Pan is of limited use on days with rainfall events of greater than 30mm (203mm rain gauge) unless it is emptied more than once per 24 hours (Wikipedia , , 2008). Analysis of the daily rainfall and evaporation readings in areas with regular heavy rainfall events shows that almost without fail, on days with rainfall in excess of 30mm (203mm Rain Gauge) the daily evaporation is spuriously higher than other days in the same month where conditions were more receptive to evaporation that prevailed.

The most common and obvious error is in daily rainfall events of more than 55 mm (203 mm rain gauge) where the Class A Evaporation pan will likely overflow (Wikipedia ,2008). The less obvious is the influence of heavy or intense rainfall causing spuriously high daily evaporation totals without obvious overflow. Again, reflection of solar radiation from the water surface is only 5-8 percent, from most vegetative surfaces if is 20-25 percent (Doorenbos and Pruitt, 1996). Storage of heat within the pan can be appreciable and may cause almost equal evaporation during night and day. Also, the difference in water losses from the pans and crops can be caused by differences in turbulence, temperature and humidity of air immediately above the surfaces. Heat transfer through the sides of the pan can occur. Besides, the colour of the pan and the use of screens will affect water losses. In addition, the siting of the pan and the pan environment influence the measured results, especially when the pan is placed in fallow rather than cropped field. Finally, the Pan method can be graded with possible error of 15 percent, depending on the location of the pan (Doorenbos and Pruitt, 1996).

2. Blaney-Criddle Method

This method is suggested for areas where available climatic data cover air temperature data only. This empirical temperature-based method requires only mean monthly temperatures and an estimate of the monthly percentage of annual daytime hours. Using measured temperature data as well as general levels of humidity, sunshine and wind, an improved prediction of effect of climate on evapotranspiration should be obtainable. The Blaney-Criddle method should only be applied for periods of one month or longer; in humid, windy, mid-latitude winter conditions and over and under prediction of up to 25 percent (Doorenbos and Pruitt, 1996).

The relationship recommended, representing mean value over the given month, is expressed as:

$$ETo = c[p(0.46T + 8)] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

where,

$ETo = reference\ crop\ evapotranspiration (mm/day)$

$T = mean\ daily\ temperature (^oC)$

$p = mean\ daily\ percentage\ of\ total\ annual\ daytime\ hours\ obtained\ from\ tables\ for\ a$ $given\ month\ and\ latitude$

$c = adjustment\ factor\ which\ depends\ on\ \mathrm{min}imum\ relative\ humidity, sunshine\ hours$ $and\ daytime\ wind\ estimates$

3. Radiation Method

This method is suggested for areas where climatic data include measured air temperature and sunshine, cloudiness or radiation but not measured wind and humidity. Knowledge of general levels of humidity and wind is required. The Radiation method, in extreme conditions, involves a possible error of up to 20 percent in the summer (Doorenbos and Pruitt, 1996).

The relationship recommended (representing mean value over the given period) is expressed as:

$$ETo = c(W.Rs) \qquad (3.3)$$

where,

$ETo = reference\ crop\ evapotranspiration (mm/day)$

$Rs = solar\ radiation\ in\ equivalent\ evaporation\ (mm/day)$

$W = weighting\ factor\ which\ depends\ on\ temperature\ and\ altitude$

$c = adjustment\ factor\ which\ depends\ on\ mean\ humidity\ and\ daytime\ wind\ conditions$

4. Penman Method

The Penman equation consists of two terms: the energy (radiation) term and aerodynamic term (wind and humidity). The equation varies with climatic conditions. Under calm weather conditions the aerodynamic term is usually less important than the energy term. The modified Penman method would offer the best results with minimum possible error of plus or minus 10 percent in summer, and up to 20 percent under low evaporative conditions (Doorenbos and Pruitt, 1996).

The form of the equation used in this method is:

$$ETo = c[W \cdot Rn + (1-W) \cdot f(u) \cdot (ea - ed)] \qquad (3 \cdot 4)$$

where,

$ETo = reference\ crop\ evapotranspiration\ (mm/day)$

$W = temperature - related\ weighting\ factor$

$Rn = net\ radiation\ in\ equivalent\ evaporation\ (mm/day)$

$f(u) = wind - related\ function$

$(ea - ed) = difference\ between\ the\ saturation\ vapour\ pressure\ at\ mean\ air\ temperature$

$and\ the\ mean\ actual\ vapour\ pressure\ of\ the\ air (mbar)$

$c = adjustment\ factor\ to\ compensate\ for\ the\ effect\ of\ day\ and\ night\ weather\ conditions$

5. Thornthwaite method

The Thornthwaite method also depends on temperature and latitude. The largest possible error is 56 percent of ET in April and the smallest error is 22 (Shelton, 1978). This is computed as follows:

1. Tabulate the mean monthly temperature T^{O} C.

2. For each monthly value of T find the corresponding value of the heat index i from monthly heat index for estimating moisture requirements by Thornwthwaite method table.

3. Add the monthly values of i to get the annual heat index *I*.

4. On a Nomograph, draw a line joining the point of convergence to the appropriate value of *I* on the *I* scale.

5. From the line drawn on figure, find and tabulate, for each monthly value of T, the corresponding value of PET (potential evapotranspiration).

6. From latitude correction factors for the Thornthwaite method find and tabulate the monthly correction factors for the latitude.

7. The monthly values of the PET are then multiplied by the latitude correction factor to give the estimated monthly consumptive use of moisture.

3.3. CALCULATION OR DETERMINATION OF CROP WATER REQUIREMENT OF MANGO.

After determining ETo, ETcrop can be predicted using the appropriate crop coefficient of mango (Kc). By selecting cropping pattern and determining time of planting or sowing, rate of crop development, length of crop development stages and growing period one can select Kc for mango and stage of mango development under prevailing climatic conditions. Crop water requirement of mango (ET) can be obtained from:

$$ET = K_C ET_O \text{ ....} (3.5)$$

$where,$

$ET = crop\ water\ requirement\ of\ mango\ (mm/day)$

$Kc = crop\ coefficient\ of\ mango$

$ET_o = reference\ crop\ evapotranspiration\ (mm/day)$

To calculate ETcrop a three-stage procedure is recommended:

1.The effects of climate on crop water requirements is given by the reference crop evapotranspiration (ETo) which is defined as "the rate of evapotranspiration 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 water. The five methods presented, the Blaney-Criddle, Radiation, Penman, Pan Evaporation and Thornthwaite method, are modified to calculate ETo using the mean daily climatic data for 30 day periods. ETo is expressed in mm per day and represents the mean value over that period. Climatic data needed for the different methods are temperature, humidity, wind, sunshine, radiation and evapotranspiration.

2. The effect of the crop characteristics on crop water requirements is given by the crop coefficient (Kc) which presents the relationship between reference (ETo) and crop evapotranspiration ETcrop. Values of Kc given as shown vary with the crop, its stage of growth, growing season and the prevailing weather conditions.

3. The effect of local conditions and agricultural practices or crop water requirements includes the local effect of variations in climate over time, distance and altitude, size of fields, advectioin, soil water availability, salinity, methods of irrigation and cultivation methods and practice, for which local field data is required.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 DETERMINATION OF OPTIMUM CROP WATER REQUIREMENT OF MANGO.

Results of water requirements of mango are shown in the tables below.

Table 4.5 AMOUNT OF WATER REQUIRED FOR MANGO USING BLANEY-CRIDDLE METHOD FOR ATEBUBU (MONTHLY)

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	149	94	67	19	31	29	52	67	97	97	90	89

Table 4.22 CROP WATER REQUIREMENT (ANNUAL)

METHODS	ATEBUBU Mm	BEREKUM mm	EJURA mm	WENCHI mm
Blaney-Criddle	880	1021	938	1127
Radiation	1271	1235	1224	1256
Penman	1432	1409	1367	1446
Thornthwaite	1694	1607	1567	1780
Pan Evaporation.	-	-	-	1111

Table 4.24 AVERAGE ANNUAL RAINFALL

TOWNS	ATEBUBU mm	BEREKUM mm	EJURA mm	WENCHI mm
	1882	1116	1288	1237

Table 4.26 (a) POTENTIAL EVAPOTRANSPIRATION USING BLANEY-CRIDLLE FOR ATEBUBU (MONTHLY): SAMPLE CALCULATION.

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETo mm/day	4	4.2	4.3	3.2	3.3	3.2	2.8	2.7	2.7	2.6	2.5	2.4
No. of day	31	28	31	30	31	30	31	31	30	31	30	31
ETo mm/month	124.0	117.6	133.3	96.0	102.3	96.0	86.8	83.7	81.0	80.6	75.0	74.4

ANNUAL =1150.7 mm = **1151** mm.

Table 4.26 (b) POTENTIAL EVAPOTRANSPIRATION (ANNUAL)

METHODS	ATEBUBU Mm	BEREKUM mm	EJURA mm	WENCHI mm
Blaney-Criddle	**1151**	1303	1216	1446
Radiation	1639	1576	1567	1621
Penman	1858	1818	1776	1303
Thornthwaite	1652	1557	1526	1737
Pan Evaporation.	-	-	-	1391

Table 4.27 DEFICIT OR SURPLUS OF RAINFALL

METHODS	ATEBUBU Mm	BEREKUM mm	EJURA mm	WENCHI mm
Blaney-Criddle	731 SURPLUS	187 DEFICIT	72 SURPLUS	209 DEFICIT
Radiation	243 SURPLUS	460 DEFICIT	279 DEFICIT	384 DEFICIT
Penman	24 SURPLUS	702 DEFICIT	488 DEFICIT	67 DEFICIT
Thornthwaite	230 SURPLUS	441 DEFICIT	238 DEFICIT	500 DEFICIT
Pan Evaporation	-	-	-	154 DEFICIT

4. 1.1 BLANEY-CRIDDLE

ATEBUBU (VALUES ARE CORRECTED TO NEAREST WHOLE NUMBERS)

The least amount of crop water requirement of mango was 19 mm in the month of April. The highest amount of crop water requirement of mango was 149 mm in the month of January as shown in Table 4.5. It had an annual crop water requirement for mango of 880 mm also shown in Table 4.5 and this means that 880 mm of water is required to meet the water loss through evapotranspiration of a disease-free mango annually in Atebubu using Blaney-Criddle method.

Also, the average annual rainfall of 1882 mm as illustrated in Table 4.24 exceeded the annual potential evapotranspiration of mango of 1151 mm as depicted in Table 4.26 by 731 mm. This means that there is a surplus of 731 mm of water (Table 4.27). Therefore, there is the need to design, construct and manage supplementary irrigation systems for short duration droughts. The average annual rainfall compensates the water loss through evapotranspiration at Atebubu.

BEREKUM

Table 4.6 BLANEY-CRIDDLE METHOD FOR BEREKUM

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	167	108	76	20	30	30	65	80	115	123	104	104

The highest amount of crop water requirement of mango was 167 mm in the month of January as shown in Table 4.6. It had the lowest mean relative humidity of 54.5 % as shown in Table 4.2. The least amount of crop water requirement of mango was 20 mm in the month of April. Berekum had the annual crop water requirement of 1021 mm as illustrated in Table 4.22. This means that 1021 mm of water is required to compensate the water loss through evapotranspiration of a disease-free mango annually in Berekum using Blaney-Criddle method.

Moreover, the average annual rainfall of 1116 mm as illustrated in Table 4.24 and is less than the annual potential evapotranspiration of mango of 1303 mm as depicted in

Table 4.26 by 187 mm. This means that there is a deficit of 187 mm of water as shown in Table 4.27 As a result, there is the need to design, construct and manage supplementary irrigation systems. The average annual rainfall is inadequate to meet the water loss through evapotranspiration.

EJURA

Table 4.7 BLANEY-CRIDDLE METHOD FOR EJURA

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	112	76	54	22	33	32	65	79	118	119	112	115

It had the highest amount of crop water requirement of mango of 119 mm in the month of October as illustrated in Table 4.7. The least amount of crop water requirement of mango was in the month of April with the value of 22 mm. The annual crop water requirement of mango was 938 mm. This means that 938 mm of water is required to meet the water loss through evapotranspiration of a disease-free mango annually in Ejura using Blaney-Criddle method.

Again, the average annual rainfall of 1288 mm as illustrated in Table 4.24 is more than the annual potential evapotranspiration of 1216 mm as depicted in Table 4.26 by 72 mm. This means that there is a surplus of 72 mm of water as shown in Table 4.27. For this reason, there is the need to design, construct and manage supplementary irrigation systems for short duration droughts. The average annual rainfall compensates for the water loss through evapotranspiration.

WENCHI

Table 4.8 BLANEY-CRIDDLE METHOD FOR WENCHI

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	160	112	81	23	35	34	69	89	130	134	126	134

As shown in Table 4.8, the highest amount of crop water requirement of mango was 160 mm in the month of January. The least amount of crop water requirement of mango was 23 mm in the month of April. The annual crop water requirement of mango was 1127 mm. This means that 1127 mm of water is required to compensate the water loss through evapotranspiration of a disease-free mango annually in Wenchi using Blaney-Criddle method.

Furthermore, according to Tindall *et al* (1993), for commercial production a minimum of 635 mm of rainfall is recommended. The average annual rainfall of 1237 mm as illustrated in Table 4.24 and Figure 4.32 is less than the annual potential evapotranspiration of 1446 mm as depicted in Table 4.26 by 209mm. This means that there is a deficit of 209 mm of water as shown in Table 4.27. Thus, there is the need to design, construct and manage supplementary irrigation systems. The average annual rainfall is insufficient to meet the water loss through evapotranspiration.

4.1.2. RADIATION

ATEBUBU

Table 4.9 RADIATION METHOD FOR ATEBUBU

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	193	130	90	31	46	36	65	80	137	156	154	153

Table 4.9 indicated that the highest crop water requirement of mango was 193 mm in the month of January. The least amount of crop water requirement of mango was 31 mm in the month of April. The annual crop water requirement of mango was 1271 mm. This means that in Atebubu 1271 mm of water is required annually to meet the water loss through evapotranspiration of a disease-free mango using Radiation method.

Besides, the average annual rainfall of 1882 mm as illustrated in Table 4.24 exceeded the annual potential evapotranspiration of 1639 mm as depicted in Table 4.22 by 243 mm. This means that there is an excess of 243 mm of water as shown in Table 4.27. For this reason, there is the need to design, construct and manage supplementary irrigation systems for short duration droughts. The average annual rainfall is sufficient to meet the water loss through evapotranspiration.

BEREKUM

Table 4.10 RADIATION METHOD FOR BEREKUM

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	193	119	82	30	42	36	60	80	130	156	155	157

Table 4.10 depicts that the highest crop water requirement of mango was 193 mm in the month of January. In the month of April it had least value of crop water requirement of 30 mm. The annual crop water requirement of mango was 1235 mm. This means that in Berekum, 1235 mm of water is required annually to meet the water loss through evapotranspiration of a disease-free mango using Radiation method.

Apart from this, the average annual rainfall of 1116 mm as illustrated in Table 4.24 and Figure 4.32 is less than the annual potential evapotranspiration of 1576 mm as depicted in Table 4.26 by 460mm. This means that there is a deficit of 460 mm of water as shown in Table 4.27. Consequently, supplementary irrigation systems should be designed, constructed and managed to meet deficiencies in potential evapotranspiration caused by shortages in precipitation or soil-moisture shortage capacities (Cuenca, 1989).

EJURA

Table 4.11 RADIATION METHOD FOR EJURA

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	182	116	78	31	40	36	68	80	137	153	155	149

From Table 4.11, the highest amount of crop water requirement of mango was 182 mm in the month of January. The least amount of crop water requirement of mango was 31 mm in the month of April. It had an annual crop water requirement of mango of 1224 mm. This means that at Ejura 1224 mm of water is required annually to compensate the water loss through evapotranspiration of a disease-free mango using Radiation method.

That is the average annual rainfall of 1288 mm as illustrated in Table 4.24 and Figure 4.32 is less than the annual potential evapotranspiration of 1567 mm as depicted in Table 4.26 by 279 mm. This means that there is a deficit of 279 mm of water as shown in Table 4.27. In consequence, there is the need to design, construct and manage supplementary irrigation systems. The average annual rainfall is insufficient to meet the water loss through evapotranspiration.

WENCHI

Table 4.12 RADIATION METHOD FOR WENCHI

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	205	134	90	30	45	36	65	77	130	149	151	145

The highest amount of crop water requirement of mango was 205 mm in the month of January as shown in Table 4.12. The least amount of crop water requirement of mango was 30 mm in the month of April. It had the annual crop water requirement of mango of 1256 mm. This means that in Wenchi 1256 mm of water is required annually to meet the water loss through evapotranspiration of a disease-free mango using Radiation method. The average annual rainfall of 1237 mm as illustrated in Table 4.24 is less than the annual potential evapotranspiration of 1621 mm as depicted in Table 4.26 by 384 mm. This means that there is a deficit of 384 mm of water as shown in Table 4.27. Thus, supplementary irrigation systems should be designed, constructed and managed to meet deficiencies in potential evapotranspiration caused by shortages in precipitation or soil-moisture shortage capacities (Cuenca, 1989).

4.1.3 PENMAN

ATEBUBU

Table 4.13 PENMAN METHOD FOR ATEBUBU

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	209	147	100	37	53	40	73	91	153	178	176	175

It had the highest amount of crop water requirement of mango of 209 mm in the month of January as illustrated in Table 4.13 The least amount of crop water requirement of mango was in the month of April with the value of 37 mm. The annual crop water requirement of mango was 1432 mm. This means that 1432 mm of water is needed to compensate the water loss through evapotranspirition of a disease-free mango annually in Atebubu using Penman method. The average annual rainfall of 1882 mm as illustrated in Table 4.24 exceeded the annual potential evapotranspiration of 1858 mm as depicted in Table 4.26 by 24 mm. This means that there is a surplus of 24 mm of water as shown in Table 4.27. Therefore, there is the need to design, construct and manage supplementary irrigation systems for short duration drought. The average annual rainfall is adequate to meet the water loss through evapotranspiration.

BEREKUM

Table 4.14 PENMAN METHOD FOR BEREKUM

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	203	148	94	36	50	38	73	90	153	176	168	176

From Table 4.14 the highest amount of crop water requirement of mango was 203 mm in the month of January. The least amount of crop water requirement of mango was 36 mm in the month of April. It had an annual crop water requirement of mango of 1409 mm. This means that 1409 mm of water is needed to meet the water loss through evapotranspirition of a disease-free mango annually in Berekum using Penman method.

Apart from this, the average annual rainfall of 1116 mm as illustrated in Table 4.24 is less than the annual potential evapotranspiration of 1818 mm as depicted in Table 4.26 by 702 mm. This means that there is a deficit of 702 mm of water as shown in Table 4.27. In view of this, supplementary irrigation systems should be designed, constructed and managed to compensate deficiencies in potential evapotranspiration caused by shortages in precipitation or soil-moisture shortage capacities (Cuenca, 1989).

EJURA

Table 4.15 PENMAN METHOD FOR EJURA

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	195	138	97	36	51	38	71	87	150	169	169	166

The highest amount of crop water requirement of mango was 195 mm in the month of January as shown in Table 4.15. The least amount of crop water requirement of mango was 36 mm in the month of April. It had an annual crop water requirement of 1367 mm. This means that 1367 mm of water is needed to meet the water loss through evapotranspirition of a disease-free mango annually in Ejura using Penman method.

In addition, the average annual rainfall of 1288 mm as illustrated in Table 4.24 and Figure 4.32 is less than the annual potential evapotranspiration 1776 mm as depicted in Table 4.26 by 488 mm. This means that there is a deficit of 488 mm of water as shown in Table 4.27. Hence, supplementary irrigation systems should be designed, constructed and managed to meet deficiencies in potential evapotranspiration caused by shortages in precipitation or soil-moisture shortage capacities (Cuenca, 1989).

WENCH

Table 4.16 PENMAN METHOD FOR ATEBUBU

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	219	161	105	2	12	39	71	89	149	-34	178	185

Mango had the highest amount of crop water requirement of 219 mm in the month of January at Wenchi as illustrated in Table 4.16. The highest mean temperature was 28.5^{o}C.The least amount of crop water requirement of mango was in the month of October with the value of -34 mm, the annual crop water requirement of mango was 1446 mm. This means that 1446 mm of water is needed to compensate the water loss through evapotranspirition of a disease-free mango annually in Wenchi using Penman method.

However, the average annual rainfall of 1237 mm as illustrated in Table 4.24 and Figure 4.32 is less than the annual potential evapotranspiration of 1303 mm as depicted in Table 4.26 by 66 mm. This means that there is a deficit of 66 mm of water as shown in Table 4.27. In effect, supplementary irrigation systems must be designed, constructed and managed to meet deficiencies in potential evapotranspiration caused by shortages in precipitation or soil-moisture shortage capacities (Cuenca, 1989).

1.4 THORNTHWAITE METHOD

ATEBUBU

Table 4.17 THORNTHWAITE METHOD FOR ATEBUBU

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	154	139	147	156	156	144	131	127	126	141	139	135

As shown in Table 4.17, the crop water requirement of mango was ranging from 126 mm in September to the highest of 156 mm in May. The annual crop water requirement of mango was 1694 mm. This means that in Atebubu 1694 mm of water is needed to meet the water loss through evapotranspiration of a disease-free mango annually using Thornthwaite method. The average annual rainfall of 1882 mm as illustrated in Table 4.24 exceeded the annual potential evapotranspiration of 1652 mm as depicted in Table 4.26 by 230 mm. This means that there is a surplus of 230 mm of water as shown in Table 4.27 and Figure 4.33. Therefore, there is no need to design, construct and manage supplementary irrigation systems. The average annual rainfall is sufficient to meet the water loss through evapotranspiration.

BEREKUM

Table 4.18 THORNTHWAITE METHOD FOR EJURA

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	275	124	142	138	139	115	117	116	112	112	108	109

Table 4.18 illustrates that the crop water requirement of mango ranged between 108 mm in November to 142 mm in March. The annual crop water requirement of mango was 1607 mm. This means that in Berekum 1607 mm of water is needed to compensate the water loss through evapotranspiration of a disease-free mango annually using the Thornthwaite method. The average annual rainfall of 1116 mm as illustrated in Table 4.24 is less than the annual potential evapotranspiration of 1557 mm as depicted in Table 4.26 by 441 mm. This means that there is a deficit of 441 mm of water as shown in Table 4.27. Consequently, supplementary irrigation systems should be designed, constructed and managed to meet deficiencies in potential evapotranspiration caused by shortages in precipitation or soil-moisture shortage capacities (Cuenca, 1989).

EJURA

Table 4.19 THORNTHWAITE METHOD FOR EJURA

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	151	111	140	152	150	127	122	119	118	124	134	119

Table 4.19 depicted that the crop water requirement of mango was 1567 mm. This means that in Ejura 1567 mm of water is needed to meet the water loss through evapotranspiration of a disease-free mango annually using the Thornthwaite method. The least amount of crop water requirement of mango was 111 mm in the month of February. The month of April had the highest amount of crop water requirement of mango of 152 mm. Since the average annual rainfall of 1288 mm as illustrated in Table 4.2 is less than the annual potential evapotranspiration of mango of 1526 mm as depicted in Table 4.26 by 238 mm. It means that there is a deficit of 238 mm of water as shown in Table 4.27. In view of this, supplementary irrigation systems should be designed, constructed and managed to meet deficiencies in potential evapotranspiration caused by shortages in precipitation or soil-moisture shortage capacities (Cuenca, 1989).

WENCHI

Table 4.20 THORNTHWAITE METHOD FOR WENCHI

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	157	146	174	168	164	148	118	127	145	148	146	139

From Table 4.20, the highest amount of crop water requirement of mango was 174 mm in the month of March. The least amount of crop water requirement of mango was 118 mm in the month of July. It had the annual crop water requirement of mango of 1780 mm. This means that in Wenchi 1780 mm of water is needed to compensate the water loss through evapotranspiration of a disease-free mango annually using the Thornthwaite method. The average annual rainfall of 1237 mm as illustrated in Table 4.24 is less than the annual potential evapotranspiration of mango of 1737 mm as depicted in Table 4.26 by 500 mm. This means that there is a deficit of 500 mm of water as shown in Table 4.2. Thus, supplementary irrigation systems should be designed, constructed and managed to meet deficiencies in potential evapotranspiration caused by shortages in precipitation or soil-moisture shortage capacities (Cuenca, 1989).

4.1.5. PAN EVAPORATION

WENCHI (NO DATA AVAILABLE FOR ATEBUBU, BEREKUM AND EJURA)

Table 4.21 PAN EVAPOTRANSPIRATION METHOD

Months	J	F	M	A	M	J	J	A	S	O	N	D
ETc mm/month	221	155	86	25	31	25	42	56	91	99	125	157

As shown in Table 4.21, the least amount of crop water requirement of mango was 25 mm in the month of June. The highest amount of crop water requirement of mango was 221 mm in the month of January. Wenchi had the annual crop water requirement of mango of 1111 mm using Pan Evaporation method. This means that water required to meet the water loss through evapotranspiration of a disease-free mango is 1111 mm annually in Wenchi.

Again, the average annual rainfall of 1236.5 mm as illustrated in Table 4.24 and Figure 4.32 is in excess of the annual crop water requirement of mango of 1111.3 mm as depicted in Table 4.22 by 125.2 mm. This means that there is a surplus of 125.2 mm of water as shown in Table 4.25. Thus, there is no need to design, construct and manage supplementary irrigation systems. The average annual rainfall is sufficient to meet the water loss through evapotranspiration.

4.2 COMPARISON OF CROP WATER REQUIREMENT DETERMINATION.

Compared results of water requirements of mango are shown in the tables below.

Table 4.22 COMPARISON OF VARIOUS METHODS OF CROP WATER REQUIREMENT .

METHODS	ATEBUBU Mm	BEREKUM mm	EJURA mm	WENCHI mm
Blaney-Criddle	880	1021	938	1127
Radiation	1271	1235	1224	1256
Penman	1432	1409	1367	1446
Thornthwaite	1694	1607	1567	1780
Pan Evaporation	-	-	-	1111

Table 4.28 OVERESTIMATION OR UNDERESTIMATION OF CROP WATER REQUIREMENT

METHODS	ATEBUBU Mm	BEREKUM mm	EJURA mm	WENCHI mm
Blaney-Criddle	-552	-388	-429	-319
Radiation	-161	-174	-143	-190
Penman (Standard Method)	0	0	0	0
Thornthwaite	+262	+198	+200	+334
Pan Evaporation	-	-	-	-335

KEY: POSITVE = OVERESTIMATION, NEGATIVE = UNDERESTIMATION

Table 4.29 RATIOS OF CROP WATER REQUIREMENT

METHODS	ATEBUBU	BEREKUM	EJURA	WENCHI
Blaney-Criddle	0.6	0.7	0.7	0.8
Radiation	0.9	0.9	0.9	0.9
Penman	1.0	1.0	1.0	1.0
Thornthwaite	1.2	1.1	1.1	1.2
Pan Evaporation	-	-	-	0.8

PENMAN

Penman is the standard method. From Table 4.28, taking Penman method as a standard unit of measurement, the annual crop water requirements of mango are 0 mm in Atebubu, Berekum, Ejura and Wenchi. It includes all the climatic factors that affect evapotranspiration. It is the best known combination method that applies a radiation (energy) balance plus aerodynamic (wind and humidity) approach to estimating crop evapotranspiration. This method estimates evapotranspiration using the radiation balance to indicate part of the amount of energy available for evaporation and an aerodynamic term to quantify the influence of advection conditions over the crop canopy in removing water vapour from the field. The modified Penman method would offer the best results with minimum possible error of plus or minus 10 percent in summer, and up to 20 percent under low evaporative conditions (Doorenbos and Pruitt, 1996).

BLANEY-CRIDDLE

The Blaney-Criddle method is an empirical temperature-based method. It underestimates crop water requirement. From Table 4.28, the underestimated annual crop water requirements of mango are -552 mm for Atebubu, -388 mm for Berekum, -429 mm for Ejura and -319 mm for Wenchi. The main cause of this underestimation is that the Blaney-Criddle method only includes locally measured average temperature data and evenly weights nighttime and daytime temperatures. In Ghana where there are little variations in the average daily temperatures, the Blaney-Criddle Method does not reflect the true picture of evapotranspiration computations.

At the semi-arid low elevation site, the Blaney-Criddle method underpredicts actual crop water use for the entire season and underpredicts the peak demand by about 19 percent. At the higher elevation, arid site, the performance of this method is even less satisfactory with an underestimation of the peak demand of about 29 percent (Cuenca, 1989). The Blaney-Criddle method should only be applied for periods of one month or longer; in humid, windy, mid-latitude winter conditions and over and under prediction of up to 25 percent (Doorenbos and Pruitt, 1996).

RADIATION

The Radiation method is an empirical temperature-based method. It underestimates crop water requirement. From Table 4.28, the underestimated annual crop water requirements of mango are -161 mm for Atebubu, -174 mm for Berekum, -143 mm for Ejura and -190 mm for Wenchi. The Radiation method is suggested for areas where climatic data include measured air temperature and sunshine, cloudiness or radiation but not measured wind and humidity. The Radiation method, in extreme conditions, involves a possible error of up to 20 percent in the summer (Doorenbos and Pruitt, 1996).

THORNTHWAITE

The Thornthwaite method is an empirical temperature-based method. It overestimates crop water requirement. From Table 4.28, the overestimated annual crop water requirements of mango are +262 mm for Atebubu, +198 mm for Berekum, +200 mm for Ejura and +334 mm for Wenchi. Thornthwaite method depends on temperature and latitude (Hudson, 1975). The largest possible error is 56 percent of ET in April and the smallest error is 22 (Shelton, 1978).

PAN EVAPORATION

Pan Evaporation method underestimates crop water requirement. From Table 4.28, the underestimated annual crop water requirement of mango is -335 mm in Wenchi. Pan Evaporation is the direct method. It shows the combined of the climatic factors. Evaporation pans provide a measurement of the integrated effect of radiation, wind, temperature and humidity on evaporation from a specific open water surface. The Pan method can be graded with possible error of 15 percent, depending on the location of the pan (Doorenbos and Pruitt, 1996).

ATEBUBU

As shown in Table 4.29 the ratios of crop water requirement of mango using Penman to Thornthwaite method are 1.0:1.2 in Atebubu. This means that the ratio of crop water requirement using Thornthwaite method is more than the standard method (Penman). The crop water requirement of mango is overestimated. However, the ratios of crop water requirement of mango using Penman to Radiation to Blaney-Criddle are 1.0:0.9:0.6. This is means that the ratio of the crop water requirement using Radiation and Blaney-Criddle are less than the standard method (Penman). The crop water requirements of mango are underestimated.

BEREKUM

As shown in Table 4.29 the ratios of crop water requirement of mango using Penman to Thornthwaite method are 1.0:1.1 in Berekum. This means that the ratio of crop water requirement using Thornthwaite method is more than the standard method (Penman). The crop water requirement of mango is overestimated. But, the ratios of crop water requirement of mango using Penman to Radiation to Blaney-Criddle are 1.0:0.9:0.7. This is means that the ratio of the crop water requirement using Radiation and Blaney-Criddle are less than the standard method (Penman). The crop water requirements of mango are underestimated.

EJURA

As depicted in Table 4.29, the ratios of crop water requirement of mango using Penman to Thornthwaite method are 1.0:1.1 in Ejura. This means that the ratio of crop water requirement using Thornthwaite method is more than the standard method (Penman). The crop water requirement of mango is overestimated. However, the ratio of crop water requirement of mango using Penman to Radiation is 1.0:0.9 and Penman to Blaney-Criddle is 1.0:0.7. This is means that the ratio of the crop water requirement using Radiation and Blaney-Criddle are less than the standard method (Penman). The crop water requirements of mango are underestimated.

WENCHI

As illustrated in Table 4.29, the ratios of crop water requirement of mango using Penman to Thornthwaite method are1.0:1.2 in Wenchi. This means that the ratio of crop water requirement using Thornthwaite method is more than the standard method (Penman). The crop water requirement of mango is overestimated. However, the ratio of crop water requirement of mango using Penman to Radiation to Blaney-Criddle to Pan Evapotranspiration are 1.0:0.9:0.8:0.8. This means that the ratios of the crop water requirement using Radiation, Blaney-Criddle are less than the standard method (Penman). The crop water requirements of mango are underestimated.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

From the results of the research, the least and highest optimum crop water requirement of mango using meteorological data were 880 mm and 1127 mm for Blaney-Criddle, 1224 mm and 1271 mm for Radiation, 1367 mm and 1446 mm for Penman, 1567 mm and 1780 mm for Thornthwaite respectively. The value of 1111 mm was for the Pan Evapotranspiration method.

The Thornthwaite method had the highest annual crop water requirement of mango with the values of 1694 mm in Atebubu, 1607 mm in Berekum, 1567 mm in Ejura and 1780 mm in Wenchi. However, the Blaney-Criddle method had the least values with 880 mm in Atebubu, 1021 mm in Berekum, 938 mm in Ejura and 1127 mm in Wenchi.

These values mean the water required to compensate the water loss through evapotranspiration of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment.

Penman is the standard or best method. It includes all the climatic factors that affect evapotranspiration. The Penman expression uses data on temperature, humidity, wind (speed) and sunshine duration or radiation. The instruments for measuring the data are thermometer (temperature), hygrometer or psychrometer (humidity), anemometer (wind speed), and Campbell Stokes Sunshine Recorder (sunshine duration). It provides reliable estimates and most satisfactory results compared to other methods, but I t is difficult to obtain accurate field measurement. Penman method is laborious, time-consuming and costly (instruments). The modified Penman method which would offer the best results with minimum possible error of plus or minus 10 percent in summer, and up to 20 percent under low evaporative conditions (Doorenbos and Pruitt, 1996).

The Pan Evaporation is the direct method. It shows the combination of the climatic factors. The Evaporation pan integrates the effects of several climate elements: temperature, humidity, solar radiation (sunshine), and wind speed. The Class A pan method is relatively inexpensive and simple to handle. This is the simplest and most widespread method of obtaining a direct measurement. The Pan method can be graded next with possible error of 15 percent, depending on the location of the pan (Doorenbos and Pruitt, 1996). The most common and obvious error is in daily rainfall events of greater than 55 mm (203mm rain gauge) where the Class A Evaporation pan will likely overflow (Wikipedia, 2008). Again, reflection of solar radiation from the water surface is only 5-8 percent, and from most vegetative surfaces it is 20-25 percent (Doorenbos and Pruitt, 1996).

The Radiation method is a temperature based method. It underestimates the crop water requirement. The Radiation method is suggested for areas where climatic data include measured air temperature and sunshine, cloudiness or radiation but not measured wind and humidity. Knowledge of general levels of humidity and wind speed is required. It is more reliable than Blaney-Criddle approach. It is not an accurate method. The Radiation method, in extreme conditions, involves a possible error of up to 20 percent in the summer (Doorenbos and Pruitt, 1996).

The Blaney-Criddle is a temperature based method. It underestimates the crop water requirement. The Blaney-Criddle method is suggested for areas where available climatic data cover air temperature data only. It is not accurate and easy to calculate. The Blaney-Criddle method should only be applied for periods of one month or longer; in humid, windy, mid-latitude winter conditions and over and under prediction of up to 25 percent (Doorenbos and Pruitt, 1996). In Ghana where there are little variations in the average daily temperatures, the Blaney-Criddle Method does not reflect the true picture of evapotranspiration computations.

However, the Thornthwaite is temperature- based method. It overestimates the crop water requirement. The Thornthwaite method depends on temperature and latitude. It is easy to calculate. The largest possible error is 56 percent of ET in April and the smallest error is 22 (Shelton, 1978).

Mango under rainfed conditions can produce one crop per year but under supplementary irrigation it is possible to harvest two crops per year. Mango is emerging as an important non-traditional export crop and requires that some programme is put in place to promote its cultivation.

5.2 RECOMMENDATIONS

It is recommended that the computations are carried out for other agroecological zones of Ghana, especially in the three northern regions (Savannah areas) of Ghana and the south-eastern part of Ghana.

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APPENDICES: TABLES

TABLE 4.1 ATEBUBU CLIMATIC DATA. LAT 7.55 N LON 2.3 W ATL 122 m

Months	Rain(mm) Average	Tmax(^{0}C)	Tmin(^{0}C)	Tm(^{0}C)	RH(%) 0600hrs	RH (%) 1500hrs	RH (%) mean
J	21.2	34.2	19.8	27	77	43.41	60.205
F	15.4	35.6	21.4	28.5	79	43.82	61.41
M	68	35.3	22.4	28.85	84	49.12	66.56
A	158.3	34.3	23.3	28.8	88	60.06	74.03
M	217.8	33.4	22.1	27.75	90	63.59	76.795
J	579.9	32.3	21.5	26.9	92	68.88	80.44
J	199.4	31.3	21.3	26.3	93	70.71	81.855
A	145.7	31	21.3	26.15	92	72.06	82.03
S	242.3	31.4	21.5	26.45	92	72.29	82.145
O	167.6	32.5	21.4	26.95	91	67.24	79.12
N	62.3	33.3	21	27.15	90	59.35	74.675
D	4.4	33.3	20.1	26.7	87	53.94	70.47
ANNUAL	**1882.3**						

TABLE 4.2 BEREKUM CLIMATIC DATA. LAT 7.45 N LON 2.59 W ALT 304 m

Months	Rain(mm) Average	Tmax(^{0} C)	Tmin(^{0}C)	Tm(^{0} C)	RH (%) 0600hrs	RH (%) 1500hrs	RH (%) mean
J	21.7	32	18	25	74	35.17	54.585
F	56.7	33.5	19.7	26.6	80	36.5	58.25
M	105	33	20.8	26.9	87	45.67	66.335
A	135.1	32.1	20.9	26.5	90	57.61	73.805
M	157.5	31.4	20.6	26	91	62.11	76.555
J	140.5	30.2	20.3	25.25	93	67.78	80.39
J	79.1	29.2	19.9	24.55	93	70.94	81.97
A	92	29.3	19.8	24.55	92	70.17	81.085
S	145.5	29.7	20.1	24.9	91	69.22	80.11
O	138.2	30	20	25	90	65.5	77.75
N	37.1	30.9	19.9	25.4	90	58	74
D	7.7	31	18.6	24.8	82	47.11	64.555
ANNUAL	**1116.1**						

TABLE4.3. EJURA CLIMATIC DATA LAT.7.38N LON1.36W ALT.225 m

Months	Rain(mm) Average	Tmax(^{0} C)	Tmin (^{0} C)	Tm (^{0}C)	RH (%) 0600hrs	RH (%) 1500hrs	RH (%) mean
J	7.4	34.2	19.5	26.85	75.375	61.67	68.5225
F	25.5	35.5	21	28.25	79	55.58	67.29
M	105.3	35	22.2	28.6	85.75	59.83	72.79
A	142.8	34.1	22.2	28.15	88.938	66.5	77.719
M	177.1	33.1	21.7	27.4	89.125	67.33	78.2275
J	176.6	31.5	21.1	26.3	89.75	73.29	81.52
J	121.9	30.2	20.9	25.55	89.563	77.67	83.6165
A	83	29.9	20.7	25.3	89.125	77.91	83.5175
S	214.7	30.8	20.8	25.8	90.25	77.05	83.65
O	177.5	31.8	20.9	26.35	90.688	74.45	82.569
N	36.5	32.9	20.8	26.85	89.75	70.55	80.15
D	19.3	32.6	19.8	26.2	82.563	67.82	75.1915
ANNUAL	**1287.5**						

TABLE 4.4

	WENCHI	CLIMATIC	DATA	LAT.7.75N	LON2.1W	ALT 340 m	RH(%)
Months	**Rain(mm) Average**	**Tmax (^{0}C)**	**Tmax (^{0}C)**	**T m (^{0}C)**	**RH (%) 0006hrs**	**RH (%)1500hrs**	**Mean**
J	9	34.6	20.2	27.4	68	31	49.5
F	25.6	36.6	22.9	29.75	76	32	54
M	100.2	37.5	25	31.25	86	44	65
A	157	36	25.1	30.55	92	59	75.5
M	157.3	33.6	24	28.8	94	65	79.5
J	152.8	31.6	22.8	27.2	96	70	83
J	124.9	30	21.1	25.55	96	72	84
A	92	29.6	21.9	25.75	95	72	83.5
S	179.6	30.5	21.9	26.2	96	72	84
O	177.5	32.9	22.5	27.7	96	70	83
N	48.9	34.9	21.5	28.2	94	62	78
D	11.8	34.6	19.7	27.15	84	46	65
ANNUAL	**1236.5**	**1 Knot=**	**0.515 m/s,1 Knot=1.85 km**		**/hr,1 knot=44.5 km/day**		

U Knots	**U2 m/s**	**U2 km/hr**	**U2 km/day**	**Sun hrs**	**Pot Eva mm**
2.6	1.339	4.81	115.7	7.2	184.1
3.1	1.5965	5.735	137.95	7.6	193.3
3.4	1.751	6.29	151.3	7.1	171.3
3.5	1.8025	6.475	155.75	7.4	123.9
3.2	1.648	5.92	142.4	6.9	102.7
3	1.545	5.55	133.5	6	82.2
3.2	1.648	5.92	142.4	4.3	69.8
3.4	1.751	6.29	151.3	3.3	70
3	1.545	5.55	133.5	4.2	75.5
2.7	1.3905	4.995	120.15	6	82.9
2.6	1.339	4.81	115.7	7.1	104.3
2.3	1.1845	4.255	102.35	6.9	130.6

	METHOD ONE:		**BLANEY-CRIDDLE**		**METHOD**	**LAT.7.55N**	**LON.2.3W**	**ALT.122m**
	TABLE4.5	**ATEBUBU**				**RH(%)**	**ET 0**	
Months	**T m ^{O}C**	**T m*0.46**	**Tm*0.46+8**	**p**	**(Tm*0.46+8)*(p)**	**1500hrs**	**mm/day**	**K c**
J	27	12.42	20.42	0.26	5.3092	43.41	4	1.2
F	28.5	13.11	21.11	0.27	5.6997	43.82	4.2	0.8
M	28.85	13.271	21.271	0.27	5.74317	49.12	4.3	0.5
A	28.8	13.248	21.248	0.28	5.94944	60.06	3.2	0.2
M	27.75	12.765	20.765	0.28	5.8142	63.59	3.3	0.3
J	26.9	12.374	20.374	0.29	5.90846	68.88	3.2	0.3
J	26.3	12.098	20.098	0.29	5.82842	70.71	2.8	0.6
A	26.15	12.029	20.029	0.28	5.60812	72.06	2.7	0.8
S	26.45	12.167	20.167	0.28	5.64676	72.29	2.7	1.2
O	26.95	12.397	20.397	0.27	5.50719	67.24	2.6	1.2
N	27.15	12.489	20.489	0.26	5.32714	59.35	2.5	1.2
D	26.7	12.282	20.282	0.26	5.27332	53.94	2.4	1.2

ET c mm/day	No.of days	ET c mm/ month	ET o mm/ month
4.8	31	**148.8**	**124**
3.36	28	**94.08**	**117.6**
2.15	31	**66.65**	**133.3**
0.64	30	**19.2**	**96**
0.99	31	**30.69**	**102.3**
0.96	30	**28.8**	**96**
1.68	31	**52.08**	**86.8**
2.16	31	**66.96**	**83.7**
3.24	30	**97.2**	**81**
3.12	31	**96.72**	**80.6**
3	30	**90**	**75**
2.88	31	**89.28**	**74.4**
	TOTAL	***880.46***	**1150.7**

For the factor c refer to the graph under Blaney-Criddle. (Doorenbos and Pruitt, 1996).

NOTE: 1. Crop Establishment Stage-May and June-Kc < 1

2. Crop Development Stage-July and August-Kc <1

3	**Crop Maturity Stage-**		**September ,October ,November**	**,December and January- Kc >1**
4	**Late**	**Season Stage -**	**January, Febuary, March ,and**	**April-Kc<1.**

As shown in figure 4.1.

Assume wind speed ,U2 m/s and duration sunhine, hrs for Wenchi to be the same for ATEBUBU ,BEREKUM AND EJURA.

TABLE4.6		BEREKUM	LAT.7.45N	LON 2.59W	ALT.304m	RH(%)
Months	T m (^{0}C)	T m*0.46	Tm*0.46+8	p	(Tm*0.46+8)*(p)	1500hrs
J	25	11.5	19.5	0.26	5.07	35.17
F	26.6	12.236	20.236	0.27	5.46372	36.5
M	26.9	12.374	20.374	0.27	5.50098	45.67
A	26.5	12.19	20.19	0.28	5.6532	57.61
M	26	11.96	19.96	0.28	5.5888	62.11
J	25.25	11.615	19.615	0.29	5.68835	67.78
J	24.55	11.293	19.293	0.29	5.59497	70.94
A	24.55	11.293	19.293	0.28	5.40204	70.17
S	24.9	11.454	19.454	0.28	5.44712	69.22
O	25	11.5	19.5	0.27	5.265	65.5
N	25.4	11.684	19.684	0.26	5.11784	58
D	24.8	11.408	19.408	0.26	5.04608	47.11

ET o mm/ day	K c	ET c mm/day	No.of days	ET c mm/ month	ET o mm/ month
4.5	1.2	5.4	31	**167.4**	**139.5**
4.8	0.8	3.84	28	**107.52**	**134.4**
4.9	0.5	2.45	31	**75.95**	**151.9**
3.3	0.2	0.66	30	**19.8**	**99**
3.2	0.3	0.96	31	**29.76**	**99.2**
3.3	0.3	0.99	30	**29.7**	**99**
3.5	0.6	2.1	31	**65.1**	**108.5**
3.2	0.8	2.56	31	**79.36**	**99.2**
3.2	1.2	3.84	30	**115.2**	**96**
3.3	1.2	3.96	31	**122.76**	**102.3**
2.9	1.2	3.48	30	**104.4**	**87**
2.8	1.2	3.36	31	**104.16**	**86.8**
			TOTAL	***1021.11***	1302.8

TABLE4.7	EJURA	LAT.7.38W	LON 1.36	W	ALT.225m.	RH(%)
Months	T m (^{0}C)	T m *0.46	Tm*0.46+8	P	(Tm*0.46+8)*(p)	1500hrs
J	26.85	12.351	20.351	0.26	5.29126	61.67
F	28.25	12.995	20.995	0.27	5.66865	55.58
M	28.6	13.156	21.156	0.27	5.71212	59.83
A	28.15	12.949	20.949	0.28	5.86572	66.5
M	27.4	12.604	20.604	0.28	5.76912	67.33
J	26.3	12.098	20.098	0.29	5.82842	73.29
J	25.55	11.753	19.753	0.29	5.72837	77.67
A	25.3	11.638	19.638	0.28	5.49864	77.91
S	25.8	11.868	19.868	0.28	5.56304	77.05
O	26.35	12.121	20.121	0.27	5.43267	74.45
N	26.85	12.351	20.351	0.26	5.29126	70.55
D	26.2	12.052	20.052	0.26	5.21352	67.82

ET o mm/ day	K c	ET c mm/day	No.of days	ET c mm/ month	ET o mm/ month
3	1.2	3.6	31	**111.6**	**93**
3.4	0.8	2.72	28	**76.16**	**95.2**
3.5	0.5	1.75	31	**54.25**	**108.5**
3.6	0.2	0.72	30	**21.6**	**108**
3.5	0.3	1.05	31	**32.55**	**108.5**
3.6	0.3	1.08	30	**32.4**	**108**
3.5	0.6	2.1	31	**65.1**	**108.5**
3.2	0.8	2.56	31	**79.36**	**99.2**
3.3	1.2	3.96	30	**118.8**	**99**
3.2	1.2	3.84	31	**119.04**	**99.2**
3.1	1.2	3.72	30	**111.6**	**93**
3.1	1.2	3.72	31	**115.32**	**96.1**
			TOTAL	***937.78***	**1216.2**

TABLE4.8	**WENCHI**	**LAT.7.75**		**LON 2.1 W ALT.340m**		**RH(%)**
Months	**T m (^{0}C)**	**T m *0.46**	**Tm*0.46+8**	**p**	**(Tm*0.46+8)*(p)**	**1500hrs**
J	27.4	12.604	20.604	0.26	5.35704	31
F	29.75	13.685	21.685	0.27	5.85495	32
M	31.25	14.375	22.375	0.27	6.04125	44
A	30.55	14.053	22.053	0.28	6.17484	59
M	28.8	13.248	21.248	0.28	5.94944	65
J	27.2	12.512	20.512	0.29	5.94848	70
J	25.55	11.753	19.753	0.29	5.72837	72
A	25.75	11.845	19.845	0.28	5.5566	72
S	26.2	12.052	20.052	0.28	5.61456	72
O	27.7	12.742	20.742	0.27	5.60034	70
N	28.2	12.972	20.972	0.26	5.45272	62
D	27.15	12.489	20.489	0.26	5.32714	46

ET o mm/ day	K c	ET c mm/day	No.of days	ET c mm/ month	ET o mm/ month
4.3	1.2	5.16	31	**159.96**	**133.3**
5	0.8	4	28	**112**	**140**
5.2	0.5	2.6	31	**80.6**	**161.2**
3.9	0.2	0.78	30	**23.4**	**117**
3.8	0.3	1.14	31	**35.34**	**117.8**
3.8	0.3	1.14	30	**34.2**	**114**
3.7	0.6	2.22	31	**68.82**	**114.7**
3.6	0.8	2.88	31	**89.28**	**111.6**
3.6	1.2	4.32	30	**129.6**	**108**
3.6	1.2	4.32	31	**133.92**	**111.6**
3.5	1.2	4.2	30	**126**	**105**
3.6	1.2	4.32	31	**133.92**	**111.6**
			TOTAL	***1127.04***	**1445.8**

TABLE4.9	METHOD	TWO :	RADIATON	ATEBUBU	LAT 7.55 N LON 2.3 W		ALT 122 m
Months	**T m(^{0}C)**	**R a mm/ day**	**N**	**N**	**n/N**	**0.5*n/N**	**0.25+ 0.5*n/N**
J	27	13.8	11.7	7.2	0.6153846	0.3076923	0.5576923
F	28.5	14.6	11.8	7.6	0.6440678	0.3220339	0.5720339
M	28.85	15.3	12	7.1	0.5916667	0.2958333	0.5458333
A	28.8	15.3	12.2	7.4	0.6065574	0.3032787	0.5532787
M	27.75	15.2	12.4	6.9	0.5564516	0.2782258	0.5282258
J	26.9	14.9	12.6	6	0.4761905	0.2380952	0.4880952
J	26.3	15	12.5	4.3	0.344	0.172	0.422
A	26.15	15.3	12.3	3.3	0.2682927	0.1341463	0.3841463
S	26.45	15.3	12.1	4.2	0.3471074	0.1735537	0.4235537
O	26.95	15.1	11.9	6	0.5042017	0.2521008	0.5021008
N	27.15	14	11.8	7.1	0.6016949	0.3008475	0.5508475
D	26.7	13.5	11.6	6.9	0.5948276	0.2974138	0.5474138

R s mm/day	W	W*R s mm/day	RH mean (%)	ET o mm/day	K c	ET c mm/day	No.of days	ET c mm/ month	ET o mm / month
7.6961538	0.77	5.9260385	60.205	5.2	1.2	6.24	31	**193.44**	**161.2**
8.3516949	0.78	6.514322	61.41	5.8	0.8	4.64	28	**129.92**	**162.4**
8.35125	0.78	6.513975	66.56	5.8	0.5	2.9	31	**89.9**	**179.8**
8.4651639	0.78	6.6028279	74.03	5.2	0.2	1.04	30	**31.2**	**156**
8.0290323	0.78	6.2626452	76.795	4.9	0.3	1.47	31	**45.57**	**151.9**
7.272619	0.76	5.5271905	80.44	4	0.3	1.2	30	**36**	**120**
6.33	0.76	4.8108	81.855	3.5	0.6	2.1	31	**65.1**	**108.5**
5.877439	0.76	4.4668537	82.03	3.2	0.8	2.56	31	**79.36**	**99.2**
6.4803719	0.76	4.9250826	82.145	3.8	1.2	4.56	30	**136.8**	**114**
7.5817227	0.76	5.7621092	79.12	4.2	1.2	5.04	31	**156.24**	**130.2**
7.7118644	0.77	5.9381356	74.675	4.3	1.2	5.16	30	**154.8**	**129**
7.3900862	0.77	5.6903664	70.47	4.1	1.2	4.92	31	**152.52**	**127.1**
							TOTAL	***1270.85***	**1639.3**

	TABLE 4.10 BEREKUM			LAT.7.45N	LON 2.59W	ALT.304m	
Months	**T m C**	**R a mm/ day**	**N**	**n**	**n/N**	**0.5*n/N**	**0.25+ 0.5*n/N**
J	25	13.8	11.7	7.2	0.6153846	0.3076923	0.5576923
F	26.6	14.6	11.8	7.6	0.6440678	0.3220339	0.5720339
M	26.9	15.3	12	7.1	0.5916667	0.2958333	0.5458333
A	26.5	15.3	12.2	7.4	0.6065574	0.3032787	0.5532787
M	26	15.2	12.4	6.9	0.5564516	0.2782258	0.5282258
J	25.25	14.9	12.6	6	0.4761905	0.2380952	0.4880952
J	24.55	15	12.5	4.3	0.344	0.172	0.422
A	24.55	15.3	12.3	3.3	0.2682927	0.1341463	0.3841463
S	24.9	15.3	12.1	4.2	0.3471074	0.1735537	0.4235537
O	25	15.1	11.9	6	0.5042017	0.2521008	0.5021008
N	25.4	14	11.8	7.1	0.6016949	0.3008475	0.5508475
D	24.8	13.5	11.6	6.9	0.5948276	0.2974138	0.5474138

R s mm/day	W	W*R s mm/day	RH mean (%)	ET o mm/day	K c	ET c mm/day	No.of Days	ET c mm/ month	ET o mm/ month
7.6961538	0.74	5.6951538	54.585	5.2	1.2	6.24	31	**193.44**	**161.2**
8.3516949	0.76	6.3472881	58.25	5.3	0.8	4.24	28	**118.72**	**148.4**
8.35125	0.76	6.34695	66.335	5.3	0.5	2.65	31	**82.15**	**164.3**
8.4651639	0.76	6.4335246	73.805	5	0.2	1	30	**30**	**150**
8.0290323	0.76	6.1020645	76.555	4.5	0.3	1.35	31	**41.85**	**139.5**
7.272619	0.74	5.3817381	80.39	4	0.3	1.2	30	**36**	**120**
6.33	0.74	4.6842	81.97	3.2	0.6	1.92	31	**59.52**	**99.2**
5.877439	0.74	4.3493049	81.085	3.1	0.8	2.48	31	**76.88**	**96.1**
6.4803719	0.74	4.7954752	80.11	3.6	1.2	4.32	30	**129.6**	**108**
7.5817227	0.74	5.6104748	77.75	4.2	1.2	5.04	31	**156.24**	**130.2**
7.7118644	0.74	5.7067797	74	4.3	1.2	5.16	30	**154.8**	**129**
7.3900862	0.74	5.4686638	64.555	4.2	1.2	5.04	31	**156.24**	**130.2**
							TOTAL	***1235.44***	**1576.1**

TABLE 4.11 EJURA LAT.7.38W LON 1.36W ALT.225m.

Months	T m ^{o}C	R a mm/ day	N	n	n/N	0.5*n/N	0.25+ 0.5*n/N
J	26.85	13.8	11.7	7.2	0.6153846	0.3076923	0.5576923
F	28.25	14.6	11.8	7.6	0.6440678	0.3220339	0.5720339
M	28.6	15.3	12	7.1	0.5916667	0.2958333	0.5458333
A	28.15	15.3	12.2	7.4	0.6065574	0.3032787	0.5532787
M	27.4	15.2	12.4	6.9	0.5564516	0.2782258	0.5282258
J	26.3	14.9	12.6	6	0.4761905	0.2380952	0.4880952
J	25.55	15	12.5	4.3	0.344	0.172	0.422
A	25.3	15.3	12.3	3.3	0.2682927	0.1341463	0.3841463
S	25.8	15.3	12.1	4.2	0.3471074	0.1735537	0.4235537
O	26.35	15.1	11.9	6	0.5042017	0.2521008	0.5021008
N	26.85	14	11.8	7.1	0.6016949	0.3008475	0.5508475
D	26.2	13.5	11.6	6.9	0.5948276	0.2974138	0.5474138

R s mm/day	W	W*R s mm/day	RH mean (%)	ET o mm/day	K c	ET c mm/day	No.of days	ET c mm/ month	ET o mm/ month
7.6961538	0.77	5.9260385	68.5252	4.9	1.2	5.88	31	**182.28**	**151.9**
8.3516949	0.78	6.514322	67.29	5.2	0.8	4.16	28	**116.48**	**145.6**
8.35125	0.78	6.513975	72.79	5	0.5	2.5	31	**77.5**	**155**
8.4651639	0.78	6.6028279	77.719	5.1	0.2	1.02	30	**30.6**	**153**
8.0290323	0.77	6.1823548	78.2275	4.3	0.3	1.29	31	**39.99**	**133.3**
7.272619	0.76	5.5271905	81.52	4	0.3	1.2	30	**36**	**120**
6.33	0.76	4.8108	83.6165	3.7	0.6	2.22	31	**68.82**	**114.7**
5.877439	0.75	4.4080793	83.5175	3.2	0.8	2.56	31	**79.36**	**99.2**
6.4803719	0.76	4.9250826	83.65	3.8	1.2	4.56	30	**136.8**	**114**
7.5817227	0.76	5.7621092	82.569	4.1	1.2	4.92	31	**152.52**	**127.1**
7.7118644	0.77	5.9381356	80.15	4.3	1.2	5.16	30	**154.8**	**129**
7.3900862	0.76	5.6164655	75.1915	4	1.2	4.8	31	**148.8**	**124**
							TOTAL	***1223.95***	**1566.8**

Months	TABLE 4.12 WENCHI T m^{O} C	R a mm/ day	N	LAT.7.75 N n	LON 2.1W n/N	ALT.340m 0.5*n/N	0.25+ 0.5*n/N
J	27.4	13.8	11.7	7.2	0.6153846	0.3076923	0.5576923
F	29.75	14.6	11.8	7.6	0.6440678	0.3220339	0.5720339
M	31.25	15.3	12	7.1	0.5916667	0.2958333	0.5458333
A	30.55	15.3	12.2	7.4	0.6065574	0.3032787	0.5532787
M	28.8	15.2	12.4	6.9	0.5564516	0.2782258	0.5282258
J	27.2	14.9	12.6	6	0.4761905	0.2380952	0.4880952
J	25.55	15	12.5	4.3	0.344	0.172	0.422
A	25.75	15.3	12.3	3.3	0.2682927	0.1341463	0.3841463
S	26.2	15.3	12.1	4.2	0.3471074	0.1735537	0.4235537
O	27.7	15.1	11.9	6	0.5042017	0.2521008	0.5021008
N	28.2	14	11.8	7.1	0.6016949	0.3008475	0.5508475
D	27.15	13.5	11.6	6.9	0.5948276	0.2974138	0.5474138

R s mm/day	W	W*R s mm/day	RH mean (%)	ET o mm/day	K c	ET c mm/day	No.of days	ET c mm/ month	ET o mm/ month
7.6961538	0.78	6.003	49.5	5.5	1.2	6.6	31	**204.6**	**170.5**
8.3516949	0.79	6.597839	54	6	0.8	4.8	28	**134.4**	**168**
8.35125	0.81	6.7645125	65	5.8	0.5	2.9	31	**89.9**	**179.8**
8.4651639	0.79	6.6874795	75.5	5	0.2	1	30	**30**	**150**
8.0290323	0.79	6.3429355	79.5	4.8	0.3	1.44	31	**44.64**	**148.8**
7.272619	0.76	5.5271905	83	4	0.3	1.2	30	**36**	**120**
6.33	0.75	4.7475	84	3.5	0.6	2.1	31	**65.1**	**108.5**
5.877439	0.75	4.4080793	83.5	3.1	0.8	2.48	31	**76.88**	**96.1**
6.4803719	0.76	4.9250826	84	3.6	1.2	4.32	30	**129.6**	**108**
7.5817227	0.77	5.8379265	83	4	1.2	4.8	31	**148.8**	**124**
7.7118644	0.78	6.0152542	78	4.2	1.2	5.04	30	**151.2**	**126**
7.3900862	0.77	5.6903664	65	3.9	1.2	4.68	31	**145.08**	**120.9**
							TOTAL	***1256.2***	**1620.6**

TABLE 4.13	***METHOD THREE :*** Tm(^{0}C)	RH mean (%)	PENMAN METHOD ea mbar	ATEBUBU RH mean /100	LAT.7.55N ed mbar	LON.2.3W ea-ed mbar	ALT.122m U2 km/day	f(U2)
J	27	60.205	35.7	0.60205	21.493185	14.206815	115.7	0.58
F	28.5	61.41	38.7	0.6141	23.76567	14.93433	139.95	0.65
M	28.85	66.56	40	0.6656	26.624	13.376	151.3	0.67
A	28.8	74.03	39.5	0.7403	29.24185	10.25815	155.75	0.68
M	27.75	76.795	37.8	0.76795	29.02851	8.77149	142.4	0.65
J	26.9	80.44	35.7	0.8044	28.71708	6.98292	133.5	0.62
J	26.3	81.855	33.6	0.81855	27.50328	6.09672	142.2	0.65
A	26.15	82.03	33.6	0.8203	27.56208	6.03792	151.3	0.67
S	26.45	82.145	33.6	0.82145	27.60072	5.99928	133.5	0.62
O	26.95	79.12	35.7	0.7912	28.24584	7.45416	120.15	0.59
N	27.15	74.675	35.7	0.74675	26.658975	9.041025	115.7	0.58
D	26.7	70.47	35.7	0.7047	25.15779	10.54221	102.15	0.54

1-W	(1-W)*f(U2) *(ea-ed) mm/day	R a mm/ day	N	n	n/N	0.5*n/N	0.25+ 0.5*n/N	R s mm/day
0.23	1.8951891	13.8	11.7	7.2	0.6153846	0.3076923	0.5576923	7.6961538
0.22	2.1356092	14.6	11.8	7.6	0.6440678	0.3220339	0.5720339	8.3516949
0.22	1.9716224	15.3	12	7.1	0.5916667	0.2958333	0.5458333	8.35125
0.22	1.5346192	15.3	12.2	7.4	0.6065574	0.3032787	0.5532787	8.4651639
0.22	1.2543231	15.2	12.4	6.9	0.5564516	0.2782258	0.5282258	8.0290323
0.23	0.9957644	14.9	12.6	6	0.4761905	0.2380952	0.4880952	7.272619
0.24	0.9510883	15	12.5	4.3	0.344	0.172	0.422	6.33
0.24	0.9708975	15.3	12.3	3.3	0.2682927	0.1341463	0.3841463	5.877439
0.24	0.8926929	15.3	12.1	4.2	0.3471074	0.1735537	0.4235537	6.4803719
0.24	1.0555091	15.1	11.9	6	0.5042017	0.2521008	0.5021008	7.5817227
0.23	1.2060727	14	11.8	7.1	0.6016949	0.3008475	0.5508475	7.7118644
0.23	1.3093425	13.5	11.6	6.9	0.5948276	0.2974138	0.5474138	7.3900862

Rns mm/day	f(T)	f(ed)	f(n/N)	Rnl mm/day	Rn mm/day	W	W*R n	W*Rn +(1-W)f(U2)*(ea-ed)
5.7721154	15.6	0.13	0.64	1.29792	4.4741954	0.77	3.4451304	5.3403196
6.2637712	16.5	0.12	0.68	1.3464	4.9173712	0.78	3.8355495	5.9711587
6.2634375	16.5	0.12	0.64	1.2672	4.9962375	0.78	3.8970653	5.8686877
6.348873	16.5	0.1	0.64	1.056	5.292873	0.78	4.1284409	5.6630601
6.0217742	16.5	0.1	0.6	0.99	5.0317742	0.78	3.9247839	5.1791069
5.4544643	15.9	0.1	0.58	0.9222	4.5322643	0.76	3.4445209	4.4402852
4.7475	15.9	0.11	0.41	0.71709	4.03041	0.76	3.0631116	4.0141999
4.4080793	15.9	0.11	0.34	0.59466	3.8134193	0.76	2.8981986	3.8690962
4.8602789	15.9	0.11	0.41	0.71709	4.1431889	0.76	3.1488236	4.0415164
5.686292	16.1	0.11	0.55	0.97405	4.712242	0.76	3.5813039	4.636813
5.7838983	16.1	0.12	0.64	1.23648	4.5474183	0.77	3.5015121	4.7075848
5.5425647	16.1	0.12	0.64	1.23648	4.3060847	0.77	3.3156852	4.6250277

RH(%) 0600hrs	U2 m/s	c	E To mm/day	K c	E T c mm/day	No.of days	ET c mm/ month	ET o mm / month
77	1.339	1.05	5.6073355	1.2	6.7288027	31	**208.59288**	**173.8274**
79	1.5965	1.1	6.5682746	0.8	5.2546197	28	**147.12935**	**183.91169**
84	1.751	1.1	6.4555564	0.5	3.2277782	31	**100.06112**	**200.12225**
88	1.8025	1.1	6.2293662	0.2	1.2458732	30	**37.376197**	**186.88098**
90	1.648	1.1	5.6970176	0.3	1.7091053	31	**52.982264**	**176.60755**
92	1.545	0.99	4.3958824	0.3	1.3187647	30	**39.562942**	**131.87647**
93	1.648	0.98	3.9339159	0.6	2.3603496	31	**73.170836**	**121.95139**
92	1.751	0.95	3.6756414	0.8	2.9405131	31	**91.155906**	**113.94488**
92	1.545	1.05	4.2435923	1.2	5.0923107	30	**152.76932**	**127.30777**
91	1.3905	1.03	4.7759174	1.2	5.7311009	31	**177.66413**	**148.05344**
90	1.339	1.04	4.8958882	1.2	5.8750659	30	**176.25198**	**146.87665**
87	1.1845	1.02	4.7175282	1.2	5.6610339	31	**175.49205**	**146.24337**
	U2 m/s =	**Uday/Unight**				TOTAL	***1432.209***	**1857.6038**

TABLE 4.14 BEREKUM **LAT.7.45 N** **LON 2.59W** **ALT.304 m**

Months		RH mean (%)	ea mbar	RH mean /100	ed mbar	ea-ed mbar	U2 km/day	f(U2)
J	25	54.585	31.7	0.54585	17.303445	14.396555	115.7	0.58
F	26.6	58.25	35.7	0.5825	20.79525	14.90475	139.95	0.65
M	26.9	66.335	35.7	0.66335	23.681595	12.018405	151.3	0.67
A	26.5	73.805	35.7	0.73805	26.348385	9.351615	155.75	0.68
M	26	76.555	33.6	0.76555	25.72248	7.87752	142.4	0.65
J	25.25	80.39	31.7	0.8039	25.48363	6.21637	133.5	0.62
J	24.55	81.97	31.7	0.8197	25.98449	5.71551	142.2	0.65
A	24.55	81.085	31.7	0.81085	25.703945	5.996055	151.3	0.67
S	24.9	80.11	31.7	0.8011	25.39487	6.30513	133.5	0.62
O	25	77.75	31.7	0.7775	24.64675	7.05325	120.15	0.59
N	25.4	74	31.7	0.74	23.458	8.242	115.7	0.58
D	24.8	64.555	31.7	0.64555	20.463935	11.236065	102.15	0.54

1-W	*(ea-ed) mm/day	R a mm/ day	N	n	n/N	0.5*n/N	0.25+ 0.5*n/N	R s mm/day
0.26	2.1710005	13.8	11.7	7.2	0.6153846	0.3076923	0.5576923	7.6961538
0.24	2.325141	14.6	11.8	7.6	0.6440678	0.3220339	0.5720339	8.3516949
0.24	1.9325595	15.3	12	7.1	0.5916667	0.2958333	0.5458333	8.35125
0.24	1.5261836	15.3	12.2	7.4	0.6065574	0.3032787	0.5532787	8.4651639
0.24	1.2288931	15.2	12.4	6.9	0.5564516	0.2782258	0.5282258	8.0290323
0.26	1.0020788	14.9	12.6	6	0.4761905	0.2380952	0.4880952	7.272619
0.26	0.9659212	15	12.5	4.3	0.344	0.172	0.422	6.33
0.26	1.0445128	15.3	12.3	3.3	0.2682927	0.1341463	0.3841463	5.877439
0.26	1.016387	15.3	12.1	4.2	0.3471074	0.1735537	0.4235537	6.4803719
0.26	1.0819686	15.1	11.9	6	0.5042017	0.2521008	0.5021008	7.5817227
0.26	1.2428936	14	11.8	7.1	0.6016949	0.3008475	0.5508475	7.7118644
0.26	1.5775435	13.5	11.6	6.9	0.5948276	0.2974138	0.5474138	7.3900862

Rns mm/day	f(T)	f(ed)	f(n/N)	Rnl mm/day	Rn mm/day	W	W*R n	W*Rn +(1-W)f(U2)*(ea-ed)
5.7721154	15.6	0.17	0.64	1.69728	4.0748354	0.74	3.0153782	5.1863787
6.2637712	16.1	0.13	0.68	1.42324	4.8405312	0.76	3.6788037	6.0039447
6.2634375	16.1	0.11	0.64	1.13344	5.1299975	0.76	3.8987981	5.8313576
6.348873	16.1	0.12	0.64	1.23648	5.112393	0.76	3.8854186	5.4116022
6.0217742	15.9	0.12	0.6	1.1448	4.8769742	0.76	3.7065004	4.9353935
5.4544643	15.6	0.12	0.58	1.08576	4.3687043	0.74	3.2328412	4.23492
4.7475	15.6	0.12	0.41	0.76752	3.97998	0.74	2.9451852	3.9111064
4.4080793	15.6	0.12	0.34	0.63648	3.7715993	0.74	2.7909835	3.8354962
4.8602789	15.6	0.12	0.41	0.76752	4.0927589	0.74	3.0286416	4.0450286
5.686292	15.6	0.11	0.55	0.9438	4.742492	0.74	3.5094441	4.5914126
5.7838983	15.6	0.14	0.64	1.39776	4.3861383	0.74	3.2457423	4.4886359
5.5425647	15.6	0.14	0.64	1.39776	4.1448047	0.74	3.0671554	4.644699

RH(%) 0600hrs	U2 m/s	c	E To mm/day	K c	E T c mm/day	No.of days	ET c mm/ month	ET o mm/ month
74	1.339	1.05	5.4456976	1.2	6.5348371	31	**202.57995**	**168.81663**
80	1.5965	1.1	6.6043392	0.8	5.2834713	28	**147.9372**	**184.9215**
87	1.751	1.1	6.4144934	0.5	3.2072467	31	**99.424647**	**198.84929**
90	1.8025	1.1	5.9527624	0.2	1.1905525	30	**35.716575**	**178.58287**
91	1.648	1.1	5.4289329	0.3	1.6286799	31	**50.489076**	**168.29692**
93	1.545	0.99	4.1925708	0.3	1.2577712	30	**37.733137**	**125.77712**
93	1.648	0.98	3.8328843	0.6	2.2997306	31	**71.291647**	**118.81941**
92	1.751	0.95	3.6437214	0.8	2.9149771	31	**90.364291**	**112.95536**
91	1.545	1.05	4.24728	1.2	5.096736	30	**152.90208**	**127.4184**
90	1.3905	1.03	4.729155	1.2	5.674986	31	**175.92457**	**146.60381**
90	1.339	1.04	4.6681814	1.2	5.6018177	30	**168.05453**	**140.04544**
82	1.1845	1.02	4.737593	1.2	5.6851115	31	**176.23846**	**146.86538**
TOTAL							***1408.6562***	**1817.9521**

TABLE 4.15 EJURA LAT.7.38W LON 1.36W ALT.225 m.

Months	T m(^{0} C)	RH mean (%)	ea mbar	RH mean /100	ed mbar	ea-ed mbar	U2 km/day	f(U2)
J	26.85	68.5252	35.7	0.685252	24.463496	11.236504	115.7	0.58
F	28.25	67.29	37.8	0.6729	25.43562	12.36438	139.95	0.65
M	28.6	72.79	40.1	0.7279	29.18879	10.91121	151.3	0.67
A	28.15	77.719	37.8	0.77719	29.377782	8.422218	155.75	0.68
M	27.4	78.2275	35.7	0.782275	27.927218	7.7727825	142.4	0.65
J	26.3	81.52	33.6	0.8152	27.39072	6.20928	133.5	0.62
J	25.55	83.6165	33.6	0.836165	28.095144	5.504856	142.2	0.65
A	25.3	83.5175	31.7	0.835175	26.475048	5.2249525	151.3	0.67
S	25.8	83.65	33.6	0.8365	28.1064	5.4936	133.5	0.62
O	26.35	82.569	33.6	0.82569	27.743184	5.856816	120.15	0.59
N	26.85	80.15	35.7	0.8015	28.61355	7.08645	115.7	0.58
D	26.2	75.1915	33.6	0.751915	25.264344	8.335656	102.15	0.54

1-W	(1-W)*f(U2) *(ea-ed) mm/day	R a mm/ day	N	n	n/N	0.5*n/N	0.25+ 0.5*n/N	R s mm/day
0.23	1.4989496	13.8	11.7	7.2	0.6153846	0.3076923	0.5576923	7.6961538
0.22	1.7681063	14.6	11.8	7.6	0.6440678	0.3220339	0.5720339	8.3516949
0.22	1.6083124	15.3	12	7.1	0.5916667	0.2958333	0.5458333	8.35125
0.22	1.2599638	15.3	12.2	7.4	0.6065574	0.3032787	0.5532787	8.4651639
0.23	1.162031	15.2	12.4	6.9	0.5564516	0.2782258	0.5282258	8.0290323
0.24	0.9239409	14.9	12.6	6	0.4761905	0.2380952	0.4880952	7.272619
0.24	0.8587575	15	12.5	4.3	0.344	0.172	0.422	6.33
0.25	0.8751795	15.3	12.3	3.3	0.2682927	0.1341463	0.3841463	5.877439
0.24	0.8174477	15.3	12.1	4.2	0.3471074	0.1735537	0.4235537	6.4803719
0.24	0.8293251	15.1	11.9	6	0.5042017	0.2521008	0.5021008	7.5817227
0.23	0.9453324	14	11.8	7.1	0.6016949	0.3008475	0.5508475	7.7118644
0.24	1.080301	13.5	11.6	6.9	0.5948276	0.2974138	0.5474138	7.3900862

Rns mm/day	f(T)	f(ed)	f(n/N)	Rnl mm/day	Rn mm/day	W	W*R n	W*Rn +(1-W)f(U2)*(ea-ed)
5.7721154	16.1	0.12	0.64	1.23648	4.5356354	0.77	3.4924392	4.9913888
6.2637712	16.3	0.12	0.68	1.33008	4.9336912	0.78	3.8482791	5.6163855
6.2634375	16.5	0.1	0.64	1.056	5.2074375	0.78	4.0618013	5.6701136
6.348873	16.3	0.1	0.64	1.0432	5.305673	0.78	4.1384249	5.3983887
6.0217742	16.1	0.11	0.6	1.0626	4.9591742	0.77	3.8185641	4.9805951
5.4544643	15.9	0.12	0.58	1.10664	4.3478243	0.76	3.3043465	4.2282873
4.7475	15.9	0.11	0.41	0.71709	4.03041	0.76	3.0631116	3.9218691
4.4080793	15.6	0.12	0.34	0.63648	3.7715993	0.75	2.8286995	3.703879
4.8602789	15.9	0.11	0.41	0.71709	4.1431889	0.76	3.1488236	3.9662713
5.686292	15.9	0.11	0.55	0.96195	4.724342	0.76	3.5904999	4.4198251
5.7838983	16.1	0.11	0.64	1.13344	4.6504583	0.77	3.5808529	4.5261853
5.5425647	15.9	0.12	0.64	1.22112	4.3214447	0.76	3.2842979	4.364599

RH(%) 0600hrs	U2 m/s	c	E To mm/day	K c	E T c mm/day	No.of days	ET c mm/ month	ET o mm/ month
75.375	1.339	1.05	5.2409583	1.2	6.2891499	31	**194.96365**	**162.46971**
79	1.5965	1.1	6.178024	0.8	4.9424192	28	**138.38774**	**172.98467**
85.75	1.751	1.1	6.237125	0.5	3.1185625	31	**96.675437**	**193.35087**
88.938	1.8025	1.1	5.9382276	0.2	1.1876455	30	**35.629366**	**178.14683**
89.125	1.648	1.1	5.4786546	0.3	1.6435964	31	**50.951488**	**169.83829**
89.75	1.545	0.99	4.1860044	0.3	1.2558013	30	**37.67404**	**125.58013**
89.563	1.648	0.98	3.8434318	0.6	2.3060591	31	**71.487831**	**119.14638**
89.125	1.751	0.95	3.518685	0.8	2.814948	31	**87.263389**	**109.07924**
90.25	1.545	1.05	4.1645848	1.2	4.9975018	30	**149.92505**	**124.93754**
90.688	1.3905	1.03	4.5524198	1.2	5.4629038	31	**169.35002**	**141.12501**
89.75	1.339	1.04	4.7072327	1.2	5.6486793	30	**169.46038**	**141.21698**
82.563	1.1845	1.02	4.4518909	1.2	5.3422691	31	**165.61034**	**138.00862**
						TOTAL	***1367.3787***	**1775.8843**

TABLE 4.16 WENCHI LAT.7.75 N LON 2.1 W ALT.340 m

Months	T m (^{0}C)	RH mean (%)	ea mbar	RH mean /100	ed mbar	ea-ed mbar	U2 km/day	f(U2)
J	27.4	49.5	35.7	0.495	17.6715	18.0285	115.7	0.58
F	29.75	54	42.4	0.54	22.896	19.504	139.95	0.65
M	31.25	65	44.9	0.65	29.185	15.715	151.3	0.67
A	30.55	75.5	44.9	0.755	33.8995	11.0005	155.75	0.68
M	28.8	79.5	40.1	0.795	31.8795	8.2205	142.4	0.65
J	27.2	83	35.7	0.83	29.631	6.069	133.5	0.62
J	25.55	84	33.6	0.84	28.224	5.376	142.2	0.65
A	25.75	83.5	33.6	0.835	28.056	5.544	151.3	0.67
S	26.2	84	33.6	0.84	28.224	5.376	133.5	0.62
O	27.7	83	37.8	0.83	31.374	6.426	120.15	0.59
N	28.2	78	37.8	0.78	29.484	8.316	115.7	0.58
D	27.15	65	35.7	0.65	23.205	12.495	102.15	0.54

1-W	*(ea-ed) mm/day	R a mm/ day	N	n	n/N	0.5*n/N	0.25+ 0.5*n/N	R s mm/day
0.22	2.3004366	13.8	11.7	7.2	0.6153846	0.3076923	0.5576923	7.6961538
0.21	2.662296	14.6	11.8	7.6	0.6440678	0.3220339	0.5720339	8.3516949
0.19	2.0005195	15.3	12	7.1	0.5916667	0.2958333	0.5458333	8.35125
0.21	1.5708714	15.3	12.2	7.4	0.6065574	0.3032787	0.5532787	8.4651639
0.21	1.1220983	15.2	12.4	6.9	0.5564516	0.2782258	0.5282258	8.0290323
0.24	0.9030672	14.9	12.6	6	0.4761905	0.2380952	0.4880952	7.272619
0.25	0.8736	15	12.5	4.3	0.344	0.172	0.422	6.33
0.25	0.92862	15.3	12.3	3.3	0.2682927	0.1341463	0.3841463	5.877439
0.24	0.7999488	15.3	12.1	4.2	0.3471074	0.1735537	0.4235537	6.4803719
0.23	0.8720082	15.1	11.9	6	0.5042017	0.2521008	0.5021008	7.5817227
0.22	1.0611216	14	11.8	7.1	0.6016949	0.3008475	0.5508475	7.7118644
0.23	1.551879	13.5	11.6	6.9	0.5948276	0.2974138	0.5474138	7.3900862

Rns mm/day	f(T)	f(ed)	f(n/N)	Rnl mm/day	Rn mm/day	W	W*R n	W*Rn +(1-W)f(U2)*(ea-ed)
5.7721154	16.1	0.15	0.64	1.5456	4.2265154	0.78	3.296682	5.5971186
6.2637712	16.7	0.12	0.68	1.36272	4.9010512	0.79	3.8718304	6.5341264
6.2634375	16.9	0.1	0.64	1.0816	5.1818375	0.81	4.1972884	6.1978079
6.348873	16.9	0.8	0.64	8.6528	-2.303927	0.79	-1.8201024	-0.249231
6.0217742	16.5	0.9	0.6	8.91	-2.8882258	0.79	-2.2816984	-1.1596001
5.4544643	16.1	0.1	0.58	0.9338	4.5206643	0.76	3.4357049	4.3387721
4.7475	15.9	0.11	0.41	0.71709	4.03041	0.75	3.0228075	3.8964075
4.4080793	15.9	0.11	0.34	0.59466	3.8134193	0.75	2.8600645	3.7886845
4.8602789	15.9	0.11	0.41	0.71709	4.1431889	0.76	3.1488236	3.9487724
5.686292	16.1	0.9	0.55	7.9695	-2.283208	0.77	-1.7580701	-0.8860619
5.7838983	16.3	0.1	0.64	1.0432	4.7406983	0.78	3.6977447	4.7588663
5.5425647	16.1	0.12	0.64	1.23648	4.3060847	0.77	3.3156852	4.8675642

RH(%) 0600hrs	U2 m/s	c	E To mm/day	K c	E T c mm/day	No.of days	ET c mm/ month	ET o mm/ month
68	1.339	1.05	5.8769745	1.2	7.0523694	31	**218.62345**	**182.18621**
76	1.5965	1.1	7.1875391	0.8	5.7500313	28	**161.00088**	**201.25109**
86	1.751	1.1	6.8175887	0.5	3.4087943	31	**105.67262**	**211.34525**
92	1.8025	1.1	-0.2741541	0.2	-0.0548308	30	**-1.6449244**	**-8.224622**
94	1.648	1.1	-1.2755602	0.3	-0.382668	31	**11.862709**	**-39.542365**
96	1.545	0.99	4.2953843	0.3	1.2886153	30	**38.658459**	**128.86153**
96	1.648	0.98	3.8184794	0.6	2.2910876	31	**71.023716**	**118.37286**
95	1.751	0.95	3.5992502	0.8	2.8794002	31	**89.261406**	**111.57676**
96	1.545	1.05	4.146211	1.2	4.9754532	30	**149.2636**	**124.38633**
96	1.3905	1.03	-0.9126438	1.2	-1.0951726	31	**-33.95035**	**-28.291958**
94	1.339	1.04	4.9492209	1.2	5.9390651	30	**178.17195**	**148.47663**
84	1.1845	1.02	4.9649155	1.2	5.9578986	31	**184.69486**	**153.91238**
						TOTAL	***1148.913***	**1304.3101**

TABLE4.17

ATEBUBU	*METHOD FOUR :*	THORNTHWAITE		ATEBUBU	LAT.7.55N	LON.2.3W	ALT.122m
Months	T m ^{o}C	Heat Index i	PET cm	Latitude factor	Monthly consumptive use . cm	mm	ET o mm / month
J	27	12.9	14	1.1	15.4	**154**	**140**
F	28.5	14	15.1	0.92	13.892	**138.92**	**151**
M	28.85	14.2	14.3	1.03	14.729	**147.29**	**143**
A	28.8	14.2	15.3	1.02	15.606	**156.06**	**153**
M	27.75	14.1	14.6	1.07	15.622	**156.22**	**146**
J	26.9	12.8	13.8	1.04	14.352	**143.52**	**138**
J	26.3	12.4	12.2	1.07	13.054	**130.54**	**122**
A	26.15	12.1	12	1.06	12.72	**127.2**	**120**
S	26.45	12.5	12.3	1.02	12.546	**125.46**	**123**
O	26.95	12.9	13.8	1.02	14.076	**140.76**	**138**
N	27.15	12.9	14.2	0.98	13.916	**139.16**	**142**
D	26.7	12.8	13.6	0.99	13.464	**134.64**	**136**
	TOTAL	**157.8**			**TOTAL**	***1693.77***	**1652**

TABLE 4.18

BEREKUM	LAT.7.45N	LON 2.59W	ALT.304m				
Months	T m ^{o}C	Heat Index i	PET cm	Latitude factor	Monthly consumptive use . cm	mm	ET o mm/ month
J	25	11.4	25	1.1	27.5	**275**	**250**
F	26.6	12.7	13.5	0.92	12.42	**124.2**	**135**
M	26.9	12.9	13.8	1.03	14.214	**142.14**	**138**
A	26.5	12.5	13.5	1.02	13.77	**137.7**	**135**
M	26	12.1	13	1.07	13.91	**139.1**	**130**
J	25.25	11.4	11.1	1.04	11.544	**115.44**	**111**
J	24.55	11.1	10.9	1.07	11.663	**116.63**	**109**
A	24.55	11.1	10.9	1.06	11.554	**115.54**	**109**
S	24.9	11.4	11	1.02	11.22	**112.2**	**110**
O	25	11.4	11	1.02	11.22	**112.2**	**110**
N	25.4	11.6	11	0.98	10.78	**107.8**	**110**
D	24.8	11.2	11	0.99	10.89	**108.9**	**110**
	TOTAL	**140.8**			**TOTAL**	***1606.85***	**1557**

TABLE 4.19

EJURA	LAT.7.38W	LON 1.36W	ALT.225m.				
Months	T m ^{o}C	Heat Index i	PET cm	Latitude factor	Monthly consumptive use . cm	mm	ET o mm/ month
J	26.85	12.9	13.7	1.1	15.07	**150.7**	**137**
F	28.25	13.8	12.1	0.92	11.132	**111.32**	**121**
M	28.6	13.7	13.6	1.03	14.008	**140.08**	**136**
A	28.15	13.7	14.9	1.02	15.198	**151.98**	**149**
M	27.4	13	14	1.07	14.98	**149.8**	**140**
J	26.3	11.4	12.2	1.04	12.688	**126.88**	**122**
J	25.55	11.6	11.4	1.07	12.198	**121.98**	**114**
A	25.3	11.5	11.2	1.06	11.872	**118.72**	**112**
S	25.8	11.9	11.6	1.02	11.832	**118.32**	**116**
O	26.35	11.4	12.2	1.02	12.444	**124.44**	**122**
N	26.85	12.6	13.7	0.98	13.426	**134.26**	**137**
D	26.2	12.3	12	0.99	11.88	**118.8**	**120**

	TOTAL	149.8			TOTAL	*1567.28*	1526

TABLE 4.20 WENCHI LAT.7.75 N LON 2.1W ALT.340m

Months	T m ^{O}C	Heat Index i	PET cm	Latitude factor	Monthly consumptive use . cm	mm	ET o mm/ month
J	27.4	12.2	14.3	1.1	15.73	**157.3**	**143**
F	29.75	15	15.9	0.92	14.628	**146.28**	**159**
M	31.25	16	16.9	1.03	17.407	**174.07**	**169**
A	30.55	15.4	16.5	1.02	16.83	**168.3**	**165**
M	28.8	14.2	15.3	1.07	16.371	**163.71**	**153**
J	27.2	13	14.2	1.04	14.768	**147.68**	**142**
J	25.55	11.7	11	1.07	11.77	**117.7**	**110**
A	25.75	11.8	12	1.06	12.72	**127.2**	**120**
S	26.2	12.3	14.2	1.02	14.484	**144.84**	**142**
O	27.7	13.1	14.5	1.02	14.79	**147.9**	**145**
N	28.2	13.8	14.9	0.98	14.602	**146.02**	**149**
D	27.15	13	14	0.99	13.86	**138.6**	**140**
	TOTAL	**161.5**			**TOTAL**	***1779.6***	**1737**

TABLE 4.21 WENCHI

Months	Pot Eva ,ET o mm / month	K c	ET c mm/ month
J	184.1	1.2	220.92
F	193.3	0.8	154.64
M	171.3	0.5	85.65
A	123.9	0.2	24.78
M	102.7	0.3	30.81
J	82.2	0.3	24.66
J	69.8	0.6	41.88
A	70	0.8	56
S	75.5	1.2	90.6
O	82.9	1.2	99.48
N	104.3	1.2	125.16
D	130.6	1.2	156.72
TOTAL	**1390.6**		**1111.3**

NOTE: No data available on Potential Evapotranspiration for Atebubu, Berekum and Ejura.

Table4.22 COMPARISON OF VARIOUS METHODS OF CROP WATER REQUIREMENT DETERMINATION

TOWNS METHODS	ATEBUBU mm	BEREKUM mm	EJURA mm	WENCHI Mm
Blaney-Criddle	**880.46**	**1021.11**	**937.78**	**1127.04**
Radiation	**1270.85**	**1235.44**	**1223.95**	**1256.2**
Penman	**1432.209**	**1408.656**	**1367.379**	**1445.913**
Thornthwaite	**1693.77**	**1606.85**	**1567.28**	**1779.6**
Pan Evapotranspiration		-	-	

Table 4.24 AVERAGE ANNUAL RAINFALL (mm)

TOWNS	ATEBUBU	BEREKUM	EJURA	WENCHI
VALUES	**1882.3**	**1116.1**	**1287.5**	**1236.5**

APPENDICES

Atebubu Mean Monthly Rainfall (mm)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	8.4	53.9	45.2	189.7	82.6	229.3	39.1	63.2	259.9	133.7	88.3	0.0
1977	9.7	16.8	60.7	89.6	62.8	121.0	37.0	39.3	162.2	156.1	40.6	7.9
1978	0.0	66.6	149.4	191.4	205.8	192.3	73.3	39.7	146.7	172.2	22.1	10.7
1979	0.0	0.0	88.1	23.7	189.1	143.0	269.1	158.9	280.1	281.1	31.0	0.0
1980	32.8	22.9	48.6	116.3	195.1	109.9	176.9	100.9	387.8	198.6	18.3	0.0
1981	0.0	22.6	141.2	99.6	67.7	128.0	168.9	317.0	163.3	52.3	0.0	0.0
1982	0.0	29.2	55.4	62.7	94.5	90.1	93.2	120.7	78.4	108.6	25.2	0.0
1983	0.0	0.0	15.2	56.8	114.8	124.4	55.3	64.3	277.9	16.8	31.5	32.0
1984	0.0	0.0	206.5	130.2	212.7	197.5	177.6	235.7	112.3	138.4	25.2	0.0
1985	TR	0.0	62.4	71.6	52.9	209.0	236.4	198.3	326.4	103.4	37.6	0.0
1986	TR	64.8	153.2	82.1	49.1	209.3	132.7	95.2	171.4	220.1	26.7	0.0
1987	TR	32.8	45.7	83.5	96.0	126.0	158.3	282.2	452.5	180.0	0.0	0.0
1988	5.8	11.7	37.6	60.0	207.4	270.1	221.5	65.3	271.2	80.4	TR	40.9
1989	0.0	4.3	147.0	257.7	130.8	275.0	260.9	175.5	197.6	206.6	0.0	34.7
1990	0.8	24.1	0.0	195.5	131.7	139.0	59.8	113.0	189.2	141.8	52.2	109.7
1991	0.0	66.5	84.8	109.9	184.6	213.7	198.8	214.5	86.6	204.6	8.8	4.5
1992	0.0	0.0	33.2	123.1	135.3	334.4	63.6	7.6	79.2	90.2	90.5	0.0
1993	0.0	1.9	173.0	55.9	114.6	133.2	82.0	140.7	195.2	206.1	69.9	0.0
1994	TR	0.0	105.8	89.9	110.7	80.4	27.9	100.4	138.0	259.4	3.0	0.0
1995	0.0	1.0	28.9	175.4	135.9	167.7	221.2	162.5	234.3	105.0	10.0	48.7
1996	1.0	84.4	94.0	69.1	313.0	355.1	179.7	124.4	243.3	212.9	TR	1.0
1997	51.1	0.0	42.3	203.4	183.0	182.2	129.7	155.2	318.4	173.2	9.8	18.6
1998	1.3	26.9	13.0	141.3	102.1	346.4	103.3	127.4	107.1	316.6	47.5	71.2
1999	TR	30.1	116.8	312.5	236.7	113.7	167.2	227.4	295.8	254.7	16.0	0.0
2000	51.5	0.0	130.9	221.1	167.5	185.2	230.0	240.7	220.3	67.0	27.0	0.0
2001	0.0	0.0	3.0	188.1	223.2	217.9	277.4	64.3	169.3	41.5	TR	1.7
2002	3.0	2.4	24.8	80.2	247.6	192.5	431.9	123.8	243.0	229.0	31.5	7.1
2003	7.0	19.9	43.9	174.2	90.1	195.3	69.2	89.0	193.3	152.5	103.9	5.0
2004	22.6	13.5	98.3	204.5	319.4	173.1	111.9	286.3	233.3	325.9	145.2	12.8
2005	10.0	20.6	80.6	133.6	224.8	2925.0	192.8	140.0	348.7	97.4	38.6	0.0
2006	54.5	51.4	94.3	106.4	252.0	170.0	82.6	76.1	288.5	259.8	27.4	tr
AVE	**21.2**	**15.4**	**68.0**	**158.3**	**217.8**	**579.9**	**199.4**	**145.7**	**242.3**	**167.6**	**62.3**	**4.4**

AVERAGE ANNUAL RAINFALL=1882.3 mm

Atebubu Mean Monthly Maximum Temperature (°C)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	33.9	35.5	35.2	34.2	33.3	31.4	30.5	30.8	31.9	31.7	32.7	32.3
1977	33.4	36.2	36.4	34.4	34.3	31.7	31.1	30.8	31.7	32.6	34.4	31.9
1978	33.8	36.1	34.5	34.1	33.5	32.3	31.5	32.4	32.6	32.5	33.1	32.7
1979	34.2	36.1	35.3	35.2	33.3	33.1	31.8	31.4	31.1	32.5	32.3	32.6
1980	32.8	36.3	33.9	32.6	33.4	32.5	31.8	30.8	31.3	32.0	33.6	33.4
1981	32.7	33.6	33.7	33.5	31.4	33.1	31.3	30.3	31.2	33.6	33.3	33.7
1982	33.9	33.3	33.7	33.1	33.3	33.9	32.9	32.5	33.5	33.5	31.9	33.2
1983	34.5	36.2	35.4	34.5	33.3	32.1	31.2	30.5	31.3	33.3	33.6	33.4
1984	33.6	33.5	33.1	33.3	33.2	33.3	33.2	33.3	31.3	33.2	33.2	33.3
1985	33.2	33.3	33.2	33.2	33.2	33.0	33.1	32.8	32.6	32.5	33.3	33.4
1986	34.6	36.2	35.9	34.9	33.1	32.8	31.1	31.3	33.2	33.4	33.6	33.4
1987	33.2	33.0	32.9	33.2	33.1	32.9	32.8	32.3	32.6	32.4	33.1	33.0
1988	33.3	33.4	33.3	33.3	33.2	33.2	33.0	33.1	31.2	32.7	34.1	34.3
1989	32.9	33.0	33.0	33.3	33.0	32.2	31.5	30.7	31.3	32.8	32.9	33.1
1990	35.3	33.0	32.5	32.5	32.8	32.4	31.4	29.6	28.8	29.3	29.6	31.2
1991	31.9	31.2	31.5	33.1	30.8	30.6	30.7	30.2	31.2	30.4	31.5	31.4
1992	32.2	37.1	32.8	32.8	31.4	30.2	28.3	28.5	29.6	30.9	31.8	33.3
1993	33.7	36.4	33.8	33.8	33.6	31.4	30.9	30.7	30.9	32.7	32.9	29.6
1994	33.4	36.4	35.2	35.7	34.2	32.5	31.4	32.1	31.0	32.1	33.9	34.1
1995	35.7	37.7	38.0	35.7	33.7	32.9	31.3	31.1	32.2	32.8	34.0	33.9
1996	35.9	36.8	36.1	34.8	34.2	31.9	31.2	31.0	31.3	32.3	33.7	33.9
1997	35.3	37.0	37.3	34.9	33.2	31.8	31.3	30.6	31.8	33.4	34.5	34.2
1998	36.1	38.2	39.4	36.2	35.0	32.5	30.7	30.9	31.6	32.8	34.8	34.2
1999	35.1	36.5	37.4	34.4	33.9	33.0	31.5	31.5	31.1	31.9	34.4	34.8
2000	35.4	35.9	37.4	34.4	34.3	32.0	30.4	29.9	30.4	32.1	34.1	33.6
2001	35.7	37.4	38.2	34.6	33.7	32.0	30.8	29.5	30.2	33.2	34.7	35.5
2002	35.3	37.8	37.1	35.5	33.6	32.2	31.1	30.2	31.1	31.9	33.7	34.0
2003	35.8	37.6	37.9	35.0	34.8	31.7	31.0	30.7	31.5	33.2	33.4	33.5
2004	34.7	36.6	36.3	35.0	33.2	31.7	30.8	30.3	31.4	33.1	33.4	33.9
2005	34.1	37.0	36.6	35.7	33.9	31.9	30.7	30.2	31.5	32.9	34.3	34.6
2006	35.7	36.2	35.9	37.2	33.4	32.5	31.3	30.8	31.1	32.8	34.0	34.3
AVE	***34.2***	***35.6***	***35.3***	***34.3***	***33.4***	***32.3***	***31.3***	***31.0***	***31.4***	***32.5***	***33.3***	***33.3***

Atebubu Mean Monthly Minimum Temperature (°C)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	18.4	22.3	22.3	22.0	22.4	21.3	20.9	21.4	21.7	22.2	21.5	19.6
1977	20.0	21.3	22.9	23.0	22.3	21.5	21.3	20.9	21.8	21.1	20.0	21.0
1978	20.7	21.3	21.8	21.9	21.7	21.5	21.1	21.0	21.1	21.4	20.8	21.3
1979	19.6	22.1	22.0	21.7	21.5	20.7	21.4	20.8	21.2	21.4	21.6	21.4
1980	21.3	21.3	21.4	21.6	22.3	21.5	20.5	21.4	21.5	21.1	21.1	20.1
1981	21.3	21.0	21.1	21.9	21.5	21.2	22.1	20.9	21.3	21.1	21.3	20.2
1982	20.4	21.1	21.0	21.3	21.1	21.3	21.3	20.8	21.3	21.4	20.9	21.4
1983	20.1	21.3	22.3	21.9	22.3	22.3	21.8	22.1	21.9	21.1	19.9	20.6
1984	21.0	21.1	21.3	21.0	21.1	21.0	20.9	21.0	21.8	20.9	21.0	20.9
1985	21.0	20.9	20.9	20.9	20.8	20.8	20.8	21.0	24.2	21.3	21.1	19.9
1986	19.3	21.2	22.8	22.6	20.8	20.8	21.4	21.3	21.1	21.0	21.2	19.9
1987	20.9	21.1	21.0	21.2	21.0	21.1	21.2	21.2	21.2	21.5	21.3	21.3
1988	21.3	21.0	21.0	21.0	20.3	21.0	21.0	21.1	21.3	21.3	21.2	20.1
1989	20.9	20.9	21.1	21.0	21.0	20.7	20.3	20.8	20.7	21.9	21.0	21.0
1990	19.6	21.0	20.3	20.3	21.0	20.5	19.6	19.4	19.5	21.3	21.1	20.0
1991	19.4	19.7	20.6	20.7	20.2	20.6	20.7	21.3	21.3	20.1	20.5	18.1
1992	17.0	22.1	22.2	21.9	21.5	20.6	20.2	20.2	20.4	20.2	19.4	18.4
1993	16.6	22.0	21.7	22.0	23.4	22.1	22.1	20.9	21.0	21.9	21.8	19.4
1994	18.4	19.7	21.3	23.3	23.1	21.9	22.2	22.5	22.7	22.2	20.8	17.4
1995	16.8	20.5	24.5	24.3	23.1	22.7	22.5	22.2	22.1	22.1	20.9	20.7
1996	21.0	22.6	24.0	23.8	23.4	22.6	22.1	22.2	22.2	21.8	20.2	21.4
1997	21.5	19.7	24.2	23.4	22.9	22.5	22.0	22.0	22.3	23.0	22.0	20.9
1998	19.5	22.9	25.1	24.1	24.3	23.0	22.9	22.1	22.3	22.4	22.4	20.8
1999	20.5	21.3	23.9	23.3	23.2	22.9	22.3	21.9	22.1	22.0	21.9	19.0
2000	21.2	19.3	23.5	23.8	23.4	22.7	21.9	22.0	22.7	22.5	22.3	19.6
2001	18.7	21.4	24.9	24.0	23.5	22.7	22.4	22.2	22.0	22.6	22.5	22.0
2002	19.9	21.7	23.6	22.5	21.5	20.5	20.4	20.1	19.9	19.7	19.2	15.0
2003	15.5	18.8	18.8	17.5	17.3	15.8	15.3	15.5	15.1	14.6	16.2	19.3
2004	21.3	23.5	24.4	24.5	24.0	23.1	22.1	22.8	22.5	22.7	22.6	22.8
2005	18.8	23.8	24.2	24.7	23.9	23.4	23.0	22.7	22.9	22.9	23.2	21.4
2006	22.7	24.2	24.4	24.8	23.8	23.7	23.4	23.2	22.9	23.1	21.6	19.5
AVE	***19.8***	***21.4***	***22.4***	***22.3***	***22.1***	***21.5***	***21.3***	***21.3***	***21.5***	***21.4***	***21.0***	***20.1***

Atebubu Mean Monthly RH at 0600 hours (%)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1991	94	96	98	97	95	96	98	97	92	98	99	94
1992	93	92	97	97	97	97	97	97	99	96	95	94
1993	90	92	95	93	93	94	92	93	95	90	89	94
1994	83	80	85	87	91	95	93	93	95	96	94	79
1995	72	67	86	91	95	95	98	96	96	93	93	92
1996	91	91	90	92	93	94	94	94	94	94	93	96
1997	82	70	80	91	94	96	97	94	95	96	96	90
1998	72	76	79	92	90	90	92	92	94	92	88	88
1999	82	80	84	92	94	92	94	94	94	96	93	90
2000	88	66	80	88	88	92	94	92	93	90	92	88
2001	72	68	80	86	88	92	92	92	94	90	89	87
2002	52	64	78	82	86	89	90	88	88	88	86	76
2003	70	82	76	84	84	88	88	88	88	88	88	94
2004	74	70	76	82	84	86	96	88	90	86	86	86
2005	62	82	84	84	84	85	87	86	86	84	85	81
2006	78	86	85	84	87	90	86	86	89	86	82	71
2007	62	74	77	80	85	87	86	88	89	86	87	83
AVE	***77***	***79***	***84***	***88***	***90***	***92***	***93***	***92***	***92***	***91***	***90***	***87***

Atebubu Mean Monthly RH at 1500 hours (%)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1991	68	64	61	56	65	66	72	74	77	69	71	59
1992	53	61	67	82	78	78	85	88	78	73	58	57
1993	37	54	61	66	70	70	69	69	70	71	68	85
1994	63	55	56	63	64	67	62	58	74	70	53	40
1995	30	31	44	57	67	70	70	78	71	67	52	52
1996	40	45	50	60	64	70	70	72	70	66	52	56
1997	43	30	40	58	69	72	74	75	79	68	62	52
1998	34	38	38	64	60	70	74	76	74	71	62	59
1999	53	43	50	64	62	70	72	70	72	70	60	48
2000	48	30	42	62	62	66	70	72	73	64	57	44
2001	38	40	44	58	62	68	70	74	74	63	54	46
2002	26	26	44	52	62	65	68	70	68	66	58	46
2003	34	42	36	56	58	66	66	68	66	60	58	48
2004	40	40	46	56	64	68	72	70	70	64	64	62
2005	40	48	54	56	42	69	73	74	71	65	66	55
2006	53	56	56	56	67	69	69	68	73	70	55	50
2007	38	42	46	55	65	67	66	69	69	66	59	58
AVE	***43.412***	***43.824***	***49.118***	***60.059***	***63.588***	***68.882***	***70.706***	***72.059***	***72.294***	***67.235***	***59.353***	***53.941***

Berekum Mean Monthly Rainfall (mm)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	9.7	143.0	95.8	96.9	257.7	143.4	38.9	24.0	67.3	246.4	81.8	0.0
1977	50.6	69.9	35.0	62.2	137.6	137.3	3.8	59.3	142.8	193.8	0.0	0.0
1978	0.0	57.1	126.3	117.1	182.9	249.0	34.5	79.0	159.5	139.7	49.9	0.0
1979	0.0	0.0	75.5	68.8	144.8	215.5	206.1	42.7	163.1	194.2	38.8	15.7
1980	0.0	57.4	44.6	94.4	126.0	107.8	112.8	8.9	233.4	114.6	19.6	0.0
1981	0.0	17.1	155.8	40.5	110.2	114.5	81.6	87.2	134.7	187.1	0.0	0.0
1982	0.0	71.6	107.3	92.8	138.0	61.0	90.8	31.9	35.0	163.3	7.3	0.0
1983	0.0	32.9	44.8	29.8	210.0	199.4	27.2	95.5	135.5	136.7	48.1	61.0
1984	0.0	5.9	195.8	147.3	192.8	128.7	219.7	83.5	160.2	88.5	88.5	0.0
1985	10.3	15.8	134.5	53.8	142.4	160.9	141.4	165.6	301.4	180.3	22.5	0.0
1986	64.8	112.3	115.2	90.4	281.8	68.9	67.0	82.5	156.7	5.4	0.0	12.5
1987	27.4	116.2	19.8	100.0	133.7	79.2	209.3	272.1	248.7	17.0	0.0	0.0
1988	73.8	183.2	113.0	160.5	143.8	145.6	43.7	169.2	70.0	21.7	4.8	0.0
1989	0.0	161.0	188.5	104.8	385.0	242.5	66.6	232.9	156.6	11.5	14.0	0.0
1990	35.5	0.0	193.9	72.3	142.2	70.4	30.9	141.1	179.0	110.0	177.9	0.2
1991	40.7	180.6	101.4	175.3	116.7	191.7	91.8	103.5	49.0	10.5	15.2	0.0
1992	25.3	11.8	168.9	98.0	100.5	62.2	7.0	244.3	76.8	86.5	0.0	0.0
1993	18.7	97.6	110.3	181.9	106.2	27.1	10.5	181.3	169.9	68.8	2.6	1.9
1994	1.9	22.7	51.9	87.3	138.5	107.2	15.7	12.7	115.5	208.7	59.2	0.0
1995	0.0	13.6	79.1	232.4	240.2	105.5	111.9	110.7	166.4	204.8	5.0	20.2
1996	Tr	182.6	82.9	124.3	107.0	219.2	113.3	63.2	45.5	154.8	20.3	3.1
1997	11.5	0.0	42.5	188.1	164.0	243.7	72.9	36.1	162.4	111.6	24.3	0.0
1998	24.8	25.5	65.9	233.1	39.3	150.2	27.3	24.8	162.3	212.7	36.7	22.6
1999	42.8	34.6	145.1	143.3	145.9	124.5	72.1	85.0	125.2	124.1	59.4	Tr
2000	54.6	0.0	71.5	185.5	127.7	155.1	76.4	105.8	137.5	94.7	47.6	0.0
2001	0.0	7.2	187.1	228.5	141.7	224.1	67.4	13.3	167.8	45.9	33.6	8.0
2002	28.4	11.7	149.6	323.1	116.8	130.2	142.9	60.5	74.8	212.1	69.3	43.9
2003	4.0	26.3	87.4	141.5	129.8	127.0	25.7	49.1	136.5	129.0	75.2	20.0
2004	68.2	54.4	90.7	211.3	107.0	28.3	83.0	163.6	268.8	199.5	51.8	6.7
2005	0.0	17.9	58.9	165.1	148.9	162.7	82.6	20.2	128.0	297.9	85.4	16.0
2006	56.8	28.3	115.5	138.8	223.9	171.8	77.8	1.7	181.0	312.7	10.9	0.0
AVE	***21.7***	***56.7***	***105.0***	***135.1***	***157.5***	***140.5***	***79.1***	***92.0***	***145.5***	***138.2***	***37.1***	***7.7***

AVERAGE ANNUAL RAINFALL =1116.1 mm

Berekum Mean Monthly Maximum Temperature (°C)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	31.9	32.3	32.6	31.7	31.1	29.0	27.3	27.2	28.6	28.1	29.8	30.0
1977	30.4	34.0	32.0	32.1	31.5	31.5	32.2	37.2	30.0	28.2	27.8	28.4
1978	29.4	29.8	29.5	29.5	29.4	28.6	27.7	29.3	30.8	29.4	28.9	29.4
1979	30.6	32.0	31.4	31.1	30.6	29.5	30.1	29.6	29.8	28.6	29.5	29.4
1980	29.4	32.0	31.4	31.1	30.7	29.7	29.3	30.8	29.8	29.0	29.8	30.0
1981	30.3	32.0	29.6	29.4	29.7	29.8	29.7	30.0	29.8	29.3	29.9	29.8
1982	29.8	29.5	29.7	29.5	29.6	29.4	30.0	29.8	30.4	29.8	29.3	29.8
1983	30.3	31.7	30.9	29.9	30.0	29.6	29.5	30.1	30.1	29.8	30.0	30.1
1984	30.3	30.6	29.7	30.2	30.4	30.5	30.0	29.7	29.8	29.7	29.4	30.0
1985	30.2	30.1	30.5	29.8	30.1	29.7	29.8	29.7	29.9	29.9	30.1	30.0
1986	30.1	30.5	30.2	30.4	29.8	29.7	29.6	30.3	29.1	28.9	29.4	29.7
1987	30.1	31.1	29.2	29.9	29.3	29.7	29.6	30.3	30.4	30.7	30.8	30.4
1988	32.5	35.6	33.1	32.6	32.2	30.1	28.7	27.9	28.8	31.1	32.4	31.7
1989	30.7	34.9	34.5	33.4	32.1	30.3	29.5	28.9	29.3	30.4	32.1	31.9
1990	32.9	34.9	36.5	33.3	31.8	30.9	28.2	28.0	29.5	30.8	31.5	30.9
1991	32.6	34.5	33.4	32.8	31.3	30.9	28.9	28.4	28.9	29.8	31.2	31.4
1992	32.8	35.3	35.3	33.6	31.9	30.7	28.1	28.0	29.5	30.3	30.9	31.4
1993	33.3	35.6	34.2	33.8	32.9	30.3	29.0	28.5	29.9	31.0	31.8	31.5
1994	33.2	35.1	34.9	33.0	32.5	30.4	29.1	29.4	29.7	30.3	31.8	32.7
1995	34.4	36.6	34.7	34.5	32.7	31.6	30.1	29.6	30.3	30.6	32.4	32.2
1996	34.0	33.8	33.0	33.5	32.8	30.3	29.0	29.5	29.5	30.1	32.8	31.8
1997	33.8	35.9	35.9	33.2	32.2	30.5	28.7	28.5	29.8	31.6	32.4	33.2
1998	34.9	36.0	37.5	34.3	33.4	31.4	29.4	30.0	29.7	30.7	32.6	32.0
1999	34.2	34.3	34.3	32.8	32.5	31.5	29.6	28.9	28.9	29.8	31.5	33.1
2000	33.5	35.0	36.5	33.3	32.2	29.8	28.5	27.7	29.7	30.6	32.0	32.2
2001	33.7	35.2	35.0	33.5	32.4	30.7	29.0	28.9	29.6	30.2	31.1	32.0
2002	32.7	34.3	33.9	33.2	32.2	30.6	29.1	28.7	29.8	30.3	31.6	31.7
2003	32.2	33.6	33.0	32.8	32.7	29.8	28.9	28.6	29.7	31.2	31.3	32.0
2004	33.0	34.7	33.8	31.9	31.2	30.1	28.2	28.1	29.4	30.6	31.0	30.9
2005	33.5	32.9	33.1	32.4	30.9	29.8	29.6	28.9	29.7	30.1	31.1	30.6
2006	32.4	33.7	33.3	32.3	31.6	30.3	29.2	29.1	29.6	30.3	31.2	31.3
AVE	***32.0***	***33.5***	***33.0***	***32.1***	***31.4***	***30.2***	***29.2***	***29.3***	***29.7***	***30.0***	***30.9***	***31.0***

Berekum Mean Monthly Minimum Temperature (°C)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	15.3	19.8	20.8	21.6	21.3	21.3	20.1	19.4	20.2	20.6	19.9	16.8
1977	18.5	19.5	21.3	21.0	21.0	20.2	20.0	20.0	19.5	19.4	17.8	18.8
1978	19.6	18.4	17.7	18.0	18.9	17.6	18.3	17.8	17.5	17.7	17.2	17.8
1979	19.2	19.8	21.1	19.6	17.9	17.3	17.7	17.8	18.6	17.9	16.9	17.0
1980	17.2	20.3	21.1	21.3	18.6	18.5	18.2	17.6	18.4	18.8	17.9	18.2
1981	18.1	18.3	17.7	17.5	18.1	18.2	17.8	17.8	18.7	17.5	18.1	18.0
1982	16.8	17.6	17.3	17.5	17.7	17.8	18.0	17.4	17.4	17.0	17.2	18.9
1983	17.7	18.2	19.4	17.9	19.6	18.2	17.9	19.1	18.2	18.7	18.1	17.7
1984	18.0	17.8	17.6	18.2	17.9	17.6	17.9	18.2	18.1	17.8	18.9	17.7
1985	18.3	17.6	18.3	18.0	17.5	18.0	17.7	17.3	19.4	17.7	17.8	17.5
1986	17.6	18.5	19.3	20.8	21.2	20.9	19.8	19.6	20.1	19.3	19.7	18.3
1987	17.2	19.2	17.1	21.1	17.2	20.8	19.6	20.1	21.5	20.4	20.2	17.4
1988	14.1	20.1	22.2	22.4	21.9	21.6	20.7	20.7	21.0	21.4	21.7	17.3
1989	18.9	19.4	21.8	21.7	21.5	21.1	21.1	20.6	20.8	20.9	21.6	19.2
1990	19.5	18.6	22.6	22.1	21.9	21.5	21.0	20.8	21.3	21.0	21.4	19.8
1991	18.4	21.4	21.9	21.7	22.2	22.4	21.2	21.0	20.9	20.7	20.6	16.4
1992	15.6	20.4	22.1	22.0	21.8	21.1	20.4	20.0	20.4	21.3	19.8	19.1
1993	15.2	21.1	20.3	22.0	22.2	21.4	21.1	21.0	20.9	21.3	21.6	18.2
1994	18.2	21.0	22.1	21.7	21.9	21.5	20.9	21.0	21.6	21.1	19.8	17.4
1995	14.8	18.5	21.2	21.6	20.8	20.7	20.5	20.7	20.7	20.8	20.0	18.7
1996	19.2	20.6	21.2	21.4	21.6	21.0	20.5	20.8	20.6	20.2	19.4	19.8
1997	19.9	17.8	22.3	21.8	21.7	21.3	21.0	20.7	21.1	21.7	21.8	20.2
1998	18.3	20.6	22.9	22.8	22.4	21.3	21.4	20.8	21.4	21.4	21.8	20.3
1999	20.3	19.8	21.8	21.7	21.5	21.5	21.3	20.8	20.9	20.7	21.3	19.0
2000	20.7	17.9	22.5	22.0	22.2	21.5	20.9	20.8	21.3	20.9	21.7	19.7
2001	18.3	20.5	22.6	21.8	21.9	21.7	21.0	20.7	20.2	21.0	22.2	22.1
2002	19.2	20.9	22.4	22.5	21.6	20.8	20.8	20.1	20.3	20.9	20.8	18.5
2003	18.5	21.6	21.7	21.3	21.5	20.4	20.0	20.1	20.5	20.8	20.5	18.7
2004	18.7	20.4	20.7	20.9	20.8	20.0	19.7	19.9	19.7	20.3	20.5	20.9
2005	17.2	22.6	22.7	22.1	21.8	21.3	20.8	20.3	21.1	20.7	21.2	19.5
2006	20.4	21.5	21.2	21.9	20.8	20.0	20.7	20.4	20.6	20.5	19.7	17.7
AVE	***18.0***	***19.7***	***20.8***	***20.9***	***20.6***	***20.3***	***19.9***	***19.8***	***20.1***	***20.0***	***19.9***	***18.6***

Berekum Mean Monthly RH at 0600 hours (%)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1990	86	73	84	92	93	94	95	95	92	93	93	86
1991	84	91	92	91	94	93	95	95	94	94	92	72
1992	61	89	91	92	92	95	94	94	94	94	83	82
1993	52	87	91	93	94	95	95	87	93	92	90	70
1994	61	81	88	91	93	93	93	94	94	91	88	67
1995	61	70	90	90	92	91	92	92	92	92	90	84
1996	86	90	89	91	89	94	93	93	93	93	88	92
1997	83	53	81	90	90	94	94	94	94	90	91	86
1998	61	75	78	89	90	93	93	93	95	91	90	85
1999	84	81	88	90	90	94	93	94	94	93	90	74
2000	84	59	88	92	94	95	94	93	94	92	94	93
2001	77	86	90	90	92	93	92	93	92	93	93	91
2002	71	85	91	91	91	92	92	91	93	91	89	73
2003	77	87	85	86	86	90	90	90	92	90	90	84
2004	85	79	84	89	89	90	92	92	93	92	91	93
2005	72	86	88	88	89	92	93	94	63	91	90	92
2006	86	90	89	89	90	91	91	90	91	90	88	72
2007	69	81	83	85	88	90	99	89	90	90	91	84
AVE	***74***	***80***	***87***	***90***	***91***	***93***	***93***	***92***	***91***	***92***	***90***	***82***

Berekum Mean Monthly RH at 1500 hours (%)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1990	47	43	34	55	63	65	74	74	72	65	64	60
1991	44	51	57	59	68	68	73	73	72	67	61	38
1992	31	45	48	57	63	66	71	70	72	65	57	58
1993	22	38	46	54	65	71	76	60	57	61	58	45
1994	41	41	50	57	58	69	71	71	70	70	56	38
1995	31	32	52	55	60	66	71	74	69	69	58	54
1996	51	54	57	57	60	73	74	71	71	68	49	56
1997	42	23	41	58	64	71	71	73	71	65	61	51
1998	27	27	36	58	59	70	70	68	71	67	57	49
1999	41	38	53	59	62	68	69	70	72	70	63	38
2000	45	24	36	61	63	71	72	73	74	68	57	41
2001	30	23	45	60	65	65	70	73	70	61	56	46
2002	25	27	52	61	62	65	71	68	68	64	60	40
2003	29	40	40	56	58	68	67	69	68	64	63	46
2004	37	35	44	63	65	63	72	71	69	62	61	56
2005	25	38	46	59	60	69	72	71	62	62	61	52
2006	40	43	53	54	63	67	66	63	68	66	43	34
2007	25	35	32	54	60	65	67	71	70	65	59	46
AVE	***35.167***	***36.5***	***45.667***	***57.611***	***62.111***	***67.778***	***70.944***	***70.167***	***69.222***	***65.5***	***58***	***47.111***

Ejura Mean Monthly Rainfall (mm)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	1.3	47.7	122.7	103.3	204.7	220.1	27.9	49.2	123.0	148.8	116.4	0.6
1977	2.9	4.6	28.2	106.6	148.4	209.7	24.2	36.5	256.3	295.5	0.8	6.6
1978	0.0	56.0	229.5	137.3	246.3	131.2	85.7	28.6	278.9	146.5	63.7	17.1
1979	14.0	3.8	128.1	138.0	150.2	166.5	225.9	112.6	216.1	226.0	20.4	1.0
1980	3.1	33.3	122.7	88.0	247.0	181.6	184.5	70.3	162.2	294.2	74.4	0.0
1981	0.5	4.6	238.6	57.3	263.1	80.0	141.7	123.9	321.1	119.8	0.0	0.3
1982	0.0	59.9	89.6	114.5	114.5	162.5	40.2	59.5	116.0	186.2	46.3	17.6
1983	0.0	0.0	26.1	195.2	159.0	146.2	15.9	32.3	105.8	71.7	27.2	54.6
1984	0.0	11.2	150.2	117.9	180.0	152.8	196.3	180.9	168.7	127.5	0.0	0.0
1985	18.3	2.8	97.4	117.9	92.2	120.0	233.8	180.3	336.2	128.9	10.9	0.0
1986	0.0	23.4	204.9	164.9	253.5	211.6	199.0	62.1	174.8	224.1	23.5	0.0
1987	24.4	9.9	78.7	107.6	101.0	272.0	231.2	200.7	316.8	147.6	0.0	0.0
1988	0.0	32.8	80.5	100.4	206.8	234.9	198.5	14.2	180.4	149.4	27.1	39.8
1989	0.0	3.1	142.8	155.7	68.2	372.8	270.3	100.5	225.3	174.7	7.8	6.3
1990	0.0	36.5	0.0	114.1	128.7	134.0	39.4	75.0	256.9	102.6	133.1	125.0
1991	0.0	55.1	121.9	143.9	218.3	183.9	96.7	17.9	185.2	182.4	0.8	1.3
1992	0.0	0.0	16.7	82.0	133.5	179.8	205.8	13.4	106.7	168.7	19.1	0.0
1993	0.0	57.9	105.8	110.2	176.9	154.5	16.3	109.0	339.3	260.8	0.0	1.0
1994	0.0	10.0	160.7	125.4	149.1	75.5	22.4	30.8	156.9	285.3	26.5	0.0
1995	0.0	2.3	69.7	153.6	117.6	153.2	193.1	76.3	326.6	171.2	40.7	164.7
1996	10.7	89.5	63.2	268.3	294.7	120.5	110.0	52.8	182.1	132.0	0.0	10.5
1997	55.5	0.0	81.7	189.0	276.7	207.2	89.7	85.2	237.5	206.9	4.3	0.0
1998	1.0	36.8	3.5	234.6	91.1	235.4	76.7	117.7	158.0	262.3	3.5	62.0
1999	15.9	27.9	217.0	223.5	79.6	163.9	187.6	122.7	142.4	167.2	42.9	0.0
2000	16.0	0.0	78.7	144.8	127.2	234.9	133.1	127.9	164.9	33.3	4.9	0.0
2001	0.0	0.0	97.1	248.1	123.1	142.5	88.3	29.2	282.7	105.2	7.6	0.0
2002	4.7	16.4	81.0	146.3	222.9	227.5	168.6	114.3	211.9	116.9	33.6	31.8
2003	4.3	80.9	108.8	154.3	108.0	265.6	35.8	27.0	239.6	137.4	155.7	7.5
2004	24.3	23.8	115.9	125.0	289.5	72.5	115.5	215.2	198.1	180.7	80.7	15.5
2005	0.7	35.2	134.8	204.5	133.4	94.8	46.5	98.9	234.3	182.2	120.5	14.8
2006	32.7	23.9	66.4	54.8	383.7	167.9	79.4	8.7	251.9	366.8	34.5	tr
AVE	***7.4***	***25.5***	***105.3***	***142.8***	***177.1***	***176.6***	***121.9***	***83.0***	***214.7***	***177.5***	***36.4***	***19.3***

AVERAGE ANNUAL RAINFALL =1287.5 mm

Ejura Mean Monthly Maximum Temperature (°C)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	33.6	34.8	34.1	32.9	31.8	29.9	29.1	29.5	30.4	29.5	32.1	32.0
1977	33.1	35.4	36.6	34.0	32.6	30.5	29.6	29.5	30.3	31.0	32.8	32.0
1978	34.6	35.7	32.6	32.4	32.0	30.0	28.5	29.5	30.0	30.8	32.0	32.1
1979	33.9	34.9	33.1	34.0	32.5	30.4	30.5	28.9	30.3	31.3	32.5	32.2
1980	34.1	33.3	33.3	34.1	33.0	30.2	30.4	28.7	30.6	31.7	32.4	32.1
1981	33.8	33.4	33.6	33.7	33.6	30.1	30.4	28.6	30.8	31.8	32.6	31.9
1982	35.0	35.9	33.1	33.9	32.4	31.6	30.2	29.9	31.1	31.6	32.4	32.0
1983	34.6	33.8	33.8	34.0	32.2	31.3	30.4	29.6	30.9	31.8	32.2	32.3
1984	34.4	33.7	33.6	34.3	32.2	31.8	30.3	29.8	31.1	32.0	32.1	32.2
1985	33.9	34.8	35.0	32.3	33.4	31.6	29.9	30.3	30.6	32.0	32.9	32.0
1986	34.5	36.1	33.2	33.2	32.6	31.2	29.7	29.9	30.5	31.1	32.2	32.5
1987	34.5	36.1	35.8	34.9	32.7	31.4	29.5	30.0	30.6	31.5	32.4	32.6
1988	33.8	35.9	36.1	34.1	32.5	31.5	29.1	30.0	30.5	31.9	33.2	32.1
1989	33.8	35.6	34.9	33.9	33.2	31.4	30.3	29.5	29.7	31.2	33.7	33.2
1990	34.7	35.5	37.6	34.5	32.7	31.9	29.6	30.1	30.4	31.8	32.9	31.8
1991	33.4	35.6	34.6	34.0	32.5	32.2	30.8	30.5	31.5	31.2	32.7	32.7
1992	34.2	37.0	36.8	34.7	33.2	31.2	29.3	29.5	30.6	32.0	32.5	33.6
1993	34.6	36.2	34.2	34.6	34.4	31.9	30.5	29.3	30.0	32.2	32.7	32.2
1994	33.3	36.1	34.4	33.4	32.5	31.4	30.3	31.5	30.6	31.2	32.6	32.3
1995	33.4	36.1	34.3	33.3	33.1	32.1	29.5	29.9	31.1	32.1	33.5	33.4
1996	33.8	33.6	33.8	33.1	32.8	31.9	30.1	30.3	30.9	32.6	32.8	33.4
1997	35.6	36.7	36.8	35.1	34.1	33.1	31.7	30.8	31.3	31.9	32.8	33.3
1998	33.9	34.1	35.2	34.6	33.9	32.2	29.7	29.9	31.9	32.8	33.1	33.4
1999	34.1	35.6	36.4	34.9	33.8	31.9	29.8	30.2	31.7	32.6	33.3	32.2
2000	34.5	34.9	35.2	33.9	33.1	31.8	30.5	29.8	30.9	32.3	33.0	32.4
2001	34.7	36.3	35.3	33.6	33.4	32.3	30.6	29.3	30.4	32.5	33.1	31.7
2002	35.2	37.4	36.2	33.8	33.8	33.3	31.0	29.9	31.1	32.3	34.4	33.0
2003	34.4	35.6	36.9	34.3	34.2	31.6	31.1	31.4	31.5	32.7	33.1	32.8
2004	34.1	36.2	36.1	34.4	33.4	31.5	31.2	30.5	31.7	32.5	33.3	32.5
2005	34.4	36.7	36.7	35.9	34.4	31.5	30.9	30.3	30.9	33.2	34.2	33.9
2006	34.8	36.5	36.2	36.7	33.5	32.6	31.8	30.0	30.6	32.0	33.3	34.8
AVE	***34.2***	***35.5***	***35.0***	***34.1***	***33.1***	***31.5***	***30.2***	***29.9***	***30.8***	***31.8***	***32.9***	***32.6***

Ejura Mean Monthly Minimum Temperature (°C)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	21.8	22.1	22.7	22.6	22.5	21.3	21.2	21.0	21.9	21.6	21.0	19.8
1977	21.4	22.1	23.8	23.6	22.8	21.8	21.7	21.3	22.0	21.6	21.5	19.6
1978	21.0	23.0	22.6	22.3	22.3	21.7	20.8	21.4	21.4	21.6	20.8	21.7
1979	20.9	23.4	23.3	23.1	22.4	22.1	22.6	21.9	21.4	21.0	21.8	19.2
1980	22.0	22.4	22.6	23.4	22.4	21.9	21.8	21.5	21.8	21.6	21.5	18.7
1981	17.7	22.1	22.0	22.8	22.5	21.2	21.7	21.6	21.6	21.8	20.3	21.4
1982	19.1	22.6	22.9	23.1	22.0	22.5	22.1	21.7	22.3	21.9	21.5	20.0
1983	20.1	23.0	24.4	23.9	22.9	22.7	22.2	21.8	21.9	22.0	21.9	20.9
1984	20.9	22.8	23.1	23.5	22.4	22.0	21.6	21.5	20.9	21.0	21.6	21.4
1985	21.7	21.9	23.9	22.7	23.2	21.6	20.4	20.4	21.2	21.7	22.2	18.7
1986	20.1	23.5	23.0	23.2	23.3	22.0	21.7	21.3	21.9	21.5	21.5	18.4
1987	21.4	23.1	23.5	24.0	23.6	23.0	22.6	22.0	22.2	22.6	22.9	22.4
1988	21.3	23.3	23.8	23.9	23.6	23.3	20.3	20.0	20.9	21.0	21.6	19.9
1989	18.9	21.6	23.0	23.4	23.0	22.2	22.1	22.0	21.9	22.2	22.7	21.1
1990	21.9	21.6	24.7	23.8	23.2	22.6	22.0	21.9	21.8	21.9	22.5	21.1
1991	20.5	22.7	22.7	22.9	23.0	22.7	22.2	22.0	22.3	21.5	22.1	19.7
1992	19.0	22.6	24.2	23.6	22.8	22.2	21.5	21.2	21.1	21.7	20.4	20.1
1993	18.7	22.8	22.0	23.5	23.1	22.1	22.0	21.8	21.6	21.9	20.9	20.1
1994	19.7	22.5	23.2	23.0	22.5	22.2	22.3	22.3	22.6	22.1	21.6	18.5
1995	18.2	21.5	23.6	23.2	23.1	22.5	22.5	22.5	21.8	21.6	21.3	25.8
1996	21.9	22.3	22.1	22.4	22.4	22.6	21.1	21.2	20.9	20.5	19.0	20.9
1997	20.5	19.8	22.7	21.4	21.2	19.7	20.8	19.6	20.5	22.0	22.1	19.1
1998	20.7	19.5	24.8	24.7	21.2	20.5	20.9	19.9	20.4	21.7	21.6	21.2
1999	21.1	19.6	21.5	21.6	21.6	21.5	21.4	21.1	21.4	20.7	21.4	18.1
2000	20.4	19.4	22.5	21.7	21.7	21.6	20.6	20.7	21.3	21.3	21.4	19.5
2001	20.3	13.2	21.6	21.4	21.9	21.9	21.8	22.0	21.8	22.6	22.7	23.2
2002	18.4	18.7	18.6	19.5	20.3	19.6	16.3	15.3	14.6	15.4	15.7	13.0
2003	13.7	17.1	17.5	17.2	17.0	15.7	15.4	15.8	15.7	15.9	15.5	14.0
2004	15.3	17.1	18.6	17.1	16.3	15.4	15.0	15.1	15.5	16.5	16.1	17.0
2005	10.8	17.5	16.6	17.1	16.9	16.0	15.3	15.9	15.8	16.0	16.5	16.8
2006	16.1	16.8	17	17.3	15.6	15.7	22.9	22.6	22.5	22.6	22.1	21.5
AVE	***19.5***	***21.0***	***22.2***	***22.2***	***21.7***	***21.1***	***20.9***	***20.7***	***20.8***	***20.9***	***20.8***	***19.8***

Ejura Mean Monthly RH at 0600 hours (%)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1991	84	92	90	90	93	93	91	93	92	93	92	80
1992	69	73	81	86	89	90	92	92	92	90	85	87
1993	55	86	84	87	87	88	91	91	91	92	91	82
1994	78	81	88	88	92	92	90	89	93	90	86	60
1995	50	65	80	90	91	90	92	91	94	94	92	88
1996	89	87	88	89	89	90	92	93	93	94	94	96
1997	92	78	91	96	87	91	89	86	91	90	89	80
1998	55	79	76	86	92	95	93	91	91	88	89	90
1999	88	76	91	91	90	91	90	89	90	90	89	67
2000	81	61	84	87	87	91	91	92	91	87	88	80
2001	79	55	88	91	89	91	93	92	93	93	92	88
2002	72	78	84	87	87	87	86	86	88	92	91	82
2003	75	83	83	84	86	87	85	87	88	88	89	78
2004	80	81	81	90	89	84	84	84	88	92	91	92
2005	71	98	93	90	91	88	84	85	86	91	92	90
2006	88	91	90	91	87	88	90	85	83	87	86	81
AVE	**75.375**	**79**	**85.75**	**88.9375**	**89.125**	**89.75**	**89.5625**	**89.125**	**90.25**	**90.6875**	**89.75**	**82.5625**

Ejura Mean Monthly RH at 1500 hours (%)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1995	50	53	60	66	69	74	78	75	76	74	75	73
1996	68	65	63	67	66	65	72	73	73	72	67	67
1997	61	48	51	64	70	70	75	74	75	74	70	63
1998	49	54	49	61	69	77	79	79	77	74	69	69
1999	67	56	63	67	69	73	76	76	74	74	70	54
2000	67	49	64	65	66	72	83	79	80	77	71	62
2001	55	40	60	68	69	73	77	80	78	72	67	75
2002	56	58	61	69	70	73	83	87	83	79	70	71
2003	62	60	56	70	69	77	76	75	75	74	73	69
2004	66	62	65	72	74	76	77	79	76	74	73	71
2005	70	61	64	66	69	77	78	80	81	75	71	72
2006	69	61	62	63	72	73	78	78	77	74	71	68
AVE	***61.667***	***55.583***	***59.833***	***66.5***	***69.333***	***73.292***	***77.667***	***77.909***	***77.045***	***74.455***	***70.545***	***67.818***

Wenchi Mean Monthly Rainfall (mm)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	0.0	110.0	97.2	198.7	134.5	235.7	61.3	56.7	128.0	169.3	94.0	0.0
1977	38.1	23.1	13.3	120.0	159.3	82.1	99.3	146.8	196.3	272.7	4.2	3.6
1978	0.0	19.1	144.1	108.2	110.0	221.4	154.8	21.8	151.8	152.8	52.7	3.3
1979	8.4	0.0	65.5	113.5	91.7	167.3	244.7	69.4	192.0	284.8	45.7	0.3
1980	27.8	31.0	37.1	195.4	78.1	138.5	191.2	45.0	222.2	194.0	97.2	2.3
1981	0.0	3.8	229.7	106.4	123.1	60.9	141.7	147.4	238.7	251.3	12.6	0.0
1982	0.0	23.0	129.7	179.4	118.7	63.1	144.2	67.0	103.2	153.8	9.2	0.0
1983	0.0	7.9	12.6	137.2	264.4	112.5	19.0	4.3	145.1	124.7	0.3	21.3
1984	0.0	0.5	205.5	213.4	186.0	143.4	224.1	214.0	148.6	112.4	53.1	0.0
1985	9.9	1.9	131.6	176.4	116.3	131.1	237.0	186.1	243.3	169.8	70.1	0.0
1986	4.2	11.0	116.8	164.7	102.6	114.4	100.3	109.9	178.3	219.8	47.5	0.0
1987	0.0	24.2	132.4	34.1	144.4	116.6	134.0	156.9	297.8	201.5	8.8	0.4
1988	10.4	54.5	179.8	96.6	107.4	155.7	166.5	77.7	225.2	121.2	14.6	0.0
1989	0.0	0.0	166.7	159.0	158.2	347.0	208.2	157.5	214.9	274.4	20.1	20.3
1990	3.0	29.0	0.0	124.5	101.5	156.8	35.3	93.8	284.2	144.9	89.8	96.5
1991	0.0	42.9	118.5	189.6	344.1	92.3	170.7	158.0	116.8	119.7	35.3	20.4
1992	3.2	21.6	33.8	184.4	250.7	154.8	103.1	13.5	267.5	110.3	142.8	0.0
1993	0.0	19.1	283.0	92.7	186.4	139.2	73.0	28.6	247.9	75.0	53.5	14.2
1994	0.0	2.0	103.7	80.9	116.2	119.3	19.7	87.7	90.8	206.6	37.7	0.0
1995	0.0	1.9	76.8	232.3	163.5	177.9	115.8	117.6	290.6	145.6	16.9	33.7
1996	0.0	94.4	66.8	202.4	198.1	177.8	90.8	138.6	82.5	74.5	1.8	28.0
1997	0.0	0.0	121.8	93.2	183.7	153.0	74.2	78.0	99.7	197.6	18.3	0.0
1998	2.1	10.4	2.0	207.5	156.5	205.8	25.7	57.7	174.4	157.0	40.1	13.5
1999	2.4	37.2	193.7	192.5	160.5	111.0	113.0	105.8	101.5	188.3	82.9	TR
2000	49.2	0.0	31.8	153.2	135.9	294.0	170.4	73.6	90.4	138.6	49.7	0.0
2001	0.0	tr	77.4	137.6	171.5	152.4	45.5	46.4	184.6	150.2	20.4	1.0
2002	5.2	18.6	111.7	172.2	190.9	191.9	298.2	49.5	106.6	195.3	65.9	7.0
2003	14.3	101.1	54.8	196.9	128.9	208.1	108.2	67.9	232.6	161.1	96.7	25.8
2004	30.1	28.3	15.5	304.8	86.8	63.4	116.7	173.5	202.0	187.9	128.7	12.0
2005	61.1	6.1	67.1	158.5	231.5	128.8	133.2	49.5	114.8	248.1	80.0	51.5
2006	9.4	45.6	86.1	139.5	174.8	119.7	50.7	51.2	195.7	299.1	23.8	0.0
AVE	***9.0***	***25.6***	***100.2***	***157.0***	***157.3***	***152.8***	***124.9***	***92.0***	***179.6***	***177.5***	***48.9***	***11.8***

AVERAGE ANNUAL RAINFALL =1236.5 mm

Wenchi Mean Monthly Maximum Temperature (°C)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	33.8	35.8	36.8	35.7	33.0	30.0	29.8	29.4	30.6	30.6	33.0	34.1
1977	34.7	35.6	36.6	36.1	33.3	31.3	29.7	28.8	30.3	33.3	35.6	34.2
1978	35.4	37.8	36.2	34.5	33.5	30.9	28.5	30.0	30.6	31.7	33.6	35.1
1979	35.8	37.0	36.8	36.9	32.7	30.0	29.3	29.6	30.6	32.8	35.1	34.0
1980	35.6	36.4	37.6	35.7	31.2	32.5	30.0	29.2	30.7	32.4	33.5	32.5
1981	34.0	37.2	36.5	35.6	33.3	32.0	29.8	29.7	30.7	34.0	35.5	36.0
1982	34.3	35.6	35.9	33.9	34.3	31.2	30.1	30.0	30.8	32.8	32.9	34.0
1983	31.8	37.2	38.3	36.8	33.7	31.0	30.0	29.8	30.7	34.5	35.3	35.3
1984	34.6	36.5	36.9	36.2	34.1	32.3	30.2	29.6	30.3	32.6	35.1	33.3
1985	35.3	34.4	36.8	34.9	33.8	32.3	29.0	29.1	29.5	33.7	35.7	33.1
1986	34.3	37.2	37.7	36.7	34.8	33.3	29.7	29.2	30.1	32.6	34.1	33.3
1987	35.6	37.9	37.6	37.5	35.6	32.1	30.4	29.7	31.1	32.3	35.6	34.4
1988	34.2	37.3	38.6	36.1	35.1	31.1	29.5	29.7	30.3	33.9	35.3	33.3
1989	33.3	35.1	36.3	36.7	35.7	31.6	30.1	29.2	30.3	32.6	36.1	34.4
1990	33.9	36.1	38.4	36.7	34.4	32.1	29.7	30.0	31.0	34.4	35.9	35.1
1991	35.5	38.0	38.4	35.6	31.6	32.0	29.9	29.3	31.6	32.4	35.0	34.2
1992	33.2	37.1	38.3	37.3	33.6	30.7	29.6	29.3	30.7	33.9	33.8	35.7
1993	33.7	37.3	36.8	36.1	34.5	33.0	30.3	30.0	30.6	33.3	35.6	34.9
1994	34.6	37.0	38.2	36.9	34.0	31.6	30.1	29.6	30.8	31.6	34.7	33.9
1995	34.3	36.7	38.1	36.1	34.0	32.4	30.2	29.6	31.2	33.1	35.1	35.0
1996	36.3	37.7	37.4	35.8	24.3	31.6	30.5	29.7	30.0	32.8	34.9	35.7
1997	36.2	35.8	37.3	34.8	34.1	31.0	30.4	30.4	31.1	32.8	34.7	34.9
1998	34.7	37.9	38.9	37.4	34.6	32.7	30.8	29.4	29.8	32.8	35.7	34.9
1999	35.2	35.2	37.7	36.0	35.0	32.2	29.7	29.2	29.8	31.9	35.3	34.6
2000	34.7	34.7	37.8	36.4	33.9	31.5	30.1	30.0	30.1	32.9	35.7	34.4
2001	35.6	37.0	38.9	37.1	34.7	31.9	31.0	29.5	30.4	34.5	36.1	36.8
2002	34.8	37.5	39.1	36.4	34.5	32.0	31.1	29.6	30.8	32.8	35.5	35.1
2003	35.8	37.9	38.2	36.3	34.5	30.6	30.2	29.8	30.8	33.4	34.9	35.1
2004	35.7	36.9	37.0	35.6	33.2	31.6	29.9	29.7	30.8	34.5	35.3	36.2
2005	34.0	38.0	38.4	36.4	34.4	31.8	30.2	29.8	31.6	33.7	36.1	36.2
2006	33.1	34.1	33.8	33.2	30.9	30.1	28.9	28.5	29.0	30.0	31.3	32.5
AVE	***34.6***	***36.6***	***37.5***	***36.0***	***33.6***	***31.6***	***30.0***	***29.6***	***30.5***	***32.9***	***34.9***	***34.6***

Wenchi Mean Monthly Minimum Temperature (°C)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	19.4	22.3	24.0	24.2	23.6	21.8	21.9	21.3	21.4	21.5	20.9	18.1
1977	20.8	21.2	24.1	25.5	23.5	22.3	21.6	21.4	21.6	21.5	19.5	18.9
1978	19.8	23.5	24.9	24.5	23.7	22.4	21.6	21.9	21.6	21.9	20.8	19.7
1979	21.0	21.6	24.9	25.6	23.6	22.5	21.9	22.1	21.9	22.6	22.0	19.2
1980	21.5	26.4	24.9	25.2	22.1	23.4	22.3	22.0	22.3	22.3	21.6	18.2
1981	18.3	23.1	24.3	25.2	23.9	22.1	22.3	22.1	22.1	23.1	21.2	19.7
1982	18.7	22.2	24.3	22.7	24.3	22.9	20.8	22.2	22.1	22.3	20.5	18.8
1983	17.2	23.3	25.2	25.8	24.2	22.8	21.5	22.5	21.7	22.9	21.6	19.7
1984	19.8	21.8	26.0	25.4	24.3	23.1	21.9	21.2	22.4	22.6	21.7	18.4
1985	21.0	24.0	26.3	25.1	24.2	23.2	21.6	21.8	21.4	22.7	21.7	18.4
1986	18.5	23.4	25.2	25.7	24.5	23.0	21.9	21.6	21.9	22.3	20.3	18.2
1987	20.9	24.0	25.1	26.2	25.2	23.4	22.9	22.3	23.1	22.8	21.3	20.1
1988	20.1	23.0	26.7	25.9	25.1	22.8	21.7	22.2	22.0	22.8	21.4	18.9
1989	18.1	21.0	24.1	25.1	24.0	22.2	22.0	21.9	21.1	21.8	21.2	19.8
1990	20.5	21.8	24.0	25.8	24.1	22.9	22.0	21.6	21.5	22.6	22.8	21.7
1991	20.7	24.2	26.1	24.9	23.4	23.8	22.3	21.9	22.1	21.4	20.9	19.3
1992	19.0	22.6	25.0	25.1	23.0	21.7	21.1	20.8	20.6	21.6	19.4	18.4
1993	17.3	21.0	22.1	22.5	22.7	22.4	21.9	21.6	21.9	22.8	23.3	20.3
1994	20.2	23.1	25.2	25.9	24.1	22.9	22.4	22.4	22.3	22.1	20.7	19.0
1995	18.9	22.0	25.8	25.3	24.2	23.5	22.6	22.4	22.5	22.9	21.3	21.2
1996	21.4	24.0	25.7	25.3	24.8	23.0	22.5	21.9	21.9	22.4	20.0	20.2
1997	21.6	21.5	24.8	24.8	23.9	22.7	22.2	22.5	22.7	23.1	22.2	20.3
1998	20.3	24.1	25.7	26.8	25.5	23.8	23.4	22.4	22.4	23.1	22.3	20.9
1999	21.3	22.0	25.6	25.3	24.2	23.2	22.5	22.3	21.7	22.6	22.8	19.4
2000	22.5	20.7	24.8	25.2	24.1	22.7	22.3	22.2	21.9	22.6	22.6	19.2
2001	19.9	21.3	25.5	25.6	24.4	22.8	22.9	22.3	22.2	23.6	22.8	21.4
2002	21.0	22.9	26.9	25.4	24.6	23.4	22.9	22.0	22.3	23.0	22.2	20.1
2003	21.0	24.6	25.2	25.3	24.4	22.6	22.5	22.5	22.3	23.4	22.8	20.2
2004	21.3	23.7	24.9	25.0	24.4	22.6	22.0	21.8	21.7	22.8	22.5	22.3
2005	20.6	25.7	26.5	25.6	24.3	23.0	22.4	21.8	22.2	22.8	22.3	21.4
2006	22.2	23.0	22.7	22.9	21.7	22.0	21.8	21.5	21.5	21.6	21.4	20.6
AVE	***20.2***	***22.9***	***25.0***	***25.1***	***24.0***	***22.8***	***22.1***	***21.9***	***21.9***	***22.5***	***21.5***	***19.7***

Wenchi Mean Monthly RH at 0600 hours (%)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	73	89	92	94	96	97	95	95	97	97	95	90
1977	92	83	80	86	94	95	94	94	96	97	93	83
1978	88	89	92	94	96	97	95	96	97	98	93	97
1979	94	83	84	92	94	97	96	96	97	98	96	83
1980	94	85	90	91	94	96	96	97	97	97	97	80
1981	64	89	90	94	95	95	96	96	97	97	93	96
1982	55	80	85	93	94	97	97	96	97	97	96	77
1983	29	71	75	92	87	95	97	95	97	97	95	83
1984	59	86	88	92	89	95	96	96	96	96	96	86
1985	68	88	89	89	93	95	96	95	96	97	97	93
1986	61	87	91	92	94	96	95	96	97	97	93	69
1987	79	85	89	91	92	96	97	96	97	97	95	79
1988	58	63	89	93	94	95	96	95	97	97	95	73
1989	53	41	87	92	94	96	97	96	98	98	95	85
1990	75	55	81	91	94	96	95	95	97	97	96	91
1991	79	91	90	92	97	96	96	97	97	97	97	76
1992	46	76	85	94	96	96	96	95	97	97	92	90
1993	45	82	81	91	95	97	96	96	96	97	95	79
1994	67	74	87	93	95	96	94	94	96	97	90	64
1995	37	66	86	92	96	96	96	96	97	96	92	87
1996	94	87	90	93	95	97	97	97	97	96	91	96
1997	86	47	77	92	94	96	95	96	96	95	95	82
1998	56	67	73	90	93	96	95	94	96	96	94	85
1999	81	71	90	92	95	95	96	94	96	96	95	77
2000	83	47	81	91	94	95	96	95	96	95	94	80
2001	67	63	87	92	94	95	95	95	96	95	95	91
2002	57	69	88	92	93	95	96	95	96	95	95	77
2003	68	86	85	93	93	95	95	94	95	95	94	83
2004	76	72	78	94	94	94	95	96	96	95	95	94
2005	55	86	90	93	93	95	95	95	95	95	95	90
2006	84	88	91	91	94	95	94	94	95	95	90	78
AVE	***68***	***76***	***86***	***92***	***94***	***96***	***96***	***95***	***96***	***96***	***94***	***84***

Wenchi Mean Monthly RH at 1500 hours (%)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	33	46	50	61	67	73	69	69	69	75	65	47
1977	49	29	35	49	60	69	65	72	72	69	56	43
1978	30	39	53	63	66	71	72	70	70	71	61	57
1979	49	28	36	52	62	70	75	73	73	71	68	44
1980	50	35	51	55	65	71	73	75	76	74	70	48
1981	26	43	50	65	67	63	76	74	73	71	59	55
1982	20	34	47	63	69	70	74	73	70	67	57	35
1983	15	30	28	67	68	71	73	76	71	64	56	49
1984	27	35	49	67	68	70	70	69	72	69	59	55
1985	32	36	52	68	67	69	72	73	73	70	67	52
1986	39	23	49	57	64	67	71	73	75	70	62	38
1987	36	37	42	53	60	68	71	74	73	69	60	42
1988	27	27	53	61	62	69	72	73	72	67	60	33
1989	20	20	45	59	63	74	73	75	76	72	61	49
1990	34	29	27	57	65	67	73	70	75	70	67	59
1991	37	41	53	62	71	69	73	75	73	72	67	48
1992	24	34	41	58	68	72	77	71	73	68	61	50
1993	20	30	46	56	67	73	74	74	74	69	66	41
1994	25	29	41	59	64	72	66	65	71	75	56	27
1995	14	20	44	59	66	69	73	76	72	72	57	54
1996	42	45	49	58	63	71	73	74	73	70	48	56
1997	40	17	31	56	65	73	72	73	75	72	62	45
1998	27	31	28	57	64	70	72	68	69	71	62	47
1999	30	33	50	60	64	68	71	70	71	73	69	37
2000	41	24	34	55	59	69	71	74	72	69	63	38
2001	23	20	40	61	64	67	70	71	70	69	63	46
2002	24	28	49	61	67	68	75	73	72	71	65	39
2003	28	40	43	61	51	69	69	69	71	69	67	47
2004	35	35	39	61	67	68	72	74	72	68	68	62
2005	28	43	51	59	63	71	73	73	72	67	65	52
2006	40	42	50	56	67	69	69	66	70	72	55	33
AVE	***31***	***32***	***44***	***59***	***65***	***70***	***72***	***72***	***72***	***70***	***62***	***46***

Wenchi Monthly Wind Speed (knots)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	2.9	3.8	1.4	4.1	2.3	2.7	2.4	5.0	5.0	4.6	4.7	2.5
1977	2.0	2.5	4.9	3.2	3.7	3.3	3.4	3.9	2.8	3.9	2.9	2.2
1978	2.8	3.0	2.6	2.7	3.0	2.2	1.9	3.6	3.9	3.4	4.0	3.6
1979	2.7	2.4	5.0	5.0	4.6	4.7	4.6	4.2	4.8	4.3	3.5	2.8
1980	2.4	2.8	4.5	3.7	2.3	2.6	3.8	4.1	3.3	4.1	2.9	3.2
1981	2.8	3.9	2.9	2.2	2.9	2.5	2.0	2.4	2.4	1.8	2.0	1.6
1982	2.8	3.3	3.8	3.8	3.4	3.2	3.4	3.6	2.8	2.6	2.5	3.3
1983	3.0	2.9	1.4	4.2	5.3	4.7	5.3	4.5	4.5	4.4	4.9	3.3
1984	2.6	1.8	4.1	3.3	4.1	2.9	3.2	3.0	3.7	3.1	3.2	2.7
1985	2.7	3.7	2.3	2.1	2.3	2.8	2.9	2.9	2.3	1.9	1.7	1.5
1986	3.0	3.3	2.7	2.8	3.6	2.2	0.2	1.4	2.6	2.2	1.7	1.8
1987	2.2	3.6	2.9	3.1	2.9	2.5	3.0	3.1	1.8	2.8	2.8	2.5
1988	1.9	3.2	5.0	4.5	4.0	3.7	5.1	5.3	4.1	3.3	3.9	3.1
1989	3.6	3.8	5.0	4.8	4.7	4.2	4.3	4.7	3.3	2.9	2.8	2.7
1990	3.9	4.9	4.6	6.9	5.0	4.6	5.6	5.3	4.1	4.3	3.9	3.7
1991	3.4	5.0	4.7	4.6	3.6	3.1	3.8	4.5	2.9	2.9	2.9	2.3
1992	4.0	3.4	4.6	4.8	4.1	4.4	4.9	4.5	3.2	2.8	2.2	2.1
1993	3.6	4.0	4.2	4.4	3.8	3.9	4.7	4.4	3.0	2.9	2.9	2.3
1994	3.2	4.0	4.8	4.4	3.8	3.8	5.0	4.9	3.7	2.9	2.5	2.8
1995	2.7	3.2	4.3	3.5	3.0	3.0	3.7	3.3	3.1	2.3	2.0	2.9
1996	2.8	3.4	3.5	3.1	3.2	4.3	3.1	3.2	3.2	2.7	2.4	2.9
1997	2.9	2.7	3.8	3.8	3.4	3.1	3.1	3.0	2.7	2.3	2.4	2.3
1998	2.7	2.8	2.8	3.4	2.9	2.4	2.9	2.8	2.4	2.0	1.8	1.9
1999	2.2	2.6	3.3	2.9	2.6	2.3	2.8	2.9	2.5	2.0	2.0	1.7
2000	2.5	2.6	2.7	2.9	2.5	2.3	2.3	2.1	2.0	1.7	1.6	1.5
2001	1.7	2.2	2.8	2.4	2.2	2.3	2.4	2.4	2.0	1.7	2.1	1.6
2002	1.8	2.1	2.7	2.5	2.3	2.3	1.6	2.0	1.8	1.7	1.4	1.5
2003	1.7	2.1	2.0	2.3	2.2	2.1	2.2	2.2	1.6	1.3	1.4	1.4
2004	1.4	1.6	2.1	2.2	2.1	1.9	1.6	2.0	1.3	1.5	1.3	1.6
2005	1.8	1.9	2.1	2.3	2.1	1.9	2.0	2.2	1.8	1.7	1.8	1.3
2006	1.6	2.3	2.9	3.0	2.4	2.3	2.4	3.0	3.0	2.1	1.7	1.8
AVE	***2.6***	***3.1***	***3.4***	***3.5***	***3.2***	***3.0***	***3.2***	***3.4***	***3.0***	***2.7***	***2.6***	***2.3***

Wenchi Monthly Duration of Bright Sunshine (hours)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	7.2	8.4	6.6	7.8	6.6	6.1	4.9	3.0	4.1	6.2	7.7	6.7
1977	7.3	7.6	6.0	7.1	7.2	6.9	4.8	3.2	4.3	6.3	7.3	7.9
1978	8.7	6.0	7.6	7.3	6.9	5.2	4.5	2.9	4.8	5.2	6.7	6.5
1979	7.4	7.1	7.6	7.6	6.3	5.9	4.4	2.4	4.4	6.4	7.2	6.0
1980	6.6	7.6	7.3	7.5	7.3	5.2	4.5	3.9	3.8	6.2	7.2	5.6
1981	5.6	8.4	7.7	7.8	7.1	5.5	5.1	2.5	4.7	5.4	6.0	6.1
1982	7.2	7.4	6.2	6.9	6.9	6.2	4.4	3.7	3.6	5.6	6.7	7.5
1983	7.0	8.3	7.9	7.6	6.4	6.5	4.2	3.3	4.2	5.9	6.3	7.1
1984	8.1	8.1	7.7	7.8	7.4	5.6	4.5	3.5	4.1	5.5	7.1	7.3
1985	7.0	7.4	6.5	7.1	7.2	5.8	5.2	3.7	3.7	5.9	6.6	8.0
1986	7.4	7.6	7.9	6.7	7.3	6.0	4.6	3.5	4.6	4.7	6.7	7.7
1987	8.0	8.1	6.8	7.7	6.8	6.8	3.9	2.9	4.4	6.4	6.3	6.6
1988	7.8	7.9	7.2	6.8	5.8	6.9	4.1	3.7	3.9	6.9	7.5	6.8
1989	6.8	8.3	6.9	7.2	6.4	5.5	3.8	3.8	3.7	6.6	7.1	7.5
1990	7.1	7.5	7.7	7.1	7.3	6.6	3.5	3.0	3.8	6.3	7.4	7.2
1991	7.6	7.6	6.6	7.4	6.3	6.9	4.8	3.2	4.2	5.2	6.0	6.0
1992	5.3	7.4	6.0	6.7	6.6	5.2	2.6	2.9	4.1	6.4	6.7	6.2
1993	7.2	8.0	7.6	7.8	7.2	5.9	3.4	2.4	4.3	6.2	7.3	6.7
1994	7.3	6.3	7.6	7.1	6.9	5.2	4.3	3.9	3.8	5.4	8.0	7.9
1995	8.7	8.4	7.3	7.3	6.3	5.5	4.3	2.5	4.3	5.6	7.4	6.5
1996	7.4	7.6	7.7	7.6	7.3	6.2	4.9	3.7	4.1	5.9	7.4	6.0
1997	6.6	6.0	6.2	7.5	7.1	6.5	4.8	3.3	4.3	5.5	7.8	5.6
1998	5.6	7.1	7.9	7.8	6.9	5.6	4.5	3.5	4.8	5.9	7.7	6.1
1999	7.2	7.6	7.7	6.9	6.4	5.8	4.4	3.7	4.4	4.7	7.3	7.5
2000	7.0	8.4	6.5	7.6	7.4	6.0	4.5	3.5	3.8	6.4	6.7	7.1
2001	8.1	7.4	7.9	7.8	7.2	6.8	5.1	2.9	4.1	6.9	7.2	7.3
2002	7.0	8.3	6.8	7.1	7.3	6.5	4.4	3.7	5.2	6.2	7.2	8.0
2003	7.7	7.9	7.7	7.5	8.2	5.2	4.8	3.7	4.7	7.3	7.6	8.0
2004	7.3	6.7	5.7	6.6	6.8	6.0	3.5	3.5	4.6	6.9	7.5	6.0
2005	6.8	6.7	7.0	7.3	7.4	4.7	3.2	2.9	4.8	7.4	7.1	7.5
2006	7.4	8.0	7.4	7.9	6.5	6.3	4.5	3.6	3.9	5.6	7.9	7.5
AVE	***7.2***	***7.6***	***7.1***	***7.4***	***6.9***	***6.0***	***4.3***	***3.3***	***4.2***	***6.0***	***7.1***	***6.9***

POTENTIAL EVAPOTRANSPIRATION (mm) FOR WENCHI

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1976	178.3	151.1	144.0	112.5	93.9	75.9	75.4	79.3	81.6	66.9	89.4	123.2
1977	126.5	194.6	201.3	157.5	118.1	87.1	85.5	70.8	77.6	81.5	111.9	138.3
1978	179.4	183.9	133.8	106.3	101.8	79.3	68.0	74.2	79.3	78.1	103.5	118.1
1979	131.0	201.9	184.5	147.3	113.6	79.8	68.0	72.0	74.8	80.4	83.8	136.1
1980	56.8	156.4	145.7	137.3	113.1	79.8	68.0	65.8	72.5	77.0	82.1	122.6
1981	198.0	168.2	149.6	106.3	93.9	101.8	61.3	64.1	72.0	86.6	109.1	109.1
1982	218.3	194.6	164.3	105.8	101.6	86.3	67.5	66.9	71.4	87.8	108.0	164.8
1983	108.8	125.1	112.3	87.3	73.6	59.0	49.4	49.3	52.9	55.8	68.8	91.2
1984	226.1	156.3	147.1	109.2	93.2	94.0	77.2	63.5	82.3	86.4	91.4	102.0
1985	180.8	155.6	148.3	106.3	96.3	101.8	65.3	64.1	72.0	84.6	107.6	110.0
1986	245.2	244.3	187.3	127.3	102.3	88.9	77.4	71.2	77.8	84.3	117.3	109.8
1987	156.3	166.3	156.3	124.0	115.3	82.3	75.4	69.4	74.3	84.3	134.9	104.9
1988	165.6	255.6	210.9	127.7	99.8	77.6	69.8	71.4	74.6	88.9	106.9	125.4
1989	219.9	221.3	253.1	147.4	112.5	78.9	69.2	81.3	79.3	81.0	112.3	143.4
1990	175.7	184.2	160.3	124.4	103.7	83.8	71.6	70.0	75.2	83.6	103.7	125.7
1991	165.9	174.9	146.3	115.3	87.8	84.9	73.1	65.3	77.1	75.4	87.8	132.2
1992	203.1	196.9	176.6	129.9	95.1	74.3	56.3	68.6	78.2	86.1	105.8	122.6
1993	219.9	209.3	160.3	138.9	98.4	78.8	65.8	64.1	79.3	95.6	101.3	150.2
1994	208.1	218.3	183.9	128.3	110.8	80.4	84.9	88.3	82.1	82.1	115.9	196.3
1995	246.4	245.3	185.1	128.8	104.1	89.4	73.7	70.3	78.2	84.4	115.3	119.3
1996	157.5	163.1	157.5	125.4	115.3	84.9	75.4	69.8	75.4	87.2	140.1	113.1
1997	167.1	258.2	210.9	127.7	100.1	75.9	69.2	71.4	70.3	88.9	106.9	125.4
1998	227.3	223.3	253.1	147.4	112.5	86.6	69.2	83.3	79.3	81.0	110.8	143.4
1999	199.1	192.9	157.5	126.4	123.8	81.9	66.9	74.6	74.9	82.3	112.3	125.6
2000	197.0	206.6	179.1	129.3	105.2	82.1	70.6	72.6	77.0	84.7	110.0	135.4
2001	196.9	206.3	176.8	127.6	104.3	76.3	65.6	71.7	76.4	84.3	108.6	136.4
2002	215.4	223.3	164.3	110.8	93.4	74.9	66.5	63.0	70.3	80.4	95.6	158.6
2003	200.3	168.2	172.7	117.6	112.5	78.8	74.3	74.0	81.0	87.2	93.4	135.6
2004	173.8	201.9	185.1	111.4	88.9	83.8	64.7	61.9	74.8	88.3	90.0	139.2
2005	196.7	169.3	151.9	120.9	104.1	74.8	63.6	60.8	72.6	92.8	95.1	117.6
2006	165.9	176.1	149.1	129.9	94.5	85.5	76.5	77.6	77.1	81.6	114.2	172.7
AVE	***184.1***	***193.3***	***171.3***	***123.9***	***102.7***	***82.2***	***69.8***	***70.0***	***75.5***	***82.9***	***104.3***	***130.6***