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SYMBOLS AND ABBREVIATIONS

°	-degree
-	-minus
"	-second
/	-per
%	-percent
:	-is to
‘	-minute
+	-plus
<	- less than
>	-greater than
≤	-less than or equal to
≥	-greater than or equal to
˚C	-degree Celsius
AWC	-Available Water Content
BCL	-Blaney-Criddle
Cm	-centi meter
CNM	-Christiansen Equation
CRP	-Co-ordinated research project
CWRDM	-Center for water Resource and Management
D	-particle size

DAS	-days after plantin
Dept.	-department
et al.	-and other people
etc	-etcetera
ET	- Evapotranspiration
ET_O	- Reference Evapotranspiration
fig.	- figure
FAO	-Food and Agricultural Organisation
F C	-Field capacity
FFNN	-feed forward neural network
GDD	-growing degree days
GIS	-Geographical information system
h	-hour
ha	-hectare
HGM	-Han greaves method
i.e	-that is
J.	-journal
K_C	-Crop coefficient
Kcb	-basal crop coefficient

Ke -Soil evaporation constant

K_S - water stress coefficient

Ky -Yield response factor

K -hydraulic conductivity

KAU - Kerala Agricultural University

KCAET -Kelappaji College of Agricultural Engineering and Technology

Kg -kilogram

Km -kilometer

l -Litre

IAEA -International Atomic Energy Agency

LAI - Leaf Area Index

m -meter

m^2 -square meter

m^3 -cubic meter

min - minutes

mm -millimeter

MPM -Modified Penman Method

N -cumulative percentage finer

NDD -Net derived demand

No.	-number
p	-Yield response factor
PM	-Penman Monteith
PMM	-Penman Monteith Method
PWP	-Permanent Wilting Point
RAD	-Radiation Method
S	-second
SRS	-Satellite Remote Sensing
THW	-Thornthwaite Method
V	-volume
W	-water content
WC	-Wilting Point
WUE	-Water Use Efficiency

INTRODUCTION

CHAPTER I

INTRODUCTION

Water is an irreplaceable natural resource without which humans cannot exist. Also, water is the most widely spread natural substance. It occurs in nature in the solid, liquid and gaseous state. Humans use a small part of water, however, i.e. the fresh water, which is about 2% of the total water amount on our globe. Water is a scarce resource and it is a critical input in agricultural production. There is competition between municipal, industry users and agriculture for the finite amount of available water, Estimating irrigation water requirement accurately is important for water project planning and management (Michael, 1999).

The primary objective of irrigation is to apply water to maintain crop evapotranspiration (ETA) when precipitation is insufficient. The finite total amount of available water is crucial for the economy, health and welfare of a very large part of the developing world. Rain being the primary source of water in Indian agriculture, is concentrated in only about four months of monsoon period, the remaining months being dry.

In the past with scarce population the natural soil moisture from rain was more than sufficient for agricultural production to satisfy the basic human needs of food, fabric and fat. The ever increasing populations of the world creates increasing demands for food and agricultural production and this demand combined with the uncertainty in rainfall forced man to supplement the natural moisture by artificial means like irrigation. The untimely, undistributed, scanty and erratic rainfall necessities the need of irrigation to raise crop production. The demand for water for agriculture purpose is estimated to increase from 50M ha m in 1985 to 70M ha m by 2050. The introduction of irrigation in any area increases the agricultural production by 5 to 10 times. Thus development of irrigation facilities is a vital factor in promoting agricultural productivity in most parts of the country. While more irrigation is needed for food production, less water will be available for irrigation, because of municipal and industrial demands. At the beginning of this century, 90% of all water used in the world was for irrigation. But irrigation efficiency continues to be only about 40%. The irrigated agriculture, consuming a major part of the total water being used, is therefore considered a thrust area for achieving maximum conservation in water use. Scientific management of irrigation water provides the best insurance against weather induced fluctuations in total food production.

Recently developed methods of irrigation should likewise be based on sound principles and techniques for attaining greater control over the soil-crop-water regime and for optimizing irrigation in relation to all other essential agricultural inputs and operations. Irrigated agriculture is facing new challenges that require refined management and innovative design. Formerly, emphasis was centered on project design; however, current issues involve limited water supplies with several competing users, the threat of water quality degradation through excess irrigation, and narrow economic margins. Meeting these challenges requires improved prediction of irrigation water requirements. The primary objective of irrigation is to provide plants with sufficient water to obtain optimum yields and a high quality harvested product.

Irrigation water requirements can be defined as the quantity, or depth, of irrigation water in addition to precipitation required to produce the desired crop yield and quality and to maintain an acceptable salt balance in the root zone. This quantity of water must be determined for such uses as irrigation scheduling for a specific field and seasonal water needs for planning, management, and development of irrigation projects. The amount and timing of precipitation strongly influence irrigation water requirements. The required timing and amount of applied water is determined by the prevailing climatic conditions, the crop and its stage of growth, soil properties (such as water holding capacity), and the extent of root development. Water within the crop root zone is the source of water for crop evapotranspiration. Thus, it is important to consider the field water balance to determine the irrigation water requirements. Plant roots require moisture and oxygen to live. Where either is out of balance, root functions are slowed and crop growth reduced. All crops have critical growth periods when even small moisture stress can significantly impact crop yields and quality. Critical water needs periods vary crop by crop. Soil moisture during the critical water periods should be maintained at sufficient levels to ensure the plant does not stress from lack of water. In arid areas, annual precipitation is generally less than 10 inches and irrigation is necessary to successfully grow farm crops. In semiarid areas (those typically receiving between 15 to 20 inches of annual precipitation), crops can be grown without irrigation, but are subject to droughts that reduce crop yields and can result in crop failure in extreme drought conditions. Sub humid areas, which receive from 20 to 30 inches of annual precipitation, are typically characterized by short, dry periods. Depending on the available water storage capacity of soils and the crop rooting depth, irrigation may be needed for short periods during the growing season in these areas. In humid areas, that receiving more than 30 inches of annual precipitation, the amount of precipitation normally exceeds evapotranspiration throughout most of the year. However, drought periods sometimes occur, which reduce yield and impair quality, especially for crops grown on shallow, sandy soils or that have a shallow root system. Irrigation is not needed to produce a crop in most years, but may be needed to protect against an occasional crop failure and to maintain product quality.

Producing optimal yield requires that the soil-water content be maintained between an upper limit at which leaching becomes excessive and a lower point at which crops are stressed. For irrigation management, the acceptable soil-water range is generally defined using the available soil-water concept which is the difference between the field capacity and the permanent wilting point.. To prevent reduced yield or quality, the crop should be irrigated before a given percentage of the available water in the root zone has been used by the crop. Historically, an allowable depletion of between 30 and 60 percent of the AWC has been used for management purposes. The soil can be irrigated before allowable depletion is reached if the amount of water applied does not cause the soil water in the crop root zone to exceed field capacity. The determination of irrigation water requirements and irrigation schedules requires an accurate estimate of the crop water use rate. Daily and weekly crop water use estimates are needed to schedule irrigations, while longer term estimates are needed to specify the irrigation, storage, and conveyance system capacities. Annual water use is often required to size irrigation reservoirs and establish water rights. Therefore, a procedure to predict both the short- and long-term rates of water use by a multitude of crops in varying climates is needed.

There are different methods for the computation of ETo namely direct and indirect methods. In indirect method of ETo determination empirical formulae like Blaney Criddle, radiation method, Thornthwaite method, Penman method ,Modified Penman method and Penman montieth method etc whereas direct method uses lysimeter, field experimental plots, water balance method and soil depletion method etc. Of the above mentioned methods Penman Monteith is comparatively accurate. Even then the uses of numerous tables and personnel results in time loss and errors are also common. The unscientific calculation of crop water requirement could result in irrigation losses, deficit irrigation and less irrigation efficiency.

In order to improve the crop yield and increase the water use efficiency accurate determination of crop water requirement is necessary. In this context CROPWAT seems to be increasingly effective which uses the Penman Monteith concept in computation of crop water.

Knowing the correct amount of water for irrigation will help not only in saving water but also in providing high yield. To calculate the precise amount of water that is to be applied use of many complicated equations is required. Development of software would make the process of calculation of depth of irrigation water requirement much easier.

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. CROPWAT is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation.

As scientific irrigation practices are rarely followed in KCAET instructional farm, it is good to schedule using the CROPWAT model to ensure better efficiency in water saving. Irrigation in the instructional farm is flood irrigation through hydrants connected to pipelines. As no scientific. Hence this study was undertaken at Kelappaji College of Agricultural Engineering and Technology, Tavanur to calculate the actual crop water requirement of the crops grown in the instructional farm with the following objectives.

1. To study the basic soil properties of the area.
2. To collect climate data for the study area.
3. To analyse the existing cropping pattern and the irrigation practice followed in the study area.
4. To estimate the crop water requirement & schedule irrigation for the crops grown in the study area.

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

A good estimation of irrigation is vital for proper water management, allowing for improved efficiency of water use; high water productivity and efficient farming activities. The requirement regarding the number of irrigations and their timing vary widely, spatially for different crops. The climatic parameters play a predominant role in governing the water needs of crops and a criterion for scheduling of irrigation. CROPWAT model developed by FAO enables calculation of crop water requirement. By using this software the complexity of calculation of crop water requirement using the conventional method could be eliminated. The application makes the calculations faster, precise and accurate. Irrigation scheduling becomes easier and thus a considerable savings in irrigation water could be achieved and the irrigation efficiency can be improved.

Extensive research on crop water requirement and scheduling of irrigation were carried out over the years. Some of the literature relevant to the study are reviewed and presented under the following sub headings.

2.1 Estimation of evapotranspiration

Evaporation is an important component of the water cycle, where liquid water on the surface of the earth vaporizes into the atmosphere. This occurs from large water bodies such as oceans, lakes and rivers, as well as from plants and the soil. The term evapotranspiration' refers to the combined processes of transpiration and evaporation from vegetation and the surrounding soil.

Penman (1956) defined potential evapotranspiration as the amount of water transpired in unit time by a short green crop, completely shading the ground, of uniform height and never short of water. Blaney and Criddle (1962) modified this relationship by excluding humidity term. Jensen and Haise (1963) evaluated 3,000 observations of evapotranspiration as determined by soil sampling procedures over 35-year period. Van Bavel (1966) defined potential evapotranspiration as the evapotranspiration that occurs when the vapour pressure at the evaporating surface is at the saturation point. Gangopadhyaya *et al.*(1970) defined potential evapotranspiration as the maximum quantity of water capable of being lost as water vapour in a given climate by a continuous, extensive stretch of vegetation covering the whole ground when the soil is kept saturated. Priestley and Taylor (1972) proposed a simplified version of the combination equation for use when surface areas are generally wet, which is a condition required for reference evapotranspiration. Jensen (1973) defined potential evapotranspiration as the rate at which water, if available would be removed from the soil and plant surfaces, expressed as the latent heat transfer per unit area or its equivalent depth of water per unit area. Doorenbos and Pruitt(1977) stated that the climate was the most important factor to be taken into account the effect of which on crop water requirements was given by the reference crop evapotranspiration (ET_O) which is defined as " *the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green cover of uniform height, actively growing, completely shading the ground and not short of water."* Hargreaves and Semani (1985) proposed several improvements for the Hargreaves (1968) model for estimating grass-related reference evapotranspiration.

Gupta and Goyal (2001) compared performance of various methods of ET estimation and presented their interrelationships with respect to each other for arid region of Rajasthan State.

Sakellariou and Vagenas (2006) conducted a study to map the reference crop evapotranspiration and rainfall and with the aid of these maps to estimate the total irrigation crop water requirements in central Greece irrigated both by private and public boreholes and by surface waters during the irrigation period of the year 2001 by using FAO Penman- Monteith method. Crop evapotranspiration and net water requirements were computed for each crop in the Municipalities on the Prefectures for the whole irrigation period. Finally, the total irrigation water requirements of crops during the irrigation period of the year 2001 for the 147,299 hectares of irrigated land of the region were estimated as 698,000,000m^3 with average 4,739m^3/hectare.

Ghazala and Ghulam (2007) conducted study to analyse the subsequent effects of increasing temperatures on ETo and on the agriculture water demand in the country. In the light of climate projections from various authentic sources like IPCC, increasing trends of 1-3°C have been studied which is likely in next 50 years. It has been concluded that the increase in water demand as compared to the present will appear leading to the enhanced risk of crop failure in rain fed areas where supplementary irrigation is not available. This study will help in crop monitoring and in the assessment that how much water is available in future for crops; which type of crops would suit the climate, Better management and building of new water reservoirs may help to cope the situation for an improved agriculture growth.

Hajare *et .al* (2009) conducted research that aims to arrive at a suitable empirical model for reasonable estimation of reference evapotranspiration for Nagpur region (Maharashtra State). In this research work the observations recorded at Nagpur meteorological station were used to calculate the evapotranspiration with the methods of Blaney-Criddle (BCL), Christiansen Equation (CNM), Hargreaves Method (HGM), Modified Penman method (MPM), Radiation Method (RAD), Thornthwaite Method (THW). The changing global climate has significant effect on evapotranspiration and hence here is a need to estimate continually and update evapotranspiation. The results of each method are compared with the results of the other.

Chowdhary Archana and Shrivastava (2010) estimated the monthly reference evapotranspiration are estimated by FAO Penman-Monteith method and irrigation requirements for the system are estimated based on the methodology suggested in FAO 24. Artificial Neural Network approach is found appropriate for the modeling of reference evapotranspiration for MRP command area. This study explores the potential of feed forward neural network (FFNN) for estimation and forecasting of monthly ETo values in MRP command area.

Henry (2012) reported on the use of weighing-type mini-lysimeters to estimate the crop water use of rain-fed maize and groundnut. The results of the study showed that the average daily water use of the maize crop increased from 2.70 mm/day at the early crop growth stages to 6.00 mm/day at mid-season and declined to 3.30 mm/day at the end of the season. The average daily water use of the groundnut crop was also found to increase from 2.66 mm/day at the early growth stage of the crop to 4.83 mm/day at the mid-season and declined to about 2.70 mm/day at the end of the season. The water use of both crops compared closely with estimates from weather data-crop coefficient with mean differences of 2.75 and 3.15 mm/week for the maize and groundnut crops, respectively.

2.2 Development of Crop Coefficient

Many researches were directed towards studying both the water use and development of the crop coefficients for crops grown in greenhouse. In Mediterranean areas, the seasonal ET of greenhouse horticultural crops is quite low when compared to that of irrigated crops outdoors. This is due, firstly, to a lower evaporative demand inside a plastic greenhouse, which is 30-40% lower than outdoors throughout the entire greenhouse cropping season (Fernandez, 2000). Secondly, greenhouse cultivation in the Mediterranean areas is mostly concentrated in periods of low evaporative demand (autumn, winter and spring), whereas irrigated crops outdoors are often grown during high evaporative demand periods. Orgaz *et al.*

(2005) carried out an investigation on the major horticultural crops (melon, sweet pepper, green bean, watermelon), usually, cultivated in plastic greenhouse in Spain. In this analysis, Kc values results to vary by crop, development stage and management. Thus, for melon and watermelon greenhouse crops, the mid-season Kc values proposed for outdoor crops (Allen *et al.*, 1998) appear reasonable for use. By contrast, mid-season Kc value for vertically supported greenhouse crops (melon, green bean and sweet pepper) was around 1.3. This Kc value is higher than those reported for the same crops in Italy (Rubino *et al*., 1986) and California (Snyder *et al*., 1987; Grattan *et al*., 1998), and those proposed by Allen *et al.* (1998) for sub-humid climates, all grown outdoors. The higher Kc values of the vertically supported greenhouse crops, usually reaching 1.5–2 m in height, is probably due to greater net radiation with respect to the short crops, because of the morphological features of their canopies. Manuel-Casanova *et al.* (2009) reports for lettuce grown in greenhouse conditions in Chile Kc values lower than those generally adopted for lettuce in field conditions. These differences are due to the complexity of the coefficient which integrates various functions (Katerji *et al*., 1991; Testi *et al*., 2004) such as aerodynamic factors linked to crop height, biological factors related to leaf growth and senescence, physical factors linked to soil evaporation, physiological factors of stomata response to the air vapour pressure deficit, and agronomic management factors like distance between rows and irrigation system. Furthermore, in greenhouse conditions, the differences in Kc can also be attributed to the size of the greenhouse and the substrate used.

Many studies highlight the greater accuracy in the computation of the crop coefficient curves as a function of variables more related to crop development: LAI, percent canopy that shades the ground or thermal-based index, expressed as cumulative growing degree days (GDD). This approach, in fact, is considered an improvement compared to guidelines from FAO, that propose to estimate the Kc values as function of the length of the four phenological stages in which crop development is divided. Moreover, the exact estimate of the length of each single growth stage is important since Kc pattern over time depends on it and, thus, a more accurate estimate of water use is possible (Lovelli *et al.*, 2005). Other alternative approaches have been proposed over the last years to estimate Kc curves for annual crops as a function of time in terms of days after sowing (DAS) or month of the year. This method is easy to implement but, as with the FAO methodology, it does not take into account the influence of environmental and cultural factors on the rate of canopy development.

Ayars *et al*. (2003) found that the Kc was a linear function of the amount of light intercepted by peach (Prunus persica L.) trees. It could be assumed that as leaf area increases so would the amount of solar radiation intercepted and the amount of ETc.

Linear relationships between Kc and LAI values were reported for green bean and melon by Orgaz *et al.* (2005); for grapevine by Williams *et al. (*2003) and for young olive orchard by Testi *et al*. (2004). In particular, the last author found that the Kc values determined in late autumn, winter and spring are usually high, variable and relatively independent of LAI or ground cover; during the summer the soil evaporation decreases and the Kc is lower, far less variable and LAI-dependent. This Kc values are linearly correlated to LAI or ground cover: the authors proposed a linear model to predict it. This model has shown great robustness despite their empirical nature.

Martinez-Cob (2007) obtained two crop coefficient equations as function of fraction of GDD for corn crop. The use of grown degree days to estimate Kc curves has the advantage that air temperature data is readily available and there is enough evidence of the influence of such variable on crop development (Ritchie and Nesmith, 1991). In conclusion, for real time irrigation scheduling, the authors advice is avoid the use of the methodology FAO 56 if it is possible to use GDD to estimate

Kc as by the FAO methodology the possible variations of corn development due to different climatic conditions for a particular year cannot be taken into account. De Tar (2009) for cowpea in California estimates the crop coefficient computing ETo through two methods: Penman Monteith equation and Pan evaporation. It find that the crop coefficients calculated using P-M equation for mid-season 2007 were significantly lower than for mid-season 2005, whereas, there was no significant difference with respect to the pan data for the same time periods.

Majid *et al* .(2011) had made a study on evolution of crop coefficients for sugar beet crop based on field water balance and FAO method through measuring soil moisture variation, and evaluating reference ET by FAO-penman-monteith equation in a semi-arid region. Crop coefficient curves and various mathematical relationships were developed for growth period to estimate the crop coefficient for this crop. The Kc values during the growing season was 0.59, 1.19 and 0.85 for initial, mid and end stage respectively. The Kc_{ini} that was estimated with field water balance method was greater than FAO method but Kc_{mid}, Kc_{end} were lesser than FAO method over the growth season.

2.2.1 Kc values by the dual crop coefficient approach

The dual crop coefficient consists of two coefficients: a basal crop coefficient Kcb and a soil evaporation coefficient Ke. This procedure, using the separate estimates of the plant and soil components of the crop coefficient, would allow an independent observation of both components and the comparison between them (Paço *et al*., 2006).

A good evaluation of the amount of water lost by direct soil evaporation needs a partitioning of total evapotranspiration into its soil evaporation and plant transpiration components. Therefore, separate and direct measurements of transpiration and soil evaporation are desirable (i.e. through sap flow or isotope measurements) (Williams *et al*. 2004, Rana *et al.* 2005). For this reason, the dual crop coefficient is mainly used in research, real-time irrigation scheduling for highly frequent water applications, supplemental irrigation, and detailed soil and hydrologic water balance studies.

Some studies, carried out in different regions of the world, have compared the results obtained using the approach described by Allen *et al.* (1998) with those resulting from other methodologies. From this comparison that some limitations should be expected in the application of the dual crop coefficient FAO 56 approach. For example, Dragoni *et al*. (2004), measured actual transpiration in an apple orchard in cool, humid climate (New York, USA), showed a significant overestimation (over 15%) of basal crop coefficients by the FAO 56 method compared to measurements (sap flow).

Casa *et al*. (2000) and Lopez-Urrea *et al*. (2009) reported a good agreement. In particular, the second authors found, for onion crop grown under semiarid conditions, that the dual crop coefficient approach is more reliable than the single crop coefficient, since the high values of evaporative component existed during the entire crop cycle.

Benli *et al*. (2006) and Paço *et al*. (2009) reported basal crop coefficients higher with respect to those tabulated. The first authors assign the different results probably to the difference between the climates. The seconds, for the young peach orchard, indicate a discrepancy with respect to the measured values within determine the plant component (overestimation of plant transpiration), would lead to an overestimation of water consumption by 30%. Instead, the soil component estimates in the crop coefficient were similar to measured values.

2.3 Crop yield response factor (Ky)

Crop response factors (Ky) relate the relative yield decrease to the relative evapotranspiration deficit caused by a lack of adequate water. Crop yield response factors for a variety of crop species have been independently studied by the Food and Agriculture Organization of the United Nations (FAO) and the International Atomic Energy Agency (IAEA). The results have been published in a technical document of the IAEA (IAEA, 1996) and in several technical reports and books ((Doorenbos and Kassam, 1979; Allen *et a*l.).Lists the crop response factors determined by the FAO for a number of common crop species. The values included measure the crop yield response factor for a continuous irrigation deficit suffered throughout the growth season.

A crop yield response factor, greater than one, indicates that the yield decrease is proportionally greater than the associated relative difference between the potential and actual evapotranspiration. Therefore, crops with a crop yield response factor (Ky) lower than one can generate more significant savings in irrigation cost under controlled irrigation deficit conditions. Ky values are crop specific and may vary over the growing season. In general, the decrease in yield due to water deficit during the vegetative and ripening period is relatively small, while during the flowering and yield formation periods it will be large

The researches have shown that crop yield response varies with the growth stage in which an irrigation deficit is suffered (Kirda and Kanber, 1999). An irrigation deficit suffered at one stage in the growth cycle of the crop may have little to no significant effect on crop yield, while an irrigation deficit suffered at a more critical stage in the plant cycle (generally during the flowering, fruit setting or grain formation stage) may dramatically affect yield (Kirda, 2002). For example, soybean yields decrease significantly more when an irrigation deficiency occurs during the flowering and pod development stages, when compared to an irrigation deficiency suffered during the vegetative growth stage (Kirda, 2002). Therefore, consideration must be given to the stage of the plant in its growth cycle if the value of supplemental irrigation has to be determined. As a result a series of empirically derived crop yield response factors (Ky) have been developed corresponding to irrigation deficits suffered at specific stages in the growth cycle, and for a continuous irrigation deficit suffered over the entire growth cycle.

2.4 Models on irrigation water management

A vast literature exists on irrigation water management. For the purpose of this study, the literature in three broad categories will be reviewed:

1. Deterministic crop yield studies, which predict crop yields from different irrigation schedules.
2. Irrigation scheduling studies, which focus on determining irrigation schedules. The models developed in this literature can be classified into two groups:
   - Static experimentation models that estimate a crop-response function and use the crop-response to predict yields and choose an irrigation schedule in a static framework.
   - Dynamic optimization models that optimally schedule irrigation events as the season progresses based on soil moisture measurements.
3. Irrigation system choice studies, focusing on the choice of irrigation system and evaluating irrigation efficiency and the effect of water conservation policies.

2.4.1 Deterministic Crop Yield Models

There is a large literature available on crop yield models in relation to water availability. Here, two representative studies that developed such models are briefly reviewed; the models selected are those most directly related to this study. Interested readers are directed to the following sources for more comprehensive reviews: Kang *et al.* (2002), Ghahraman and Sepaskhah (1997), Bryant *et al*. (1992), Hill et al. (1984), and Jensen *et al*. (1970).

Minhas, Parikh and Srinivasan (1974) studied the interdependence of plant water use at different time points, available soil moisture, and the quantity of water used by crop plants in a unified framework. They estimated the evapo-transpiration (ET) function of water using soil moisture data from Delhi and Ohio over a six-year period (1960-1965). Using the ET function, or the functional relationship between ET and available soil moisture, the soil moisture was predicted. The crop production function with dated inputs was estimated by simulating yield with respect to water in two periods – 71 to 90 days and 91 to harvest days from planting. The two problems in irrigation scheduling were – the decision about timing of water release and allocation of water among crops. To estimate the optimal amounts of irrigation, it is important to know the marginal product of water at each growth stage. The study concluded that the ET function performed well in estimating actual ET. The ET function was very useful in estimating production function and yield; this study could be of considerable help to formulate irrigation policy in general and to prepare irrigation schedules.

2.4.2 Static Experimentation Models

Dudek, Horner and English (1981) developed a method to assess the regional economic effects of irrigation scheduling and applied the method to develop a perspective on factors which affect the benefits and costs of irrigation scheduling. Water use and crop production coefficients under irrigation scheduling were estimated from a two-stage simulation process. The first stage of the process involved interaction of soil moisture and irrigation to simulate moisture stress and seasonal ET based on soil moisture, wind velocity, percolation depth, root zone, temperature, solar radiation and relative humidity. The second stage was comprised of the crop production model based on ET, soil moisture tension, quantity of irrigation, rainfall and number of irrigations applied to the field. Optimal water application was determined by maximizing net returns to land and management using linear programming. The regional economic model projected the amount of irrigation activity that would be scheduled as if a private company provided the service. The conclusions of this study were that irrigation scheduling could be an effective tool because the objective is to maintain soil moisture levels above the permanent wilting point and below field capacity levels with minimum irrigations. This resulted in minimizing drainage losses without reducing acreage or yields. Scheduling costs proved to be a significant factor in determining the aggregate amount of irrigated acreage.

Harris and Mapp (1986) compared the economic efficiency of alternative water conserving irrigation strategies. The authors studied the impacts of risk for alternative irrigation schedules using a stochastic dominance approach. Estimates from a crop growth simulation model were combined with crop price and input costs to estimate the net returns under different irrigation scenarios, which included up to one pre-plant and five post-plant irrigation events. The conclusions of the study were that several proposed water-conserving schedules were preferred to the intensive irrigation schedule because they provided higher expected net returns and reduced the risk of deviations from net returns. The study also identified efficient schedules with alternative risk preferences. The study found that irrigation is critical at grain filling and later stages of crop growth. The authors found that risk aversion does not explain the use of intensive irrigation policies.

Bernardo *et al*. (1987) presented a two-stage simulation model to determine optimal intraseasonal allocation of irrigation water under conditions of limited water supply. As water becomes scarce and irrigation costs increase, irrigation water management must be reoriented towards increasing precision of irrigation scheduling and application to maximize returns to scarce water resources. The authors found that the problems in intra-seasonal water allocation were computational intractability and unavailability of crop-water response information. Historically, the problems were focused on the timing and depth of irrigation events, but no study considered other management practices in conjunction with irrigation scheduling for efficient irrigation programs, such as crop substitution and reallocation of water among crops. The two-stage simulation model included crop simulation using the soil-plant-air-water irrigation model to analyze yield response to a specific irrigation schedule based on ET; the irrigation responses were then used in a mathematical programming model to maximize returns through efficient allocations of the available water supply. The conclusions of the study were that through conjunctive development and application of efficient irrigation programs, significant reductions in seasonal water application and consumptive use could be attained with small losses in producer returns. Water efficiency could be improved by employing high-frequency schedules, reducing depth of application and eliminating irrigation in non-critical stages.

Talpaz and Mjelde (1988) developed an exante method by optimizing irrigation scheduling via experimentation. The crop response to irrigation was obtained by a two-stage experimental procedure involving an estimated production function. In the first stage, crop growth was simulated using a quadratic response function, which can be interpreted as a second order Taylor's series approximation of the underlying response relationship. The objective of the second stage was to take the crop growth responses into account to provide improved decision rules for the next set of trials with the experimental procedure. The initial decision rule to schedule irrigation events was to find the soil moisture threshold level that triggers irrigation. Two important attributes for ex ante strategies are to account for stochastic weather conditions and provide flexible decision rules. One critique of this method is that a quadratic response function may not accurately reflect the true response function, which could be highly non-linear and more complex. The conclusions of the study are that the producers should be more protective of the crop during later stages of crop growth. If rainfall can be predicted, then it can improve the irrigation scheduling greatly. Ex ante rules, in general, are easy to implement in stochastic environments and in many simulation models.

Jones (2004) reviewed irrigation scheduling methods to address the advantages and pitfalls of plant-based methods. The increasing costs of irrigation and shortage of water emphasize the importance of minimum water use and maximum water use efficiency. Irrigation scheduling is conventionally based either on soil water measurement or soil water balance calculations. A potential problem with all soil-water based approaches is that the plant's physiology responds directly to changes in water content in the plant tissues, rather than changes in soil water content. It has been suggested that use of plant stress sensing can bring greater precision in irrigation. Under the plant stress approach, irrigation scheduling is based on plant responses rather than direct measurements of soil water status. Plant stress can be identified by –tissue water status and physiological responses. Both methods require highly sophisticated equipment and are very labor-intensive.

2.4.3 Dynamic Optimization Models

Yaron *et al*., (1980) developed a dynamic programming model for optimal irrigation scheduling with varying salinity. The study answers two important questions under conditions of irrigation with saline water: (a) given initial soil salinity, should a pre-planting leaching be applied, and if so, at what quantity; and (b) what is the optimal irrigation schedule - i.e., the optimal combination of quantities and timing of irrigation events during the entire irrigation season. The method developed was applied to determine optimal irrigation schedules with saline water for sorghum. The authors extended dynamic programming to account for crop response to soil moisture as well as soil salinity in two steps. The first step was to estimate a soil potential function dependent on soil moisture and soil salinity levels. The second step involved dividing the crop season into sub-periods and obtaining a yield expression. Yield was expressed as a function of maximum obtainable yield and the reduction in yield during critical days of soil salinity and moisture. The objective was to maximize the cumulative net income for every crop price and soil salinity level subject to soil moisture and state of the system by applying a dynamic programming backward induction procedure. The conclusions of the study were that frequent applications of small quantities of water were preferable to large quantities at extended intervals. Under high soil salinity conditions, extra irrigation water for leaching is justified in the beginning of the season. The authors recommend extended irrigation over long periods under relatively low saline conditions and no irrigations under saline conditions. One critique of the article is that soil salinity level may not be constant throughout the growing season. However, this model could be used for detailed analysis of optimal irrigation with saline water.

Harris and Mapp (1980) evaluated the potential impact of alternative irrigation strategies to derive optimal time path strategies to conserve water while maintaining net returns to the producer. The objective of this study was to derive an irrigation strategy for the growing season that maximizes net returns to grain sorghum producers from water use. The authors analyzed three production scenarios, first, testing the sensitivity and validating the model; second, simulating irrigation practices by applying 15 inches of groundwater; and third, applying an optimal control procedure to derive irrigation sequences to maximize net returns. The amount of irrigation water applied in the optimal control and 15 acre-inch irrigation scenarios was substantially different but the grain sorghum yields were comparable. The results indicate that there is a high potential for irrigation producers to reduce irrigation water application while maintaining yields and increasing net returns.

Bras and Cordova (1981) studied the problem of optimal temporal allocation of irrigation water considering dynamics of soil moisture depletion and intraseasonal stochasticity. The optimization problem in this study was to maximize net benefits from irrigation subject to the stochastic process of soil moisture. The yield was estimated as a function of actual ET, potential ET and a crop sensitivity factor. The solution algorithm was obtained using a backward recursive formulation of a stochastic dynamic programming model. The probability distribution of soil moisture was used to obtain an optimal irrigation policy using dynamic programming. The mean and variance of irrigation net benefits for each case were computed. This study was one of the first to analytically include a physical model into a stochastic algorithm. The net benefits obtained under stochastic control were always greater than those obtained under a fixed date schedule. The expected value of net benefits increases and its variability was reduced when using stochastic control. One critique of the study is that it may be unrealistic to assume that the soil water availability is known without actually measuring it.

Feinerman and Falkovitz (1997) developed a mathematical model to determine the economically optimal scheduling of fertilization and irrigation that maximizes a farmer's profits. The state of soil-plant-nitrogen and the water system is defined by three state variables, a measure of plant size, plant available nitrogen in the root zone and relative soil moisture. The control variables are the rates of nitrogen and water application. The authors found that the maximum yield to the optimization problem is achieved when a predetermined level of nitrogen fertilizer is applied at the beginning of the season and irrigation water is applied continuously so that the soil moisture is maintained at field capacity. The results indicate that controlling nitrogen pollution via taxation becomes more effective at higher tax rates. The limitations of the study are that it is difficult to accurately estimate the pollution and that imposing a tax on the amount of nitrogen leached is likely to be impractical. It was found that the level of leaching is much more sensitive to changes in the fertilizer price than to changes in the tax levied on leached nitrogen.

2.5 Sine-Product model

Widandi Soetopo (2011) studied on the implementation of Sine-Product model (mathematical function) for estimating the real crop water requirement of a particular region. The optimal crop water requirement is supposed to be varied spatially. The crop being investigated is corn in four different regions. The indicator of fit is the average of absolute differences between the values of yield produced by the Sine-Product model and recorded data of yield. The results indicate that the optimal crop water requirement is differ somewhat from the established one.

2.6 Irrigation System Choice Studies

Huffaker and Whittlesey (2003) formulated a conceptual model to study farm responses to economic policies with the aim of water conservation. The objective of this paper was to investigate the conceptual circumstances under which higher water prices and farm subsidies encourage water conservation. The authors use a profit maximization model to select optimal levels of water and investment in on-farm irrigation. The decision variables selected were applied water, investment in improved-on farm irrigation efficiency and farm acreage. The authors determined the optimal responses to policies intended to conserve water using comparative statics. The impact of an increase in the cost of applied water results in a reduction in the demand for water and acreage, thereby reducing consumptive water use. The impact of subsidies to improve irrigation efficiency is ambiguous. The farm ultimately adjusts its demand for applied water in a direction dictated by relative marginal adjustments in acreage and irrigation efficiency to satisfy the production constraint. The results indicate that increasing the cost of irrigation may be an effective water policy than subsidizing the cost of investing in improved irrigation efficiency. Lovelli *et al*. (2005) check the latest update proposed by the FAO to estimate evapotranspiration in the case of muskmelon crop both with plastic mulches and no mulch. The procedures suggested in FAO Irrigation and Drainage Paper 56 allows an accurate ETc estimate in the case of muskmelon cultivated without plastic mulch. For the crop under mulch, a good agreement of the estimated Kc values with the measured ones is obtained only at the initial stage of the cycle, while at the stage of maximum canopy development the measured values are underestimated with respect to the FAO crop coefficients.

Er-Raki *et al.*, (2009) used the FAO-56 single crop coefficient approaches to estimate actual evapotranspiration over an irrigated citrus orchard under drip and flood irrigations in Marrakech (Morocco). The results shows that, by using crop coefficients suggested in the FAO-56 paper, the performance of both approaches was poor for two irrigation treatments. While, after the determination of the appropriate values of Kc based on ETc measurements by eddy covariance, the performance of both approaches greatly improved. The obtained Kc values were lower than the FAO-56 values by about 20%. The lower Kc values obtained that Kc FAO reflect the practice of drip irrigation for one field and the low value of cover fraction for the other field. Additionally, the efficiency of the irrigation practices was investigated by comparing the measured Kc for two fields. The results showed that a considerable amount of water was lost by direct soil evaporation from the citrus orchard irrigated by flooding technique.

2.7 Deficit Irrigation

Steve *et al.* (2003) conducted study to determine the most profitable irrigation strategy to produce alfalfa with inadequate water supplies. Results showed that severe yield loss when irrigation was halted in late summer in some cases, but only slight losses in yield in other cases.

With increasing municipal and industrial demands for water, its allocation for agriculture is decreasing progressively. At present and more so in the future, irrigated agriculture will take place under water scarcity. Insufficient water supply for irrigation will be the norm rather than the exception, and irrigation management will shift from emphasizing production per unit area towards maximizing the production per unit of water consumed, water productivity (Fereres and Soriano, 2006). The major agricultural use of water is for irrigation, which, thus, is affected by decreased supply. Therefore, innovations are needed to increase the efficiency of use of the water that is available (Costa *et al.*, 2007). There are several possible approaches to reach that demand; drip irrigation, mulching and protected cultivation have contributed to improve WUE in agriculture by significantly reducing runoff and evapotranspiration losses (Stanghellini *et al.*, 2003; Jones, 2004; Kirnak and Demirtas, 2006) but It is necessary to develop new irrigation scheduling approaches, not necessarily based on full crop water requirement, but ones designed to ensure the optimal use of allocated water.

Deficit irrigation, defined as the application of water below full crop-water requirements (evapotranspiration) (Fereres and Soriano, 2006), or applying less water than cumulative ET, thereby allowing roots to utilize stored soil water in the winter or preseason irrigation (Shatanawi, 2006). It is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied: the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season. The expectation is that any yield reduction will be insignificant compared with the benefits gained through diverting the saved water to irrigate other crops (Kirda, 2002).

2.8 Irrigation Scheduling Models

Irrigation scheduling models aim at timing irrigation events in order to replenish soil-water once a certain minimum soil-water threshold has been reached. There is currently several irrigation scheduling models that exist, but vary slightly with regards to their methods and procedures. (Darouich, 2006) Little irrigation scheduling programming is intended to introduce in order to conceptualize how irrigation schedules are determined and to evaluate.

2.9 CROPWAT Model

During the nineties, CROPWAT, a computer program for irrigation planning and management developed by FAO (Smith, 1992), had been getting particular importance among irrigation engineers. CROPWAT provided the link with climatic data from 3261 meteorological stations of 144 countries worldwide and represented a unique practical tool for estimation of crop water requirements, simulation of irrigation scheduling scenarios and estimation of specific continuous discharge either for one or more crops grown in almost any part of the world. CROPWAT program was developed on the methodologies presented in FAO Irrigation and Drainage Papers N°24 (Crop Water Requirements) and N°33 (Yield response to water) although including the Penman-Monteith formula for crop evapotranspiration estimate. Nevertheless, in the recent years, FAO Irrigation and Drainage paper N°24 was revised and substituted with N°56 (Allen *et al.*, 1998) which recommended a new procedure based on the Penman-Monteith equation as standard method for reference evapotranspiration estimate and introduced dual Kc concept allowing better consideration of soil evaporation and plant transpiration components. Moreover, on-going activities are focused on the revision of FAO Irrigation and Drainage paper N°33 and introduction of a new approach for crop growth modeling and yield response to water.

Smith *et al*. (1992) carried out a study on to assess the applicability of the FAO CROPWAT model for deficit irrigation scheduling, a study utilized data provided in studies from a joint FAO/IAEA coordinated research project (CRP) on “The use of nuclear and related techniques in assessment of irrigation schedules of field crops to increase effective use of water in irrigation projects,” carried out in Turkey, Morocco and Pakistan on cotton, sugar beet, and potato, respectively. The study revealed that the CROPWAT model can adequately predict the effects of main crop parameters

Vasan and Shrinivasa Raju (2004) used the CROPWAT model to compare the results of the Decision Support System with other methods developed for the area of Pilani, Rajsathan. Bhakar and Singh (2004) concluded that air temperature is the main factor influencing evaporation. The study also indicated that the influence of relative humidity on evaporation is negative whereas that of wind speed is positive.

Muhammad Nazeer (2009) conducted a study on CROPWAT simulation under irrigated and rainfed conditions for maize crop, in order to provide information necessary in taking decisions on irrigation management. Simulation results analysis suggests that areas, where the maize water requirements exceeds the water supply, by application of adequate irrigation scheduling the yield losses can be significantly reduced.

Adeniran *et al*.,(2010) carried out a study to determine the crop water requirement of some selected crops for the area around Kampe (Omi) Dam Irrigation Project. Crop water requirement for each of the crops was determined by using 25-year climatic data in CROPWAT. The study shows that the dam can conveniently supply the water required for irrigation in the area used at present and also in the entire land area.

Ziad and Sireen (2010) analyzed the climate change impacts on crop and irrigation water requirements, applying the CROPWAT model to several incremental climatic change scenarios for the West Bank governorate of Jericho and Al-Aghwar as a case study. The results clearly show that the greatest threat occurs if a temperature rise of 3°C is accompanied by 20% decrease in precipitation levels

Farhad and Jayashree (2010) conducted a study on net derived demand (NDD) for irrigation water was derived based on Cropwat model and remote sensing and GIS techniques for Malayer in the west Iran in ten water years (1997- 2006). Satellite images (IRS LissIII image), Cropwat model, coupled with GIS and RS were applied to compute net irrigation water requirements. Satellite images (IRS LissIII 11th June' 2006) were used to determine type and area of cultivated crops. Cropwat model was used to calculate real evapotranspiration and (NDD) for irrigation water based on local climate data and information from agricultures on the satellite images. Groundwater is used for agriculture on the real data from the pump in the Region of Malayer.

2.10 GIS

Integration of remote sensing and geographical information system techniques provides reliable, accurate and update database on land and water resources, which is a prerequisite for an integrated approach for enhancing crop production, runoff and erosion potential zones and identifying sites for water harvesting and ground water recharge areas etc. GIS has also used as an analytical tool to evaluate the performance of irrigation command area and its management.

2.10.1 GIS in estimation of evapotranspiration

R. Tateishi and C. H. Ahn (1996) made a study on mapping evapotranspiration and water balance for global land surfaces. Here the monthly global data sets of evapotranspiration and water balance were produced using a simplified water balance model and published global data sets. For validation of the global data sets, results were compared with information obtained by previous investigations that used independent data and analytical approaches.

Julie Coonrod and Dianne McDonnell (1996) conducted a study using remote sensing and GIS to compute evapotranspiration in the semiarid regions (Rio Grande Bosque) of the United States. Semiarid regions lose a tremendous amount of water to evapotranspiration. Four towers extend above the canopy to measure evapotranspiration from the two tree species. Landsat data and AVHRR data are used in ArcView Image Analysis and ArcView Spatial Analyst to derive a method to compute evapotranspiration purely from satellite imagery.

Ahmed (1997) estimated the irrigation water demand due to crop evapotranspiration in a 347 ha command area in Smithfield, Utah. High resolution multi spectral imagery was acquired throughout the growing seasons.

Skop E and Acquarone M (1997) carried out GIS mapping of evapotranspiration in the Vejle Fjord watershed, Denmark. A soil map, land use map and time series of monthly precipitation and potential evapotranspiration were used for the estimation of evapotranspiration. An inverse distance weighting procedure was applied to interpolate monthly precipitation totals between the gauging stations. A comparison of computed catchment's average evapotranspiration based on spatially distributed precipitation with computed catchment's average evapotranspiration based on catchment's average precipitation revealed significant discrepancies. This finding suggests that a spatially variable approach is required to assess catchment's average actual evapotranspiration.

2.10.2 GIS in estimation of irrigation requirement

Vidhya *et al*. (1995) made a study on GIS based diagnostic analysis of irrigation system performance assessment of Bhadra command area. Satellite remote sensing (SRS) and geographical information (GIS) techniques were used for improved water management in canal irrigation schemes. Satellite remote sensing technique has been applied to historic and 1995 Rabi season data by National Remote Sensing Agency to generate primary data on irrigated area, cropping pattern and crop yield at disaggregated level and to access the improvement in agricultural productivity and water management. The GIS technique helped in integration of satellite and ground information to evaluate the system performance and to diagnose the inequality in the performance to aid in improving the water management

Paz *et al.* (1995) conducted a study on validation of an empirical model and prediction of irrigation requirements in Spain. Soil water balance over the study period was also simulated with an empirical model, ISAREG. The model was then used to predict the probability distribution of annual net irrigation requirements for pasture area, on the basis of 24 years' climatic data. Interannual variation was very high, with modelled irrigation requirement ranging from 0 to 232 mm.

Tim Hess (1996) conducted a study on a microcomputer scheduling program for supplementary irrigation in U.K. The package comprises four models; a reference crop evapotranspiration model, an actual evapotranspiration model, a soil water balance model and irrigation forecast model. The models used have been shown to produce reliable estimates of the soil water balance; however, the predictions are sensitive to the accuracy of the input data measured on the farm.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The estimation of water requirements of crop is essential for irrigation planning and management and also it is the basis on which irrigation project is designed. The increasing demand and scarcity of water makes it important to use the available water in the most economic way. The key to effectiveness of irrigation water management lies in proper estimation of crop water requirements, which are primarily based on cropping pattern, rainfall in the area and other climatic factors. Computer model simulation is an emerging trend in the field of water management. Water managers, irrigation agronomists, engineers and researchers are taking keen interest in model simulation for the easier solution of problems faced by them. CROPWAT is one of the models extensively used in the field of water management throughout the world. CROPWAT facilitates the estimation of the crop evapotranspiration, irrigation schedule and agricultural water requirements with different cropping patterns for irrigation planning.

The methodology adopted for estimation of crop water requirements and scheduling of irrigations for the cropping pattern followed in the instructional farm of KCAET, Tavanur is explained in this section.

3.1 Location

The study area was the instructional farm KCAET, Tavanur. The area is located at 10° 52´ 09.97´´ North Latitude and 75º 58' 34.20" East Longitude. It comes under the Malappurum District of Kerala State in India. The area is under cultivation for more than 25 years.

3.2 Climate

Agro-climatically the area falls within the border line of northern zone, central zone and kole zone of Kerala. The average annual rainfall received in the area is about 2900 mm and has a humid climate. Medium to high rainfall zones are available within 10-15 km of area. The area receives rainfall mainly from south-west monsoon and north-east monsoon. The average maximum temperature of study area was 31ºC and the average minimum temperature was 26ºC.

3.3 Land use pattern

The Table 3.1 shows the land use pattern of K.C.A.E.T campus.

Table 3.1 Land use pattern of K.C.A.E.T Campus

Land use	Area(ha)
Building, Roads, Playground ,etc	10
Wetland (Paddy,Pulses,Vegetable,Sesame)	8
Coconut alone	15
Arecanut alone	0.6
Nursery area	0.5
Banana and Plantain	0.5
Experimental area	0.5
Kharif Vegetables	0.5
Cashew	1.0
Mango, Jack fruit ,Tamarind, Gooseberry and Others	0.4
Uncultivable rock	2.0
Total area	40

3.4 Cropping pattern

The major crops grown in KCAET instructional farm are Paddy, Amaranthus, Snake gourd, Cowpea, Cucumber, Water melon, Pumpkin, Bhindi, Ash gourd, Sesamum, Banana and the estimation of water requirement of these fourteen crops and irrigation scheduling were planned .The map showing the cropping pattern of the farm area divided into different blocks is given in plate 3.1.

3.5 Irrigation system in KCAET farm

Field was usually irrigated using water pumped from an open well which uses mainly a 10 hp pump and additional two 3hp pumps.

3.6 Study of soil physical properties

3.6 .1 Soil sampling procedure

The field tests were conducted for identification and characterization of soil properties. Both disturbed and undisturbed soil samples were collected from four different locations of the study area. The selected locations were the mango orchard (C block) and coconut orchard (G block) near to the river side boundary of the farm, paddy field (B block) near to the farm pond, coconut orchard (P block) near to the workshop from which sample 1, sample 2, sample 3, and sample 4 were collected respectively. The field was divided into different homogenous units based on visual observation. The surface litter was removed at the sampling spot. The auger was driven to a plough depth of 15 cm and the soil sample was drawn. Collect at least 10 to 15 samples from each sampling unit and place in a bucket or tray. A ‘V’ shaped cut was made to a depth of 15 cm in the sampling spot using a spade .Thick slices of soil was removed from top to bottom of exposed face of the ‘V’ shaped cut and placed in a clean container.

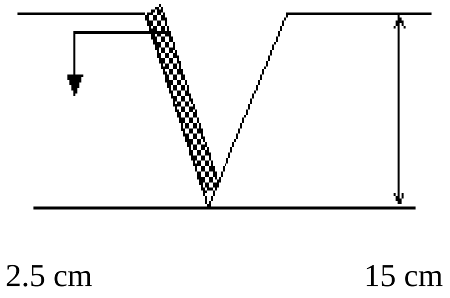


Fig. 3.1 Dimension of the sampling pit

Laboratory testing of the collected soil samples were carried out to determine the moisture content, bulk density, dry density, grain size distribution, field capacity& permanent wilting point.

3.6.2 Bulk density and dry density

A core cutter consisting of a steel cutter, 10 cm in diameter and 12.5 cm high, with a 2.5 cm high dolly was driven in to the cleaned surface with the help of a rammer, till about 1 cm of the dolly protruded above the surface. The cutter, containing the soil, was dug out of the ground. The dolly was then removed and the excess soil was trimmed off. Soil bulk density was determined from these undisturbed cores as mass per volume of dried soil. The samples were collected a day after the treatments were applied. Then bulk density was calculated by using the formula,

$$\rho = \frac{M}{V}$$

Where,

ρ= bulk density in gm/cm^3

M= mass of soil in gm

V= volume of soil in cm^3

Plate 3.2 Sampling by core cutter

3.6.3 Particle size analysis

The analysis of grain size distribution of soils from the selected three plots was done by sieving. Here dry sieve analysis was carried out using 4.75mm, 2mm, 1mm, 600µm, 425µm, 300µm, 212µm, 150µm, and 75µm size sieves. Sieving was done using sieve shaker. Weight of soil retained in each sieves were taken. The mass retained in the receiver was then subjected to sedimentation analysis by Hydrometer method

3.6.4 Determination of Soil moisture characteristics

A laboratory measurement of soil moisture characteristics was done with the pressure plate equipment developed primarily by Richards (1949, 1954). The apparatus consists of ceramic pressure plate or membranes of high air entry values contained in airtight metallic chambers strong enough to withstand high pressure (15 bars or more).The apparatus enables the development of soil moisture characteristic curves in the higher range of metric potential (>1 bar) which is not possible on suction plates.

The procedure for determining soil metric potential and water content relation involves in first saturating the porous plates and then the soil (undisturbed or disturbed) is placed on these plates. The soil samples (C block, B block, P block) were also saturated and then the plates were transferred to the metallic chambers. The chamber was closed with wrenches to tighten the nuts and bolts with the required torque for ceiling it. Pressure was applied from a compressor through control which helps in maintaining the desired two pressures 1/3 atm& 15 atm which were applied to get field capacity and permanent wilting point. It was ensured that there was no leakage from the chamber. Water starts to flow out from saturated soil samples through outlet and continues to trickle till equilibrium against the applied pressure is achieved. After that the soil samples were taken out and oven dried for determining moisture content, volume basis (undisturbed soil).Similarly, the moisture content of the soil can be determined against other pressure values .The data are presented in result.

Field capacity and permanent wilting point of samples were determined for sample1 (C block), sample 3 (B block), and sample 4 (P block).

3.7 The CROPWAT Model

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. It is a computer program that uses the FAO Penman-Monteith model to calculate reference evapotranspiration (ETo), crop water requirements (ETm) and crop irrigation requirements (FAO 1992). The program allows for the development of irrigation schedules under various management and water supply conditions and to evaluate rain fed production, drought effects and efficiency of irrigation practices (FAO 2002).This Windows version is based on the DOS versions CROPWAT 5.7 of 1992 and CROPWAT 7.0 of 1999. Apart from a completely redesigned user interface, CROPWAT 8.0 for Windows includes a host of updated and new features.

These include:

- Monthly, decade *and daily* input of climatic data for calculation of ETo
- Backward compatibility to allow use of data from CLIMWAT database
- Possibility to estimate climatic data in the absence of measured values
- Decade *and daily* calculation of crop water requirements based on updated calculation algorithms including adjustment of crop-coefficient values
- Calculation of crop water requirements and irrigation scheduling for dry crops *and for paddy & upland rice*
- Interactive user adjustable irrigation schedules
- Daily soil water balance output tables
- Easy saving and retrieval of sessions and of user defined irrigation schedules
- Graphical presentations of input data, crop water requirements and irrigation schedules
- Easy import/export of data and graphics through clipboard or ASCII text files
- Extensive printing routines, supporting all windows-based printers
- Context-sensitive help system

3.7.1 Data requirements for CROPWAT

Four main datasets are used as inputs in the CROPWAT estimation: climatic, crop, soil and irrigation. For this study climate and crop data were gives as input based on local values. The climatic data are maximum and minimum temperatures (ºC), mean daily relative humidity (in %), daily sunshine (in hours), wind speed and rainfall. The crop parameters include: water stress coefficient (Ks), length of the growing season, critical depletion level, and yield response factor (Ky). The soil data include total available soil water content, maximum infiltration rate, maximum rooting depth and initial soil water content at the start of the season.

3.7.2 Climate Module

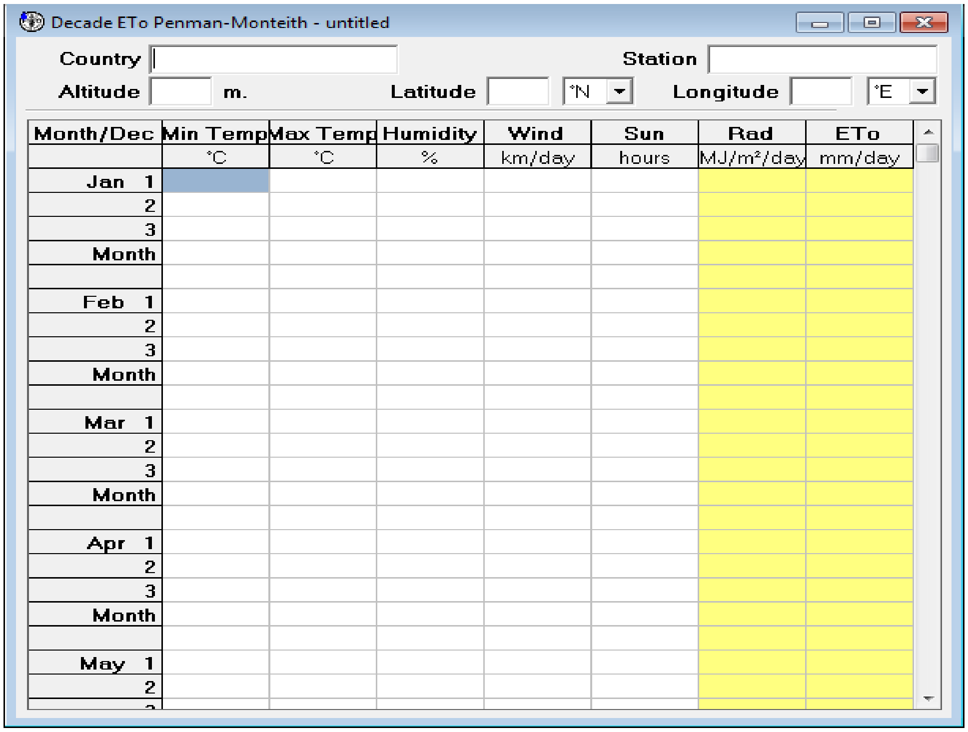
Climate module presented as in fig.3.2**.** The data of rainfall, minimum temperature, maximum temperature, humidity, sunshine hours, and wind speed were used to calculate radiation and reference crop evapotranspiration .These datas were taken from nearby Materiological station RARS, Pattambi. An average of values obtained for 20 years was considered and are provided in appendix II.

Radiation

On the base of climatic data available, CROPWAT estimates the solar radiation reaching soil surface. Radiation is expressed in MJ /m^2 /day.

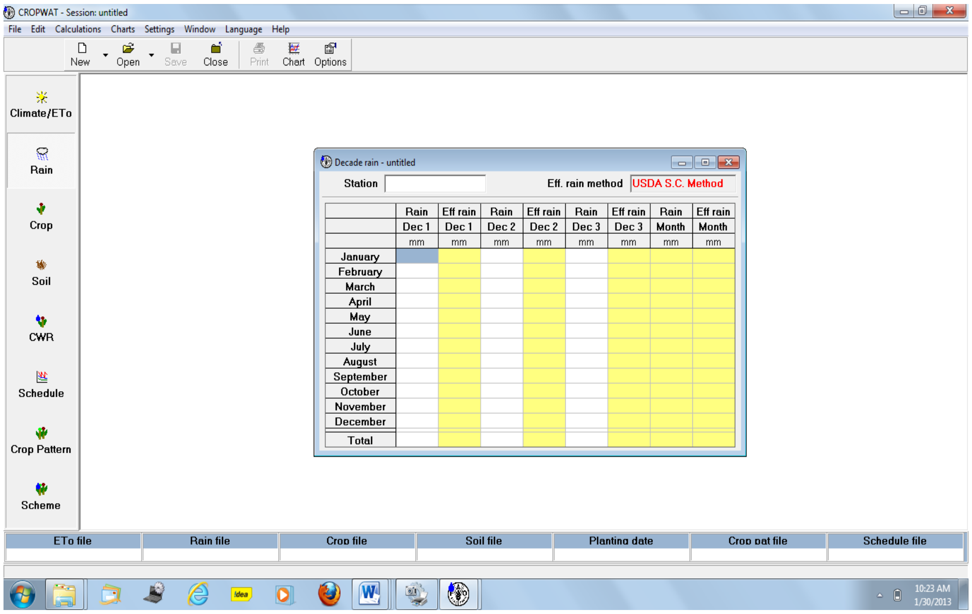
Reference Evapotranspiration (ETo)

The evapotranspiration rate from a Reference crop not short of water is called the Reference evapotranspiration (ETo).



Month/Dec	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
Jan 1							
2							
3							
Month							
Feb 1							
2							
3							
Month							
Mar 1							
2							
3							
Month							
Apr 1							
2							
3							
Month							
May 1							
2							

Fig. 3.2 Climate module



Eff. rain method USDA S.C. Method

	Rain	Eff rain	Rain	Eff rain	Rain	Eff rain	Rain	Eff rain
	Dec 1	Dec 1	Dec 2	Dec 2	Dec 3	Dec 3	Month	Month
	mm	mm	mm	mm	mm	mm	mm	mm
January								
February								
March								
April								
May								
June								
July								
August								
September								
October								
November								
December								
Total								

Fig 3.3 Rain module

3.7.3 Rain Module

Rain module presented as in figure 3.3 .As per the study USDA method is used to calculate the effective rainfall These datas were taken from nearby Materiological station RARS, Pattambi. An average of values obtained for 20 years was considered and are provided in appendix III.

USDA Soil Conservation Service

Formula developed by USCS, where effective rainfall can be calculated according to:

Monthly step:

Peff = Pmonth * (125 - 0.2 * Pmonth) / 125 for Pmonth<= 250 mm

Peff = 125 + 0.1 * Pmonth for Pmonth> 250 mm

Decade step:

Peff(dec) = Pdec * (125 - 0.6 * Pdec)) / 125 for Pdec<= (250 / 3) mm

Peff(dec) = (125 / 3)

Effective Rainfall

For agricultural production, effective rainfall refers to that portion of rainfall that can effectively be used by plants. This is to say that not all rain is available to the crops as some is lost through Runoff (RO) and Deep Percolation (DP).

3.7.4 Crop Module

Crop module presented as in figure 3.4. The details of crops in the study area is given in the table 3.2.The following parameters include in crop module.

Planting date

Planting date is normally determined from climatic conditions (for instance, at the beginning of the rainy season in tropical climates or the beginning of spring when temperature reaches a minimum for plant growth in temperate climates). It also varies according to local agricultural practices.

Harvest date

The harvest date is automatically determined from the Planting date or Transplanting date in case of rice cultivation with no direct sowing - and the total length of the crop cycle.

Table 3.2 Planting date and harvesting for different crops

Sl.No	Crop Name	Planting Date	Harvesting Date
1	Paddy	27/01/2011	26/05/2011
2	Amaranthus	07/12/2011	30/01/2012
3	Snake gourd	31/01/2012	30/05/2012
4	Cowpea	07/12/2011	26/03/2012
5	Cucumber	16/12/2011	30/01/2012
6	Watermelon	23/12/2011	11/04/2012
7	Pumpkin	10/12/2011	19/03/2012
8	Bhindi	16/12/2011	15/03/2012
9	Ash gourd	10/12/2011	13/04/2012
10	Cesamum	06/08/2011	23/11/2011
11	Banana	06/05/2011	05/05/2012

These are the crops considered for the study (Rice and non-rice).

Crop coefficient (Kc)|Non-rice crop

The Crop coefficient (Kc) integrates the effect of characteristics that distinguish a specific crop from the reference crop. According to the Crop coefficient approach, Crop evapotranspiration under standard conditions (ETc) is calculated by multiplying the Reference evapotranspiration (ETo) by the suitable Kc.

CROPWAT 8.0 requires Kc values for initial stage, mid-season stage and at harvest. Kc values during the development and late season stages are interpolated.

- Initial period (Init**)**: during this period, the leaf area is small, and evapotranspiration is predominantly in the form of soil evaporation. Therefore, the Kc during the initial period is large when the soil is wet from irrigation or rainfall and is low when the soil surface is dry.
- Development stage (Deve): as the crop develops and shades the ground more and more, evaporation becomes more restricted and transpiration gradually becomes the major process.
- Mid-season stage (Mid): In this stage the Kc reaches its maximum value.
- Late season stage (Late): The Kc value at the end of the late season stage reflects crop and water management practices. This value is high if the crop is frequently irrigated until harvested fresh. If the crop is allowed to senescence and to dry out in the field before harvest, the Kc value will be small, due to less efficient stomata conductance of leaf surfaces.

Stages|Non-rice crops

With reference to seasonal crops, the total growing period can be divided in four distinct growth stages:

- Initial stage (Init): It runs from Planting to approximately 10% ground cover. The length of this period is highly dependant on the crop, the crop variety, the planting date and the climate.
- Development stage (Deve): This stage runs from 10% ground cover to effective full cover, which usually occurs at the initiation of flowering. For row crops where rows commonly interlock leaves, effective cover can be defined as the time when some leaves of plants in adjacent rows begin to intermingle so that soil shading becomes nearly complete. In densely sown vegetation, such as cereals and grasses, the effective full cover can be difficult to be visualised, the more easily detectable stage of flowering is generally used. Another

way to estimate the occurrence of the effective full cover is when the Leaf Area Index (LAI, defined as the average total area of leaves per unit of area of ground surface) reaches three.

- Mid-season stage (Mid): This period runs from effective full cover to the start of maturity, often indicated by the beginning of the ageing, yellowing or senescence of leaves, leaf drop, or the browning of fruit. It is the longest stage for perennial and for many annual crops, but it can be relatively short for vegetables that are harvested fresh for their green vegetation.
- Late season stage (Late): This period runs from the start of maturity to harvest or full senescence.

Rooting depth

The rooting depth defines the capacity of the crop to take advantage from the soil water reservoir.

- Rooting depth of initial stage, normally taken as 0.25 - 0.30 m, representing the effective soil depth from which the small seedling abstracts its water;
- Rooting depth at full development at start of mid-season. For most irrigated field crops values vary between 1.0 and 1.40 m, vege-table crops 0.5 - 1.0 m.

Stages|Rice

The total growing period for lowland rice cultivation is divided in three distinct stages:

Nursery

In case of Transplanting, number of days starting from land preparation of the nursery area to transplanting of rice. If direct sowing is practiced, this field becomes inactive.

Land preparation:

- **Total**: Is the number of days required to carry out land preparation and inundation prior to transplanting for the given irrigation unit. Note that the total land preparation should be shorter than the Nursery period, since CROPWAT 8.0 considers the nursery area as part of the field where rice will be grown afterwards.
- **Puddling**: Is the number of days during which the puddling is carried out. This period is part of the total land preparation.

***Growth stages*:**

- **Initial stage (Init)**: It runs from Planting or Transplanting to approximately 10% ground cover. The length of this period is highly dependant on the rice variety, the planting date and the climate.
- **Development stage (Deve)**: This stage runs from 10% ground cover to effective full cover, which usually occurs at the initiation of flowering.
- **Mid-season stage (Mid)**: This period runs from effective full cover to the start of maturity.
- **Late season stage (Late)**: This period runs from the start of maturity to harvest.

Crop height

This parameter has been introduced in CROPWAT 8.0 in order to allow the adjustment of crop coefficient values under nonstandard conditions, particularly values of relative humidity that differ considerably from 45% or where wind speed is larger or smaller than 2.0 m/s. This parameter is optional and in case it is not provided no adjustment will be done.

Yield response factor (Ky)

The response of yield to water supply is quantified through the Yield response factor (Ky) which relates relative yield decrease to relative evapotranspiration deficit.

Water deficit of a given magnitude, expressed in the ratio Crop evapotranspiration under nonstandard conditions (ETcadj) and Crop evapotranspiration under standard conditions (ETc), may either occur continuously over the total growing period of the crop or it may occur during any one of the individual growth stages.

Critical depletion fraction (p)

The Critical depletion fraction (p) represents the critical soil moisture level where first drought stress occurs affecting crop evapotranspiration and crop production. Values are expressed as a fraction of Total Available Water (TAW)and normally vary between 0.4 and 0.6, with lower values taken for sensitive crops with limited rooting systems under high evaporative conditions, and higher values for deep and densely rooting crops and low evaporation rates.

Additional parameters for Rice:

Nursery area|Rice

The nursery area represents the fraction of the field initially used for the germination and initial development of seedlings to be transplanted to the whole field after a few weeks. Normal size of nurseries fluctuates between 5 and 15% of the area. Since it represents only a fraction of the total cropped area, crop water requirements are proportionally calculated.

Pudding depth

The pudding process of rice fields involves the destruction of the natural soil structure by intensive tillage when the soil is saturated with water. This is done intentionally with the objective of reducing percolation losses. Pudding makes the surface soil dispersible and produces a surface layer that has uniform aggregates and predominantly vesicular pores when dry. The thickness of such a layer represents the Pudding depth.

Transplanting date

In case of rice cultivation, plants can be initially sown in a Nursery area, to be transplanted over the whole field afterwards. Transplanting date is normally determined from climatic conditions (for instance start of the rainy season) and local agricultural practices. It is possible to choose for the same location, different transplanting dates.

3.7.5 Soil module

Soil module presented as in figure 3.5. The following parameters include in soil module.

Total Available Water (TAW)

The Total Available Water (TAW) represents the total amount of water available to the crop. It is defined as the difference in soil moisture content between Field Capacity (FC) and Wilting Point (WP). There is no water available for the plants above the FC level as water cannot be held against the force of gravity and it naturally drains as deep percolation.

Maximum infiltration rate

The Maximum infiltration rate, expressed in mm per day, represents the water depth that can infiltrate in the soil over a 24-hours period, as a function of soil type, slope class and rain or irrigation intensity. The maximum infiltration rate has the same value as the soil hydraulic conductivity under saturation. The Maximum infiltration rate allows an estimate of the Runoff (RO), occurring whenever rain intensity exceeds the infiltration capacity of the soil.

Maximum rooting depth

Although in most cases the genetic characteristics of the crop will determine the Rooting depth, sometimes the soil and certain disturbing soil layers may restrict the maximum rooting depth. This is the case, for example, when hardpans exist in fields where mechanised practices have not been managed adequately. In rice fields the hardpan is instead intentionally created in order to diminish percolation losses and it limits the rooting depth of the crop .The Maximum rooting depth is expressed in centimetres.

Initial soil moisture depletion

The Initial soil moisture depletion indicates the dryness of the soil at the start of the growing season that is at seeding in case of non-rice crops, or at the beginning of land preparation, in case of rice.

The Initial soil moisture depletion is expressed as a percentage of the Total Available Water (TAW), in terms of depletion from Field Capacity (FC). Default value of 0 % represents a fully wetted soil profile at FC, 100 % is a soil at Wilting Point (WP).

Initial available soil moisture

It is defined as the soil moisture content at the start of the growing season. It is calculated as the product of the Total Available Water (TAW) by the Initial soil moisture depletion, and expressed in mm per metre of soil depth

Additional parameters for Rice

Critical depletion for puddle cracking

The critical depletion for puddle cracking represents the soil moisture level at which cracks developing during drying penetrate into the soil reaching the pudding depth. When this occurs and depending on the drainage characteristics of the soil, added water may seep through the cracks directly into the subsoil without much remaining within the root zone. Once the puddled soil layer has cracked it cannot be restored by adding water to the soil. The soil needs to be puddled again for the next season. The critical depletion for puddle cracking depends on the way the puddle was prepared, as well as on soil texture, structure and organic matter content. Values are expressed as a fraction of the Total Available Water (TAW). A critical depletion factor for puddle cracking close to 1 represents cracking occurring in a situation of rather wetted soil profile (soil close to Field Capacity); values close to 0 indicate cracking occurring when the soil moisture is close to Wilting Point. A cero value for this parameter represents a soil that does not crack even at welting point.

Drainable porosity

Drainable porosity is the difference between saturation and field capacity of the soil.

Maximum water depth

The Maximum water depth represents the maximum level of water over the inundated rice fields. It depends on the height of the field boundaries and on the quality of field leveling.

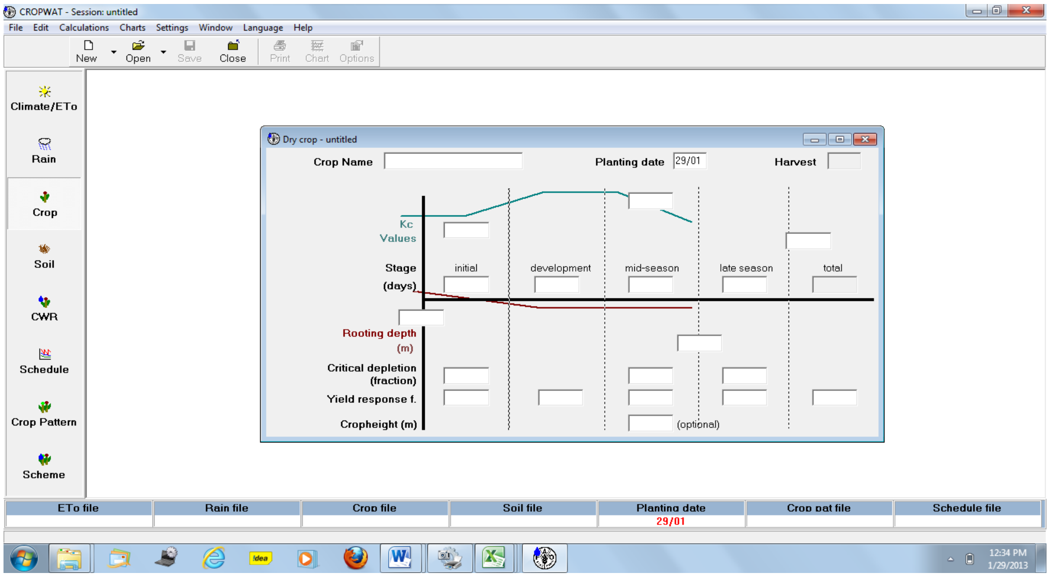


Fig. 3.4 Crop module

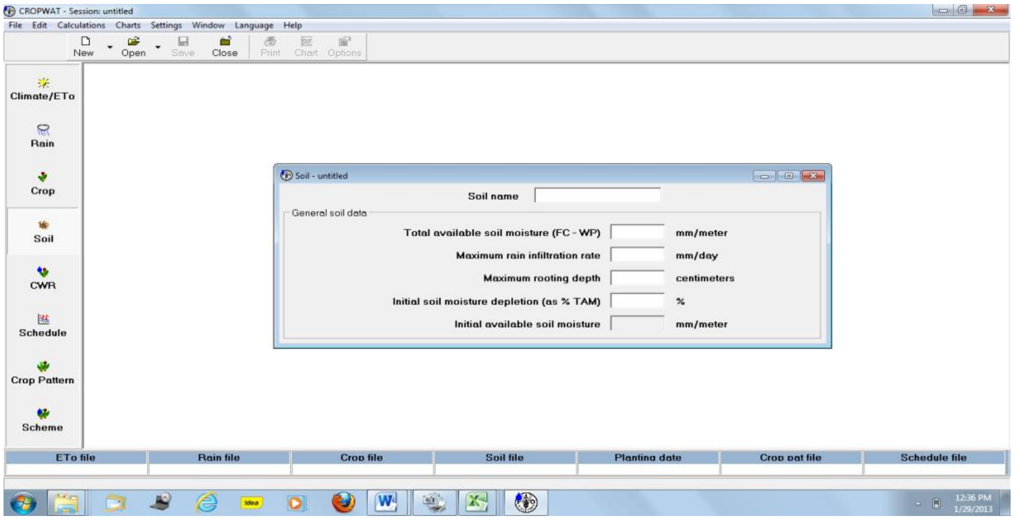


Fig. 3.5 Soil module

3.7.6 CWR (Crop Water Requirement) module

The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for Crop evapotranspiration under standard conditions (ETc) and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. The crop water requirement module includes calculations, producing the irrigation water requirement of the crop on a decade basis and over the total growing season, as the difference between the Crop evapotranspiration under standard conditions (ETc) and the Effective rainfall.

3.7.6.1 Penman-Monteith equation

In 1948, Penman combined the energy balance with the mass transfer method and derived an equation to compute the evaporation from an open water surface from standard climatological records of sunshine, temperature, humidity and wind speed. This so-called combination method was further developed by many researchers and extended to cropped surfaces by introducing resistance factors.

The resistance nomenclature distinguishes between aerodynamic resistance and surface resistance factors. The surface resistance parameters are often combined into one parameter, the 'bulk' surface resistance parameter which operates in series with the aerodynamic resistance. The surface resistance, r_s, describes the resistance of vapour flow through stomata openings, total leaf area and soil surface. The aerodynamic resistance, $r_{a,}$ describes the resistance from the vegetation upward and involves friction from air flowing over vegetative surfaces. Although the exchange process in a vegetation layer is too complex to be fully described by the two resistance factors, good correlations can be obtained between measured and calculated evapotranspiration rates, especially for a uniform grass reference surface.

The Penman-Monteith form of the combination equation is:

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$

Where R_n is the net radiation, G is the soil heat flux, $(e_s - e_a)$ represents the vapour pressure deficit of the air, ρ_a is the mean air density at constant pressure, c_p is the specific heat of the air, Δ represents the slope of the saturation vapour pressure temperature relationship, γ is the psychrometric constant, and r_s and r_a are the (bulk) surface and aerodynamic resistances. The Penman-Monteith approach as formulated above includes all parameters that govern energy exchange and corresponding latent heat flux (evapotranspiration) from uniform expanses of vegetation. Most of the parameters are measured or can be readily calculated from weather data. The equation can be utilized for the direct calculation of any crop evapotranspiration as the surface and aerodynamic resistances are crop specific.

Crop coefficient (Kc)|Non-rice crop

Explained in the previous section (Crop module).

Crop evapotranspiration under standard conditions (ETc)

Crop evapotranspiration under standard conditions (ETc) represents the evapotranspiration from disease-free, well-fertilised crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions. According to the Crop coefficient approach, ETc is calculated by multiplying the Reference evapotranspiration (ETo) (determined through the FAO Penman-Monteith method) by the Crop coefficient (Kc).

Effective Rainfall

Explained in the previous section (Rainfall module).

Irrigation requirement or Precipitation deficit

The Irrigation requirement, expressed in mm and computed over a certain period of time, expresses the difference between the Crop evapotranspiration under standard conditions (ETc) and the Effective Rainfall contributions over the same time step.

Stages|Non-rice crops

Explained in the previous section (Crop module).

3.7.7 Schedule module

The Schedule module essentially includes calculations, producing a Soil water balance on a daily step.

Soil Water Balance

The soil water balance aims to evaluate the soil moisture status accounting of all ingoing and outgoing water in the root zone over a defined time step.

To express the water content as root zone depletion is useful as it makes the adding and subtracting of losses and gains straightforward as the various parameters of the soil water budget are usually expressed in terms of water depth. In the Schedule module of CROPWAT 8.0, the soil water balance is carried out on a daily basis, according to:

$$Dr,i = Dr,i-1 + ETc\ adj,i - P,i - I,i + (RO,i + DP,i)$$

where:

Dr = Root zone depletion on days i and i-1

ETc adj = Crop evapotranspiration under non-standard conditions on day i

P = Total rainfall over day i

I = Net irrigation on day i

RO = Water loss by runoff from the soil surface on day i;

DP = Water loss by deep percolation on day i

Dr is calculated prior to irrigation application, if any.

Rainfall

Total and net effective rainfall is used for water balance calculations, since losses due to Deep Percolation (DP) and surface Runoff (RO) are estimated according to actual soil moisture content in the root zone and Maximum infiltration rate respectively.

Water stress coefficient (Ks)

The Water stress coefficient (Ks) allows to describe the effect of soil water deficit on crop evapotranspiration, which is assumed to decrease linearly in proportion to the reduction of water available in the root zone.

Crop evapotranspiration under non-standard conditions (ETc adj)

The Crop evapotranspiration under non-standard conditions (ETc adj) is the evapotranspiration from crops grown under management and environmental conditions that differ from the standard optimal conditions. ETc adj due to water shortage is calculated by mean of the Crop water stress coefficient (Ks) according to the following equation:

ETc adj = ETc * Ks

For soil water limiting conditions, Ks < 1. Where there is no soil water stress, Ks = 1.

Root zone depletion (Dr)

The Root zone depletion (Dr) represents the water shortage relative to Field Capacity (FC). It can be expressed as a percentage or in mm over the rooting depth.

Net irrigation

The Net irrigation represents the water depth (expressed in mm) that is used beneficially. It is calculated as the product of the Gross irrigation depth by the Irrigation efficiency.

Deficit

Amount of water (in mm) below field capacity.

Irrigation losses

Irrigation water reaching the root zone, that is Net irrigation, is not always advantageously used by the crop. In case the Net irrigation contribution brings the soil moisture content to exceed the Field Capacity (FC), the amount of water above FC is assumed to be lost by Deep Percolation (DP). This irrigation depth exceeding FC is computed as Irrigation losses. In the Soil water balance of the Schedule module, Irrigation losses are calculated on a daily basis and summed up over the growing season as Total irrigation losses.

Gross irrigation

Gross irrigation represents the water depth (expressed in mm) applied to the field. Since the Irrigation efficiency is usually lower than 100 %, only a fraction of the Gross irrigation depth, that is, the Net irrigation depth, effectively reaches crop root zone.

Flow

In the Schedule module, the Flow represents the continuous water discharge needed to satisfy crop irrigation requirements over the irrigation interval period. It is expressed in litre per second per hectare and calculated converting the Gross irrigation application depth into a permanent supply.

Puddling state

It is identified as Prep (Preparation, corresponding to the pre-puddling period), OK (optimal puddling condition) and Broken (occurring when the soil moisture depletion goes below the Readily Available Water (RAW) of the root zone)

Deep Percolation (DP)

Each time the water content in the root zone exceeds Field Capacity (FC), it is assumed that DP takes place. The way in which the maximum percolation rate and its daily decrease during puddling are estimated can be set in the Scheduling option | rice crop .

Depl. SM

Depletion of soil moisture corresponding to the amount of water (in mm) below field capacity.

Depl. SA

Depletion of saturation is the amount of water below saturation moisture soil content.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to estimate the crop water requirement of various crops in KCAET instructional farm. The soil physical characteristics such as bulk density, field capacity, permanent wilting point, and saturated permeability were studied.

The results obtained from the CROPWAT model were analyzed to provide basic information of crop water requirement of various crops and irrigation scheduling .The results of the study are discussed in this chapter under the following sub headings.

4.1 Evaluation of soil physical properties

The following basic soil properties which are the primary input data for CROPWAT model were determined.

4.1.1 Soil Texture

The results of the soil textural analysis are given in appendix I. The results of the mechanical analysis (sieve analysis) were plotted to get particle size distribution curve. In this curve percentage finer 'N' is taken as ordinate and particle diameter (mm) as the abscissa on logarithmic scale. It was obtained from the sieve analysis that the coarse fraction was 87.6% (C block), 85.9% (G block), 85.82% (B block) and 60 %(P block) and the rest was a mixture of silt and clay in very small amount are 12.4%, 14.1%, 14.18% and 40% respectively. The resulting curves are shown in figures 4.1, 4.2, 4.3 & 4.4.

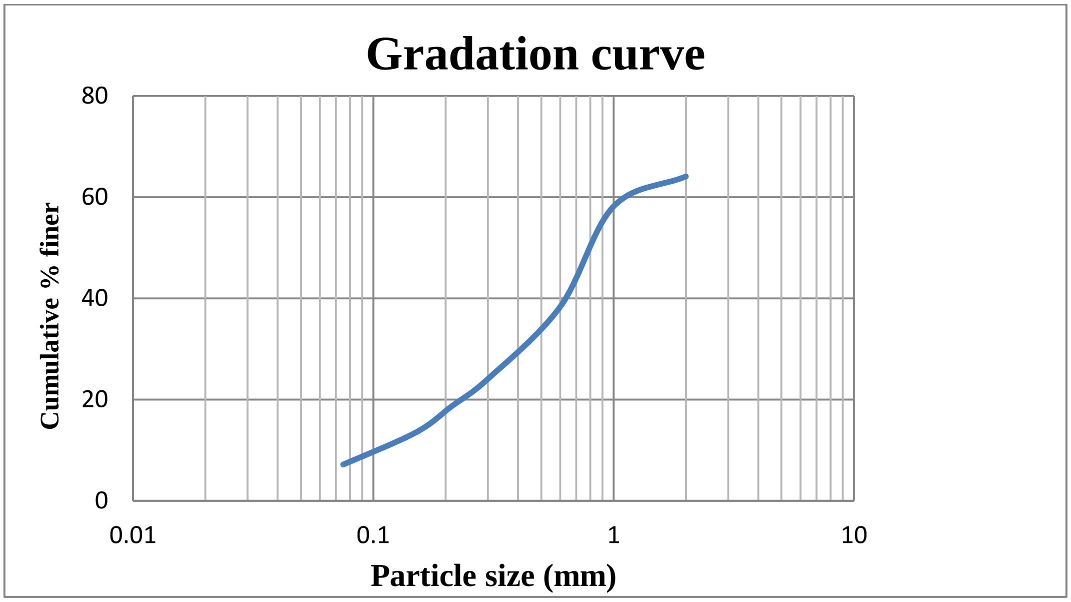


Fig.4.1 Gradation curve for the soil sample from Coconut field (P block)

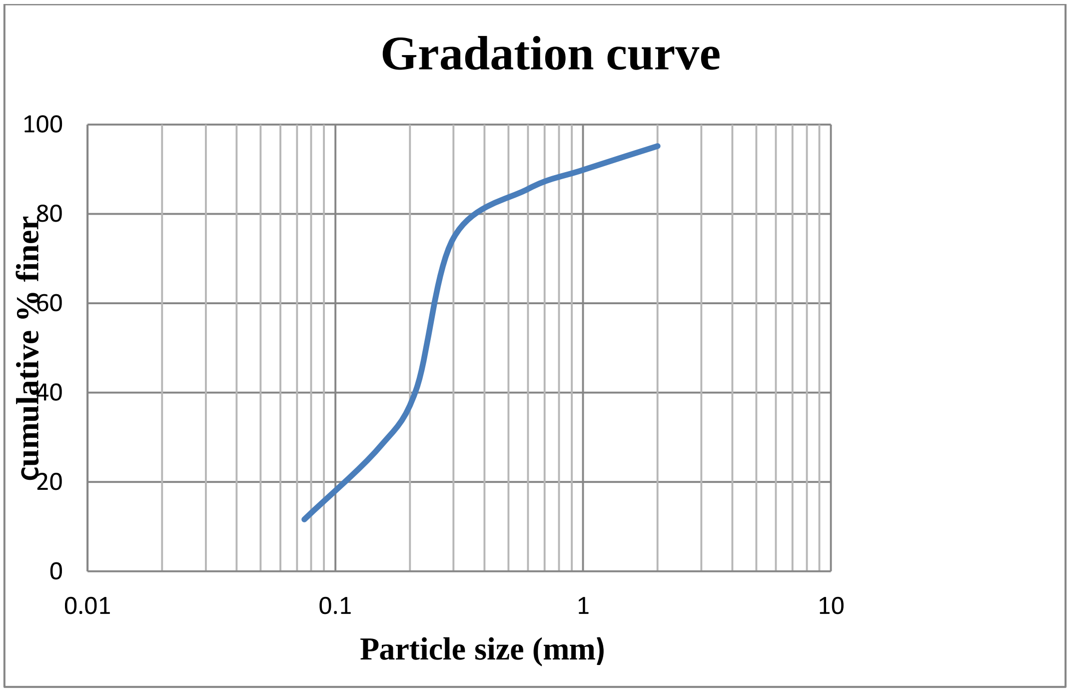


Fig. 4.2 Gradation curve for the soil sample from Mango field (C block)

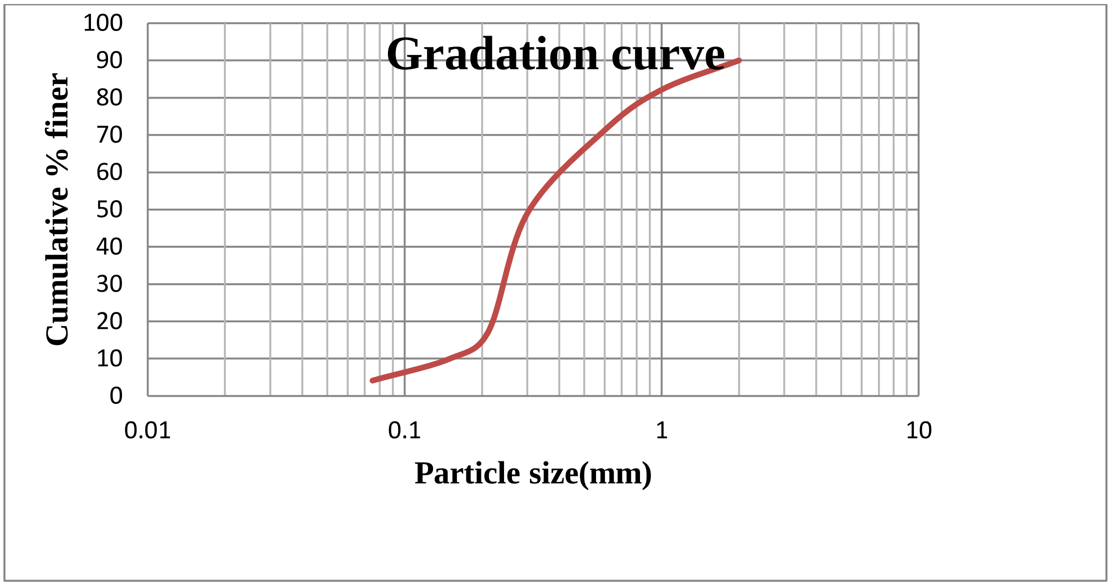


Fig. 4.3 Gradation curve for the soil sample from Coconut field (G block)

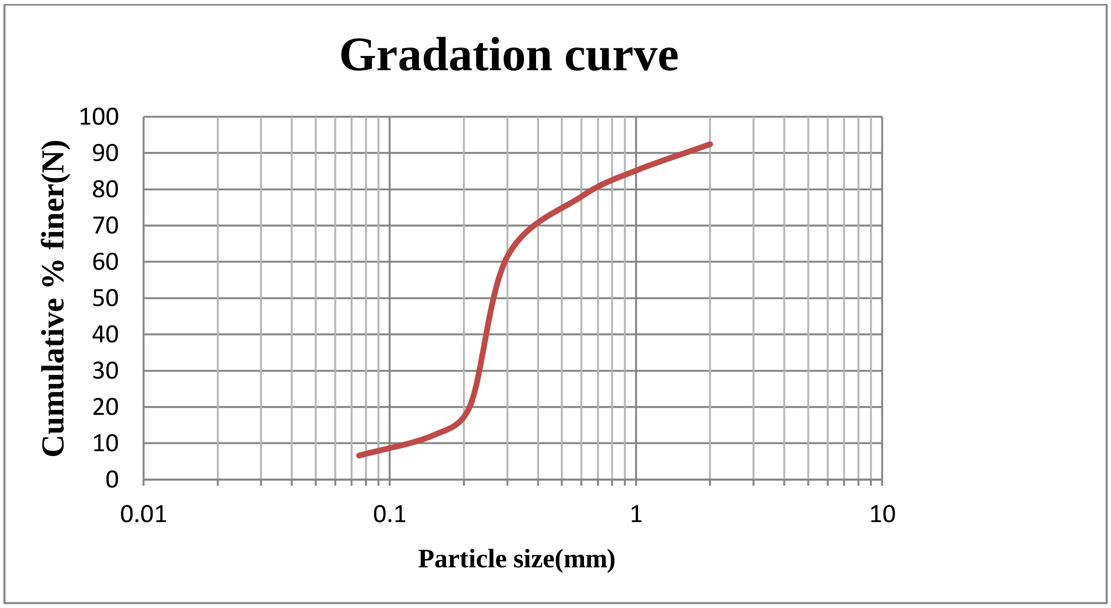


Fig. 4.4 Gradation curve for the soil sample from Paddy field (B block)

Table 4.1. Grain size distribution of soil sample (P block)

Elapsed Time (minute)	Hydrometer Reading R_b	Effective Depth(H_e)	Particle Size(mm)	Percentage finer	Factor(F)
½	7.5	16.0	0.07020	27.74	1245
1	7.5	16.0	0.04964	27.75	1245
2	6.75	16.5	0.03564	24.97	1245
4	6	16.7	0.02530	22.2	1245
8	5.75	17.3	0.01824	21.27	1245
16	3.75	17.8	0.01308	13.87	1245
30	3	17.9	0.009586	11.1	1245
60	2	18.2	0.006834	7.4	1245
120	1.5	19.1	0.004859	5.55	1245
240	1	19.3	0.0035	3.7	1245
480	0.5	19.3	0.002488	1.85	1245
960	0.5	19.3	0.001706	1.85	1245
1440	0	19.3	0.001444	0	1245

4.1.2 Bulk Density

The bulk density of the soil in the experimental field was found by core cutter method. The weight and volume of core cutter and weight of the soil samples are given in the table 4.2.

Table 4.2 Result of bulk density analysis

Sl no	Particulars	units	Sample1	Sample2
1	Mass of container + wet sample (M_1)	g	64.5	72
2	Mass of container (M_2)	g	23	22.5
3	Mass of wet sample (M_3)	g	41.5	57.5
4	Moisture content	%	0.19	0.16
5	Bulk density	g/cc	1.85	1.8
6	Dry density	g/cc	1.55	1.55

4.1.3 Soil moisture characteristics

The values of Field capacity and Permanent wilting point for samples obtained from three different blocks (P block, B block, C block) found using pressure plate apparatus is listed in the table 4.3

4.2 Climate data

The data of minimum temperature, maximum temperature, humidity, sunshine hours and wind speed obtained in 10 days interval for 20 years is fed to the climate module of the software. The model gives values of radiation ($MJ/m^2/day$) and reference evapotranspiration (mm/day) and the same is listed in appendix II.

Table 4.3 Determination of available water for soil samples

			Mass of container (g)	Mass of wet soil+ Mass of container (g)	Mass of dry soil+ Mass of container (g)	Mass of dry soil (M_d) (g)	Moisture content (%)	Available Water (%)
C block	FC	F1	7	30	28	21	9.52	2.02
	PWP	P1	14	35.5	34	20	7.5	
B block	FC	F2	9	28.5	27	18	8.33	5.47
	PWP	P2	13.5	31.5	31	17.5	2.86	
P block	FC	F3	9	30	27.5	18.5	13.5	1.96
	PWP	P3	8.5	23	21.5	13	11.54	

4.3 Rainfall data

The rainfall data for all the three decades of a month were compiled. The effective rainfall (mm) was computed using the datas obtained by the model and the same is listed in the appendix III.

4.4 Estimation by CROPWAT model

The input data i.e. soil, climate and crop related to the study area were fed to the CROPWAT model to estimate the CWR and Irrigation scheduling. Crop data, soil data, crop water requirement and irrigation scheduling of various crops are respectively shown in the following tables and the corresponding graphs are also included.

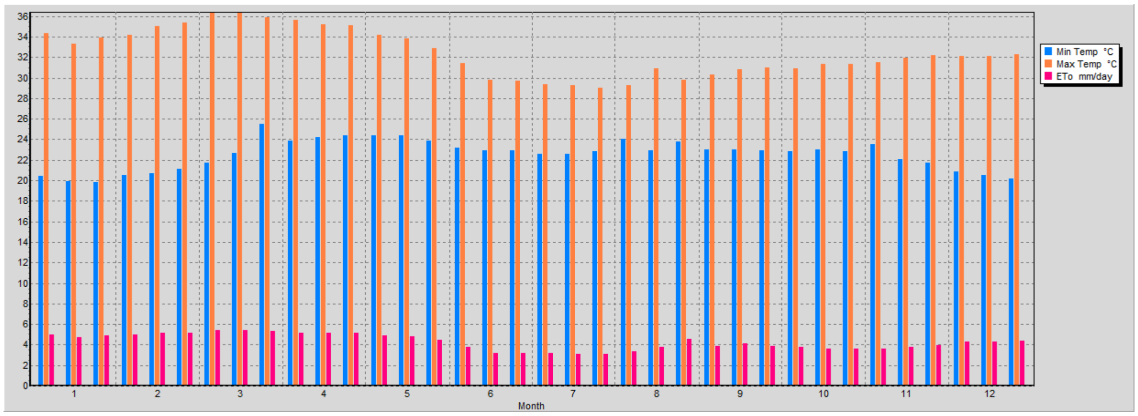


Fig.4.5 Variation of Minimum Temperature (ºc), Maximum Temperature (◦c) and ET$_o$(mm/day) with respect to Months

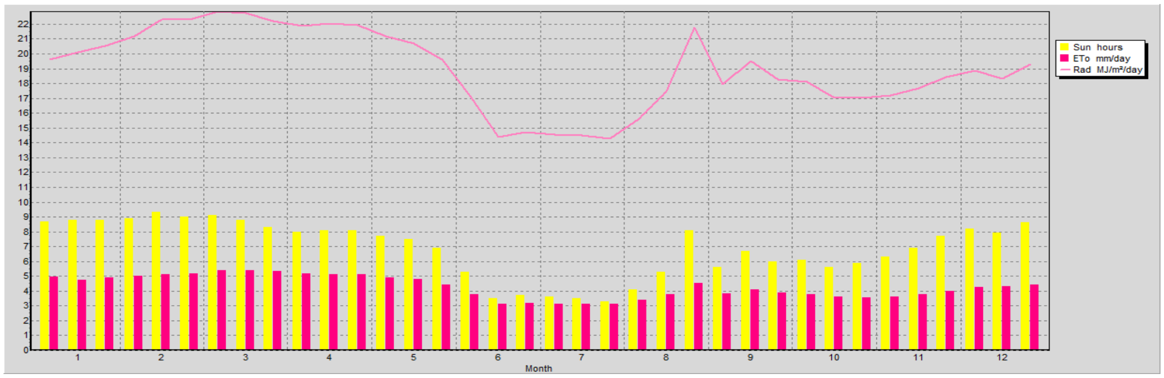


Fig 4.6 Variation of Sun (hours),ET$_o$(mm/day) and Radiation(MJ/m^2/day) with respect to Month

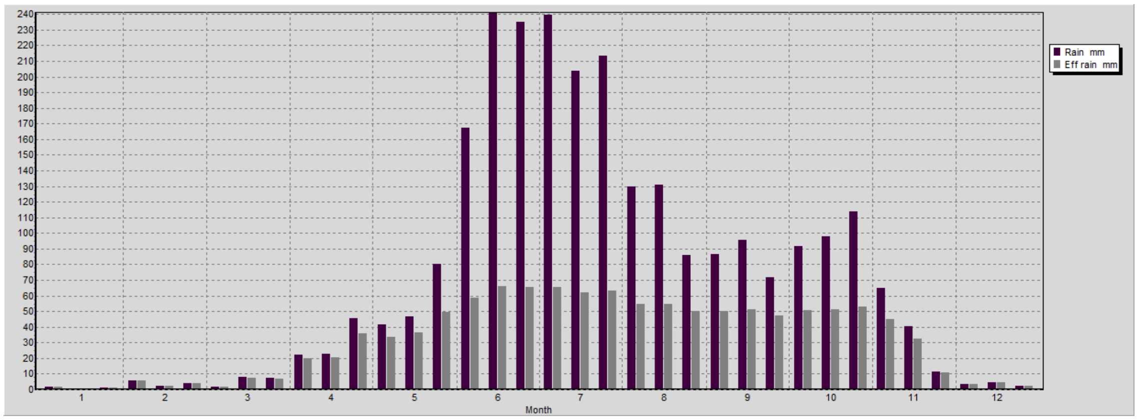


Fig 4.7 Rain (mm) and Effective rain (mm) variation during the month

The fig 4.5 shows the minimum temperature (ºc), maximum temperature (ºc), and ETo (mm/day) variation during the month. From the figure these datas can be easily distinguished. The maximum temperature was recorded during the first and second decade of March and the minimum temperature was recorded during the third decade of January. From the figure it is evident that temperature influences the ETo value and the maximum ETo is obtained for the period with maximum temperature.

The fig 4.6 presents sun (hours), ET_o (mm/day) and radiation ($MJ/m^2/day$) variation during month. From the figure these datas can be easily distinguished. The maximum sunshine hour was recorded during the second decade of February and the minimum sunshine hour was recorded during the third decade of July. The maximum ETo and radiation were recorded during the first decade of March and the minimum were third decade of July. From the figure it is clear that sunshine and radiation influences the reference evapotranspiration.

The fig 4.7 shows the Rain (mm) and Effective rain (mm) versus Month. From the figure total rainfall data and rain used for the crop can be easily distinguished. High rainfall was recorded during the month of July and low rainfall was recorded during the month of January.

4.4.1. Model input and output parameters for selected crops

The various primary data related to the crops of the study area are listed in the Tables 4.4, 4.8, 4.12,4.16,4.20,4.24,4.28,4.32,4.36,4.40 and 4.44 respectively.

The soil primary data are given as the input to each cropped area and output obtained is the initial available soil moisture. These datas are listed in the Tables 4.5, 4.9, 4.13, 4.17, 4.21, 4.25, 4.29, 4.33, 4.37, 4.41 and 4.45 respectively.

Table 4.4 Crop data- Amaranthus

Crop data Dry crop Crop name: Amaranthus			Planting date:07/12/2011 Harvest date:30/01/2012		
Stages(days)	Initial	develop	Mid	late	total
Legth(days)	10	15	20	10	55
Kc Values	0.3		1	0.95	
Rooting depth(m)	0.3			0.5	
Critical depletion(fraction)	0.3		0.3	0.3	
Yield response f.	1.1	1.1	1.1	1.1	1.1
Cropheight (m)			0.6		

Table 4. 5 Soil datas –Amaranthus

Soil name: Sandy loam General soil data:	
Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	60centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4. 6 Estimation of Crop water requirement- Amaranths

Eto station: Pattambi	Crop: Amaranthus
Rain station: Pattambi	Planting date:07/12/2011

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.3	1.28	5.1	1.3	3.4
Dec	2	Deve	0.35	1.49	14.9	4.4	10.5
Dec	3	Deve	0.76	3.36	37	2.3	34.7
Jan	1	Mid	1	4.93	49.3	1.8	47.5
Jan	2	Mid	1	4.74	47.4	0	47.4
Jan	3	Late	0.97	4.72	47.2	0.5	46.7
					200.9	10.3	190.2

Table 4.6 presents the results of CWR calculations for Amaranthus. Total irrigation requirement is computed by adding irrigation requirement of each stage of the Amaranthus and the value obtained is 190.2mm/dec.

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

Figure 4.8 presents the monthly variation of ETc and Irrigation requirement of Amaranthus. The inference obtained from the graph is as follows:

- The maximum irrigation requirement for Amaranthus was during the month of January i.e. at its middle stage and the minimum irrigation requirement was during December at its initial stage and the values obtained were 37.5mm/dec and 3.4mm/dec respectively.

- The maximum ETc of Amaranthus was obtained during the month of January and the minimum is during December and the values obtained are 49.3 and 5.1mm/dec.

Table 4. 7 Irrigation schedule – Amaranthus

CROP IRRIGATION SCHEDULE			
Total gross irrigation	274.4mm	Total rainfall	10.8 mm
Total net irrigation	192.1 mm	Effective rainfall	8.5 mm
Total irrigation losses	0 mm	Total rain loss	2.3 mm
Actual water use by crop	196.1mm	Moisture deficit at harvest	4.7mm
Potential water use by crop	196.2mm	Actual irrigation requirement	187.7mm
Efficiency irrigation schedule	100%	Efficiency rain	78.70%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Amaranthus was 274.4mm for a total net irrigation of 192.1mm.The total irrigation losses were considered as zero. The actual water use by the crop was considered to be 196.1mm and the potential water use by the crop is 196.2mm.The efficiency and deficiency of the irrigation schedule were considered to be 100 and zero respectively as the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 10.8mm and 80.5mm respectively, from which the total rain loss was calculated to be 2.3mm. Moisture deficit at harvest was considered to be zero. The efficiency of rain for the Amaranthus was 78.70%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was considered to be as 187.7mm.

Table 4.8 Crop data -Snake gourd

Crop data Dry crop Crop name: Snake gourd			Planting date:31/01/12 Harvest date:30/05/2012		
Stages(days)	initial	develop	Mid	late	total
Legth(days)	30	45	35	10	120
Kc Values	0.5		1	0.8	
Rooting depth(m)	0.6			0.8	
Critical depletion(fraction)	0.5		0.5	0.5	
Yield response f.	1.1	1.1	1.1	1.1	1.1
Cropheight (m)			2		

Table 4.9 Soil data - Snake gourd

Soil name: Sandy loam General soil data:	
Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	100centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4.10 Estimation of Crop water requirement-Snake gourd

Eto station: Pattambi Rain station: Pattambi					Crop: Snake gourd Planting date:31/01/2012		
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	3	Init	0.5	2.44	2.4	0	2.4
Feb	1	Init	0.5	2.51	25.1	5.6	19.5
Feb	2	Init	0.5	2.56	25.6	2.3	23.3
Feb	3	Init	0.5	2.58	20.7	3.7	16.9
Mar	1	Deve	0.54	2.93	29.3	1.9	27.4
Mar	2	Deve	0.64	3.45	34.5	7.5	27
Mar	3	Deve	0.74	3.95	43.5	7	36.5
Apr	1	Deve	0.84	4.33	43.3	19.8	23.5
Apr	2	Mid	0.92	4.75	47.5	20.4	27.1
Apr	3	Mid	0.93	4.8	48	35.7	12.2
May	1	Mid	0.93	4.56	45.6	33.4	12.2
May	2	Mid	0.93	4.46	44.6	36.2	8.4
May	3	Late	0.82	3.61	36.1	44.9	0
					446.1	218.5	236.5

Table 4.10 presents the total irrigation requirement is computed by adding irrigation requirement of each stages of the Snake gourd and the value obtained is 236.5mm/dec.

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

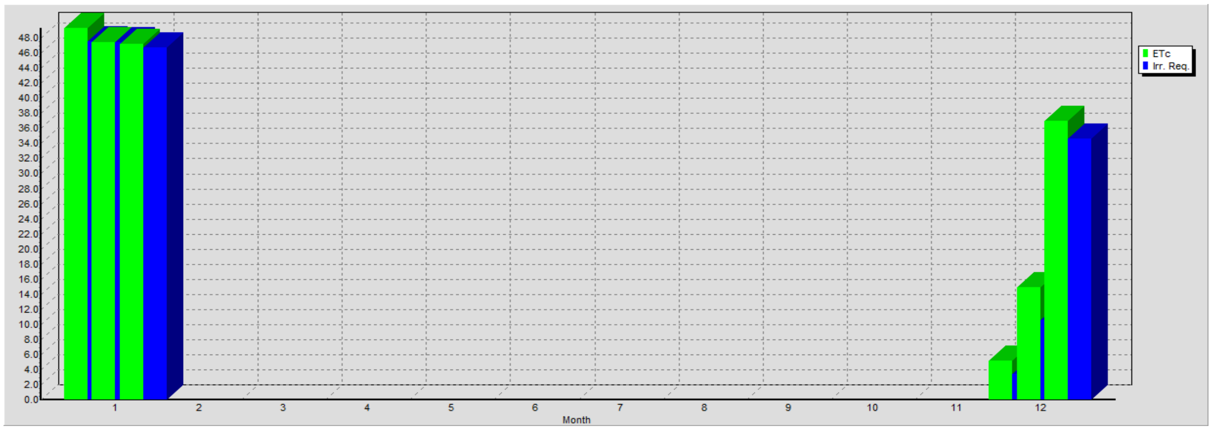


Fig 4.8 Monthly variation of ETc and Irrigation requirement of Amaranthus

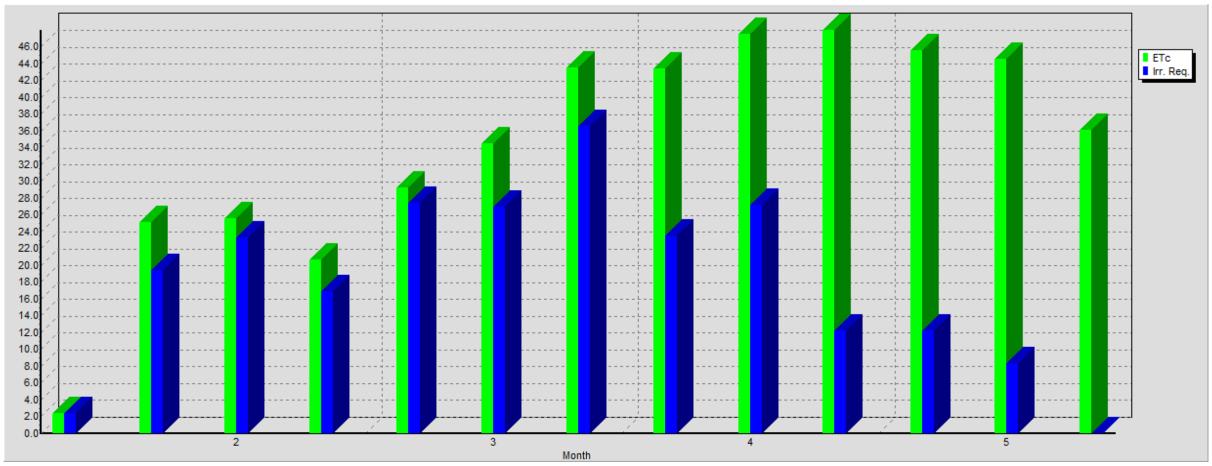


Fig4.9 Monthly variation of ETc and Irrigation requirement of snake gourd

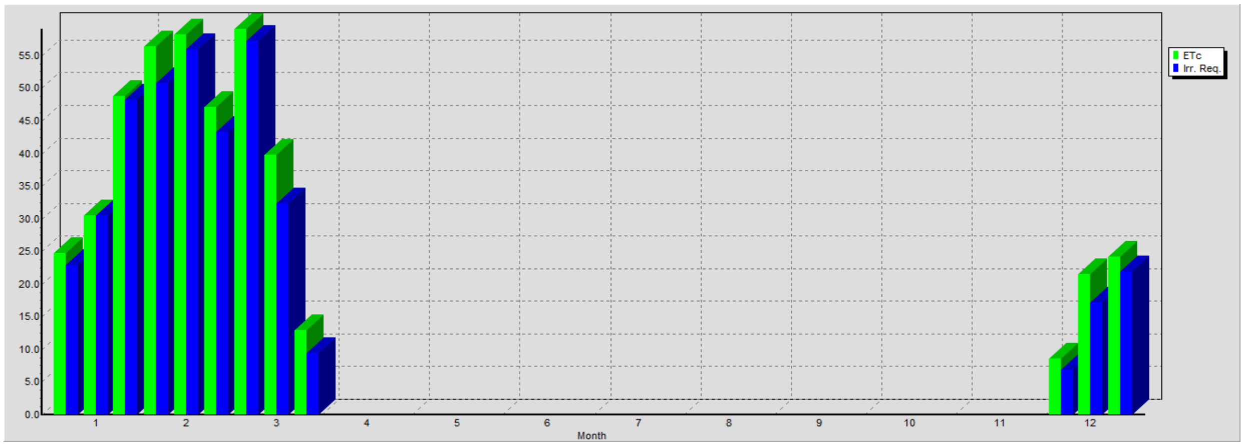


Fig 4.10 Monthly variation of ETc and Irrigation requirement of Cowpea

Figure 4.9 presents the monthly variation of ETc and Irrigation requirement of Snake gourd. The inference obtained from the graph is as follows:

- The maximum irrigation requirement for Snake gourd is during the month of March i.e. at its development stage and the minimum irrigation requirement is during May at its late stage and the values obtained are 36.5mm/dec and 0mm/dec respectively.
- The maximum ETc of Snake gourd is obtained during the month of April (mid stage) and the minimum is during January (initial stage) and the values obtained are 47.5 and 2.4mm/dec.

Table 4.11 Irrigation schedule of Snake gourd

CROP IRRIGATION SCHEDULE			
Total gross irrigation	493.5mm	Total rainfall	288.6mm
Total net irrigation	345.5mm	Effective rainfall	101mm
Total irrigation losses	0 mm	Total rain loss	187.6mm
Actual water use by crop	442.5mm	Moisture deficit at harvest	10.8mm
Potential water use by crop	442.5mm	Actual irrigation requirement	341.5mm
Efficiency irrigation schedule	100%	Efficiency rain	35.00%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Snake gourd was 493.5 mm for a total net irrigation of 345.5mm. The total irrigation losses were considered to be zero. The actual water use by the crop was found to be 442.5mm and the potential water use by the crop is 442.5mm. The efficiency and deficiency of the irrigation schedule were considered to be 100 and zero respectively as the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 288.6 mm and 101mm respectively, from which the total rain loss was calculated to be 187.6mm. Moisture deficit at harvest was considered to be 10.8mm. The efficiency of rain for the Snake gourd was 35%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was found to be as 341.5mm.

Table 4.12 Crop datas -Cowpea

Crop data — Planting date:07/12/2011
Dry crop — Harvest date:26/03/2012

Crop name: Cowpea

Stages(days)	initial	develop	mid	late	total
Legth(days)	35	25	30	20	110
Kc Values	0.5		1.15	0.3	
Rooting depth(m)	0.3			0.6	
Critical depletion(fraction)	0.45		0.45	0.45	
Yield response f.	1.15	1.15	1.15	1.15	1.15
Cropheight (m)			0.5		

Table 4. 13 Soil datas – Cowpea

Soil name: Sandy loam

General soil data:

Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	60centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4.14 Estimation of crop water requirement of Cowpea

Eto station: Pattambi Rain station: Pattambi					Crop: Cowpea Planting date:07/12/11		
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.5	2.13	8.5	1.3	6.9
Dec	2	Init	0.5	2.15	21.5	4.4	17.1
Dec	3	Init	0.5	2.2	24.2	2.3	21.9
Jan	1	Init	0.5	2.48	24.8	1.8	23
Jan	2	Deve	0.64	3.05	30.5	0	30.5
Jan	3	Deve	0.91	4.43	48.7	0.5	48.2
Feb	1	Mid	1.12	5.64	56.4	5.6	50.7
Feb	2	Mid	1.14	5.82	58.2	2.3	55.9
Feb	3	Mid	1.14	5.88	47	3.7	43.3
Mar	1	Late	1.1	5.91	59.1	1.9	57.2
Mar	2	Late	0.74	3.99	39.9	7.5	32.4
Mar	3	Late	0.4	2.16	13	3.8	9.5
					431.7	35.1	396.6

Table 4.14 presents the results of CWR calculations for Cowpea. The irrigation requirement of Cow pea is 396.6mm/dec. From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

Figure 4.10 presents the monthly variation of ETc and Irrigation requirement of Cowpea. The inference obtained from the graph is as follows:

- The maximum irrigation requirement for Cowpea is during the month of March i.e. at its late stage and the minimum irrigation requirement is during December at its initial stage and the values obtained are 57.2mm/dec and 6.9mm/dec respectively.

- The maximum ETc of Cowpea is obtained during the month of March (late stage) and the minimum is during December (initial stage) and the values obtained are 59.1 and 8.5mm/dec.

Table 4.15 Irrigation schedule of Cowpea

CROP IRRIGATION SCHEDULE			
Total gross irrigation	584.6mm	Total rainfall	36mm
Total net irrigation	410.5mm	Effective rainfall	23.7mm
Total irrigation losses	0 mm	Total rain loss	12.3mm
Actual water use by crop	429.6mm	Moisture deficit at harvest	6.5mm
Potential water use by crop	429.6mm	Actual irrigation requirement	405.9mm
Efficiency irrigation schedule	100%	Efficiency rain	65.70%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Cowpea was 493.5mm for a total net irrigation of 345.5mm. The total irrigation losses were considered as zero. The actual water use by the crop was found to be 442.5mm and the potential water use by the crop is 442.5mm. The efficiency and deficiency of the irrigation schedule were considered to be 100 and zero respectively as the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 288.6mm and 101mm respectively, from which the total rain loss was calculated to be 187.6mm. Moisture deficit at harvest was considered to be 10.8mm. The efficiency of rain for the Cowpea was 35%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was considered to be as 341.5mm.

Table 4.16 Crop data-Cucumber

Crop data Dry crop Crop name: Cucumber			Planting date:16/12/2011 Harvest date:30/03/2012		
Stages(days)	initial	develop	mid	late	total
Legth(days)	20	30	40	15	105
Kc Values	0.6		1	0.75	
Rooting depth(m)	0.5			0.8	
Critical depletion(fraction)	0.5		0.5	0.5	0.5
Yield response f.	1.1	1.1	1.1	1.1	1.1
Cropheight (m)			0.3		

Table 4.17 Soil datas –Cucumber

Soil name: Sandy loam General soil data:	
Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	150centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4.18 Estimation of crop water requirement -Cucumber

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	2	Init	0.6	2.59	12.9	2.2	10.7
Dec	3	Init	0.6	2.64	29	2.3	26.8
Jan	1	Deve	0.63	3.11	31.1	1.8	29.3
Jan	2	Deve	0.75	3.56	35.6	0	35.6
Jan	3	Deve	0.89	4.32	47.5	0.5	47
Feb	1	Mid	0.98	4.94	49.4	5.6	43.8
Feb	2	Mid	0.99	5.06	50.6	2.3	48.3
Feb	3	Mid	0.99	5.11	40.9	3.7	37.2
Mar	1	Mid	0.99	5.33	53.3	1.9	51.4
Mar	2	Late	0.96	5.18	51.8	7.5	44.3
Mar	3	Late	0.8	4.28	42.8	6.3	35.8
					444.9	34.1	410.2

Table 4.18 presents the results of CWR calculations for Cucumber. Effective rain of the Cucumber is 34.0mm/dec and the irrigation requirement is 410.2mm/dec.

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

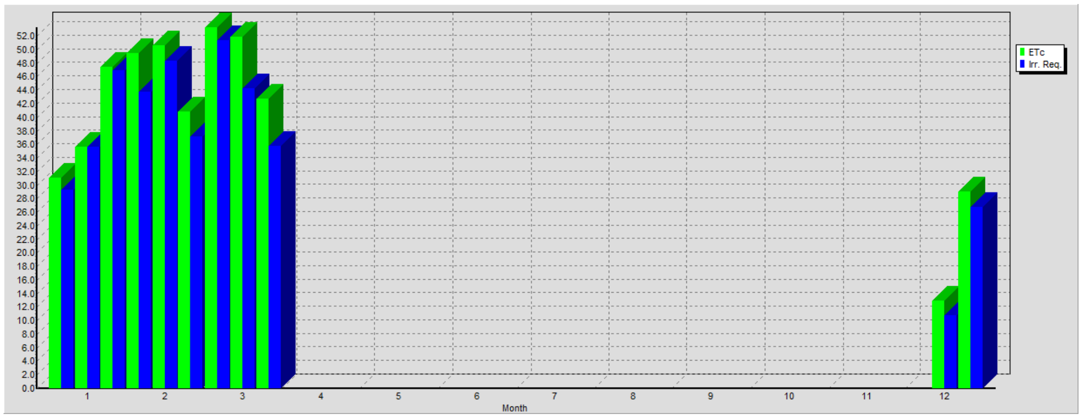


Fig 4.11 Monthly variation of ETc and Irrigation requirement of Cucumber

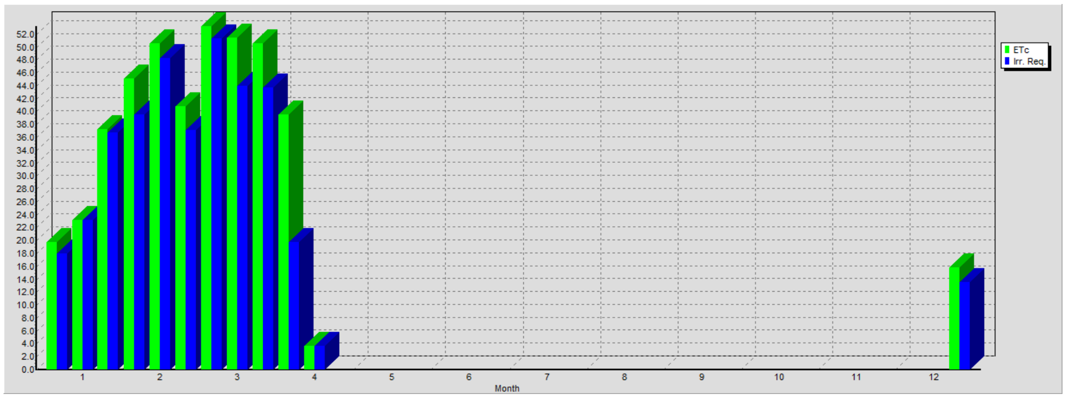


Fig 4.12 Monthly variation of ETc and Irrigation requirement of Water melon

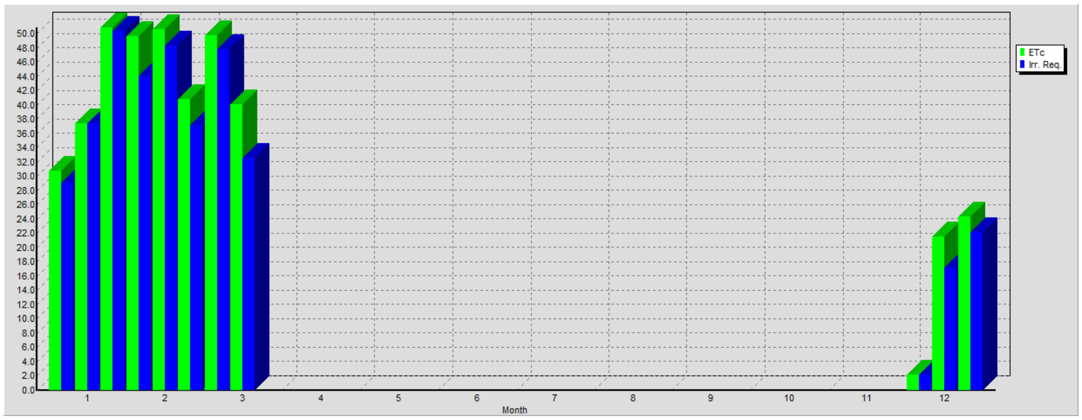


Fig 4.13 Monthly variation of ETc and Irrigation requirement of Pumpkin

Figure 4.11 presents the monthly variation of ETc and Irrigation requirement of Cucumber. The inference obtained from the graph is as follows:

- The maximum irrigation requirement for Cucumber is during the month of March i.e. at its mid stage and the minimum irrigation requirement is during December at its initial stage and the values obtained are 51.4mm/dec and 10.7mm/dec respectively.
- The maximum ETc of Cucumber is obtained during the month of March (late stage) and the minimum is during December (initial stage) and the values obtained are 53.3 and 12.9mm/dec.

Table 4.19 Irrigation schedule of Cucumber

CROP IRRIGATION SCHEDULE			
Total gross irrigation	600.2mm	Total rainfall	35.6mm
Total net irrigation	420.1mm	Effective rainfall	22.1mm
Total irrigation losses	0 mm	Total rain loss	13.1mm
Actual water use by crop	440.7mm	Moisture deficit at harvest	12.8mm
Potential water use by crop	440.7mm	Actual irrigation requirement	418.2mm
Efficiency irrigation schedule	100%	Efficiency rain	63.1%%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Cucumber was 600.2mm for a total net irrigation of 420.1mm.The total irrigation losses were considered as zero. The actual water use by the crop was found to be 440.7mm and the potential water use by the crop is 440.7mm. The efficiency and deficiency of the irrigation schedule were considered to be 100 and zero respectively as the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 35.6mm and 22.1mm respectively, from which the total rain loss was calculated to be 13.1mm. Moisture deficit at harvest was considered to be 12.8mm. The efficiency of rain for the Cucumber was 63.1%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which considered to be as 418.2mm.

Table 4.20 Crop datas- Water melon

Crop data Dry crop Crop name: Water melon				Planting date:23/12/2011 Harvest date:11/14/2012	
Stages(days)	initial	develop	mid	late	total
Legth(days)	20	30	30	30	110
Kc Values	0.4		1	0.75	
Rooting depth(m)	0.5			1.2	
Critical depletion(fraction)	0.4		0.4	0.4	
Yield response f.	1.1	1.1	1.1	1.1	1.1
Cropheight (m)			0.4		

Table 4.21. Soil datas - Water melon

Soil name: Sandy loam General soil data:	
Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	150centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4.22 Estimation of crop water requirement of Water melon

Eto station: Pattambi Rain station: Pattambi					Crop: Water melon Planting date:11/04/2012		
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	3	Init	0.4	1.76	15.8	1.9	13.6
Jan	1	Init	0.4	1.98	19.8	1.8	18
Jan	2	Deve	0.49	2.32	23.2	0	23.2
Jan	3	Deve	0.69	3.38	37.2	0.5	36.7
Feb	1	Deve	0.9	4.52	45.2	5.6	39.5
Feb	2	Mid	0.99	5.05	50.5	2.3	48.2
Feb	3	Mid	0.99	5.1	40.8	3.7	37.1
Mar	1	Mid	0.99	5.32	53.2	1.9	51.4
Mar	2	Late	0.96	5.15	51.5	7.5	44
Mar	3	Late	0.86	4.6	50.6	7	43.7
Apr	1	Late	0.77	3.96	39.6	19.8	19.7
Apr	2	Late	0.72	3.7	3.7	2	3.7
					431.2	54	378.8

Table 4.22 presents the results of CWR calculations for Water melon. The effective rain and irrigation requirement of water melon are 54mm/dec and 378.8mm/dec respectively.

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

Figure 4.12 presents the monthly variation of ETc and Irrigation requirement of Water melon. The inference obtained from the graph is as follows:

- The maximum irrigation requirement for Water melon was during the month of March i.e. at its mid stage and the minimum irrigation requirement was during

April at its late stage and the values obtained are 51.4mm/dec and 3.7mm/dec respectively.

- The maximum ETc of Water melon was obtained during the month of March (mid stage) and the minimum was during April(late stage) and the values obtained were 53.2 and 3.7mm/dec.

Table 4.23 Irrigation schedule of Water melon

CROP IRRIGATION SCHEDULE			
Total gross irrigation	571.2mm	Total rainfall	55.6mm
Total net irrigation	399.9mm	Effective rainfall	45.8mm
Total irrigation losses	0 mm	Total rain loss	9.8mm
Actual water use by crop	427.4mm	Moisture deficit at harvest	4.0mm
Potential water use by crop	427.4mm	Actual irrigation requirement	381.7mm
Efficiency irrigation schedule	100%	Efficiency rain	82.30%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Water melon was 571.2mm for a total net irrigation of 399.9mm.The total irrigation losses were considered as zero. The actual water use by the crop was considered to be 427.4mm and the potential water use by the crop is 427.5mm.The efficiency and deficiency of the irrigation schedule was found to be 100 and zero respectively as the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 55.6mm and 45.8mm respectively, from which the total rain loss was calculated to be 9.8mm. Moisture deficit at harvest was considered to be 4mm. The efficiency of rain for the Water melon was 82.30%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was considered to be as 381.7mm.

Table 4.24 Crop datas –Pumpkin

Crop data | Planting date:10/12/2011
Dry crop | Harvest date:19/03/2012

Crop name: Cucumber

Stages(days)	initial	develop	mid	late	total
Legth(days)	20	30	30	20	100
Kc Values	0.5		1	0.8	
Rooting depth(m)	0.5			1	
Critical depletion(fraction)	0.5		0.5	0.5	0.5
Yield response f.	1.1	1.1	1.1	1.1	1.1
Cropheight (m)			0.4		

Table 4.25 Soil datas - Pumpkin

Soil name: Sandy loam

General soil data:

Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	160centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4.26 Estimation of crop water requirement – Pumpkin

Eto station: Pattambi Rain station: Pattambi					Crop: Pumpkin Planting date:10/12/2011		
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.5	2.13	2.1	0.3	2.1
Dec	2	Init	0.5	2.15	21.5	4.4	17.1
Dec	3	Deve	0.5	2.22	24.4	2.3	22.1
Jan	1	Deve	0.62	3.08	30.8	1.8	29
Jan	2	Deve	0.79	3.74	37.4	0	37.4
Jan	3	Mid	0.95	4.62	50.9	0.5	50.4
Feb	1	Mid	0.99	4.97	49.7	5.6	44
Feb	2	Mid	0.99	5.06	50.6	2.3	48.3
Feb	3	Late	0.99	5.11	40.9	3.7	37.1
Mar	1	Late	0.92	4.98	49.8	1.9	47.9
Mar	2	Late	0.83	4.45	40.1	6.8	32.6
					398.1	29.6	368.1

Table 4.26 presents the results of CWR calculations for Pumpkin. Total irrigation requirement is computed by adding irrigation requirement of each stages of Pumpkin and the value obtained is 368.1mm/dec and the effective rain is 29.6mm/dec.

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

Figure 4.13 presents the monthly variation of ETc and Irrigation requirement of Pumpkin. The inference obtained from the graph is as follows:

- The maximum irrigation requirement for Pumpkin is during the month of January i.e. at its mid stage and the minimum irrigation requirement is during December at its initial stage and the values obtained are 50.4mm/dec and 2.1mm/dec respectively.
- The maximum ETc of Pumpkin is obtained during the month of January (mid stage) and the minimum is during December (initial stage) and the values obtained are 50.9 and 2.1mm/dec.

Table 4.27 Irrigation schedule of Pumpkin

CROP IRRIGATION SCHEDULE			
Total gross irrigation	550.1mm	Total rainfall	30.7mm
Total net irrigation	385.1mm	Effective rainfall	18.2mm
Total irrigation losses	0 mm	Total rain loss	12.5mm
Actual water use by crop	393.7mm	Moisture deficit at harvest	8.9mm
Potential water use by crop	393.7mm	Actual irrigation requirement	375.5mm
Efficiency irrigation schedule	100%	Efficiency rain	59.30%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Pumpkin was 550.1mm for a total net irrigation of 385.1mm.The total irrigation losses were considered as zero. The actual water use by the crop was found to be 393.7mm and the potential water use by the crop is same as actual water use by the crop. The efficiency and deficiency of the irrigation schedule was considered to be 100 and zero respectively due to the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 30.7mm and 18.2mm respectively, from which the total rain loss was calculated to be 12.5mm. Moisture deficit at harvest was considered to be 8.9mm. The efficiency of rain for the Pumpkin was 59.30%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was found to be as 375.5mm.

Table 4.28 Crop datas - Bhindi

Crop data Dry crop Crop name: Bhindi			Planting date:16/12/2011 Harvest date:15/03/2012		
Stages(days)	initial	develop	mid	late	total
Legth(days)	15	30	30	15	90
Kc Values	0.7		1	0.8	
Rooting depth(m)	0.5		1.1	0.95	
Critical depletion(fraction)	0.5		0.5	0.5	0.5
Yield response f.	1.05	1.05	1.05	1.05	1.05
Cropheight (m)			1.2		

Table 4.29 Soil datas -Bhindi

Soil name: Sandy loam General soil data:	
Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	50centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4.30Estimation of crop water requirement-Bhindi

Eto station: Pattambi Rain station: Pattambi					Crop: Bhindi Planting date:15/03/2012		
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	2	Init	0.7	3.02	15.1	2.2	12.9
Dec	3	Deve	0.7	3.08	33.9	2.3	31.6
Jan	1	Deve	0.78	3.88	38.8	1.8	37
Jan	2	Deve	0.91	4.34	43.4	0	43.4
Jan	3	Mid	1.04	5.09	56	0.5	55.5
Feb	1	Mid	1.08	5.45	54.5	5.6	48.8
Feb	2	Mid	1.08	5.55	55.5	2.3	53.2
Feb	3	Mid	1.08	5.61	44.9	3.7	41.1
Mar	1	Late	1.03	5.54	55.4	1.9	53.6
Mar	2	Late	0.95	5.13	25.6	3.8	21.9
					423.1	24	399

Table 4.30 presents the results of CWR calculations for Bhindi. Total irrigation requirement is computed by adding irrigation requirement of each stages of Bhindi and the value obtained is 399mm/dec.

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

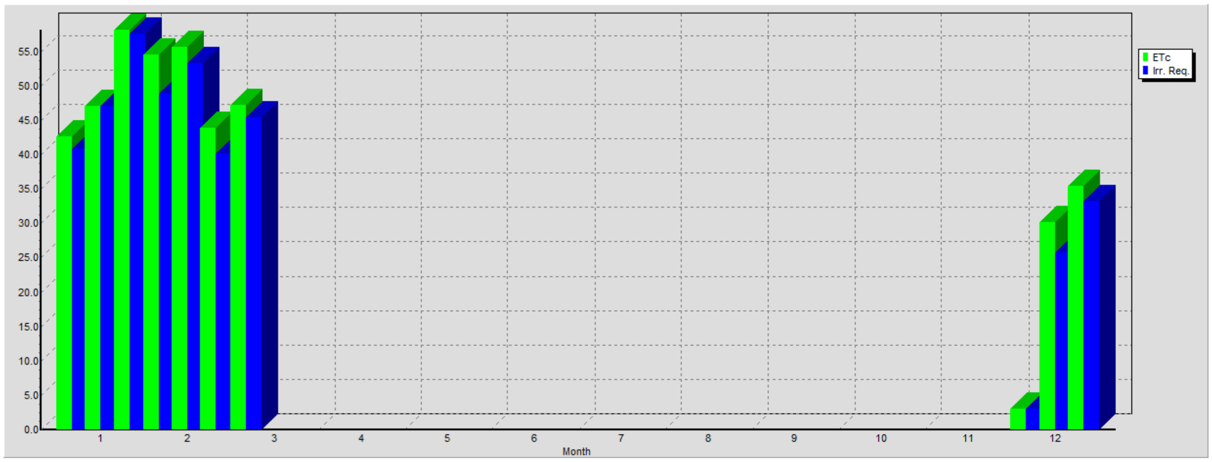


Fig 4.14 Monthly variation of ETc and Irrigation requirement of Bhindi

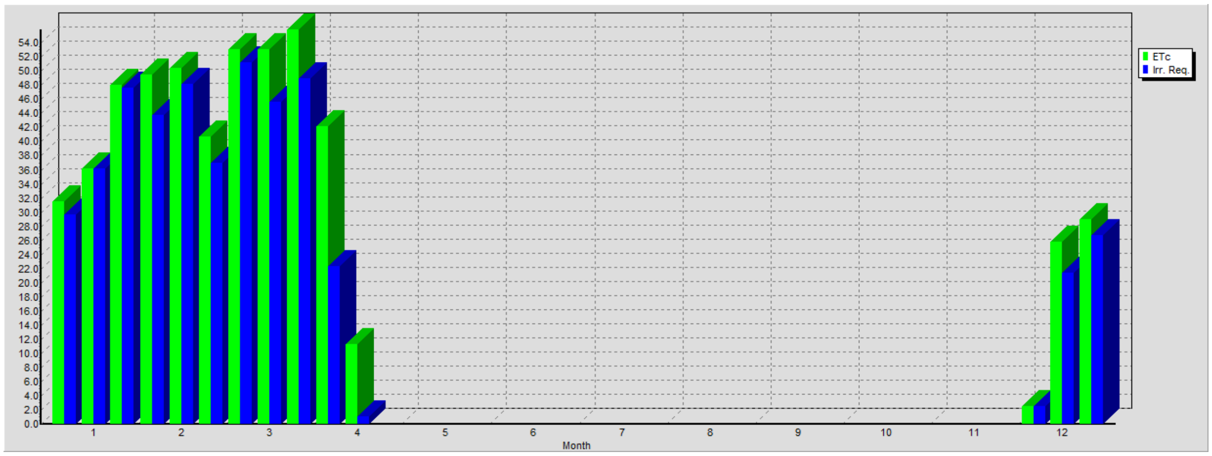


Fig 4.15 Monthly variation of ETc and Irrigation requirement of Ash gourd

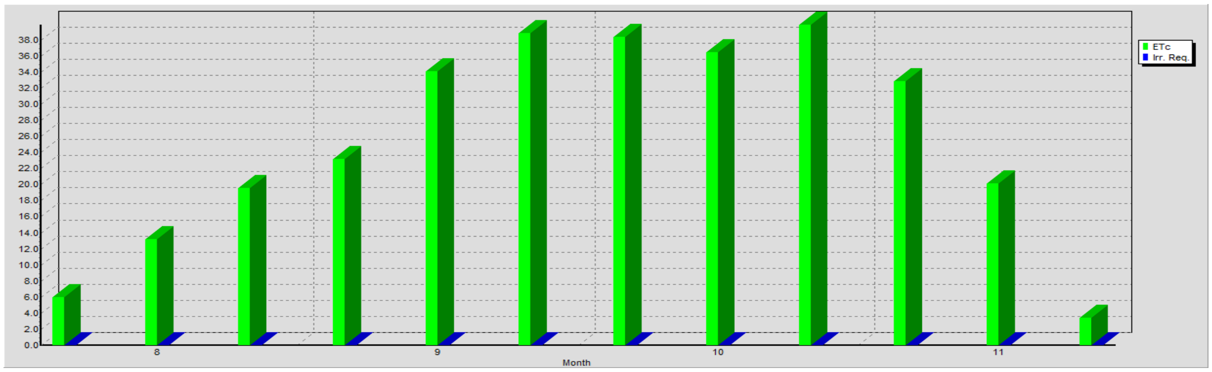


Fig 4.16 Monthly variation of ETc and Irrigation requirement of Sesamum

Figure 4.14 presents the monthly variation of ETc and Irrigation requirement of Bhindi. The inference obtained from the graph is as follows:

- The maximum irrigation requirement for Bhindi is during the month of January i.e. at its mid stage and the minimum irrigation requirement is during December at its initial stage and the values obtained are 555.5mm/dec and 12.90mm/dec respectively.
- The maximum ETc of Bhindi is obtained during the month of January (mid stage) and the minimum is during December (initial stage) and the values obtained are 56 and 15.10mm/dec.

Table 4.31 Irrigation schedule of Bhindi

CROP IRRIGATION SCHEDULE			
Total gross irrigation	579.4mm	Total rainfall	24.7mm
Total net irrigation	405.6mm	Effective rainfall	19.8mm
Total irrigation losses	0 mm	Total rain loss	4.8mm
Actual water use by crop	417.9mm	Moisture deficit at harvest	0mm
Potential water use by crop	417.9mm	Actual irrigation requirement	398.2mm
Efficiency irrigation schedule	100%	Efficiency rain	80.50%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Bhindi was 579.4mm for a total net irrigation of 405.6mm.The total irrigation losses were considered as zero. The actual water use by the crop was considered to be 417.9mm and the potential water use by the crop is same as actual water use by the crop. The efficiency and deficiency of the irrigation schedule was found to be 100 and zero respectively due to the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 24.7mm and 19.8mm respectively, from which the total rain loss was calculated to be 4.8mm. Moisture deficit at harvest was considered to be zero. The efficiency of rain for the Bhindi was 80.50%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was considered to be as 398.2mm.

Table 4.32 Crop datas - Ash gourd

Crop data Dry crop Crop name: Ash gourd				Planting date:10/12/2011 Harvest date:13/04/2012	
Stages(days)	initial	develop	mid	late	total
Legth(days)	25	30	50	20	125
Kc Values	0.6		1	0.75	
Rooting depth(m)	0.5			0.8	
Critical depletion(fraction)	0.5		0.5	0.5	0.5
Yield response f.	1.1	1.1	1.1	1.1	1.1
Cropheight (m)			0.3		

Table 4.33 Soil datas - Ash gourd

Soil name: Sandy loam General soil data:	
Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	50centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4.34 Estimation of crop water requirement of Ash gourd

Eto station: Pattambi Rain station: Pattambi					Crop: Ash gourd Planting date:10/12/2011		
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.6	2.56	2.6	0.3	2.6
Dec	2	Init	0.6	2.59	25.9	4.4	21.5
Dec	3	Init	0.6	2.64	29	2.3	26.8
Jan	1	Deve	0.64	3.15	31.5	1.8	29.7
Jan	2	Deve	0.76	3.62	36.2	0	36.2
Jan	3	Deve	0.9	4.37	48.1	0.5	47.6
Feb	1	Mid	0.98	4.95	49.5	5.6	43.8
Feb	2	Mid	0.99	5.05	50.5	2.3	48.2
Feb	3	Mid	0.99	5.1	40.8	3.7	37.1
Mar	1	Mid	0.99	5.32	53.2	1.9	51.3
Mar	2	Mid	0.99	5.32	53.2	7.5	45.6
Mar	3	Late	0.95	5.08	55.9	7	48.9
Apr	1	Late	0.82	4.22	42.2	19.8	22.3
Apr	2	Late	0.73	3.76	11.3	6.1	1.1
					529.6	63.2	462.6

Table 4.34 presents the results of CWR calculations for Ash gourd. Total irrigation requirement is computed by adding irrigation requirement of each stages of the Ash gourd and the value obtained is 462.6mm/dec and the effective rain is 63.2mm/dec.

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

Figure 4.15 presents the monthly variation of ETc and Irrigation requirement of Ash gourd. The inference obtained from the graph is as follows:

- The maximum irrigation requirement for Ash gourd is during the month of March i.e. at its mid stage and the minimum irrigation requirement is during April at its late stage and the values obtained are 51.3mm/dec and 1.1mm/dec respectively.
- The maximum ETc of Ash gourd is obtained during the month of March (late stage) and the minimum is during December (initial stage) and the values obtained are 55.9 and 2.6mm/dec.

Table 4.35 Irrigation schedule of Ash gourd

CROP IRRIGATION SCHEDULE			
Total gross irrigation	715.9mm	Total rainfall	71.5mm
Total net irrigation	501.2mm	Effective rainfall	39.5mm
Total irrigation losses	0 mm	Total rain loss	32.1mm
Actual water use by crop	525.8mm	Moisture deficit at harvest	0mm
Potential water use by crop	525.8mm	Actual irrigation requirement	486.4mm
Efficiency irrigation schedule	100%	Efficiency rain	55.20%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Ash gourd was 715.9mm for a total net irrigation of 501.2mm. The total irrigation losses were considered as zero. The actual water use by the crop was considered to be 525.8mm and the potential water use by the crop is 525.8mm.The efficiency and deficiency of the irrigation schedule was considered to be 100 and zero respectively as the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 71.5mm and 39.5mm respectively, from which the total rain loss was calculated to be 32.1mm. Moisture deficit at harvest was found to be zero. The efficiency of rain for the Ash gourd was 55.20%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was found to be as 486.4mm.

Table 4.36 Crop datas - Sesamum

Crop data Planting date:06/08/2011
Dry crop Harvest date:23/11/2011

Crop name: Sesamum

Stages(days)	initial	develop	mid	late	total
Legth(days)	20	30	40	20	110
Kc Values	0.35		1.1	0.25	
Rooting depth(m)	0.5			1	
Critical depletion(fraction)	0.6		0.6	0.6	0.6
Yield response f.	1.1	1.1	1.1	1.1	1.1
Cropheight (m)			1		

Table 4.37 Soil datas - Sesamum

Soil name: Sandy loam

General soil data:

Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	100centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4.38 Estimation of crop water requirement of Sesamum

Eto station: Pattambi Rain station: Pattambi					Crop: Sesamum Planting date:06/08/2011		
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Aug	1	Init	0.35	1.19	5.9	27.3	0
Aug	2	Init	0.35	1.32	13.2	54.7	0
Aug	3	Deve	0.39	1.78	19.6	50.3	0
Sep	1	Deve	0.61	2.32	23.2	50.3	0
Sep	2	Deve	0.83	3.4	34	51.2	0
Sep	3	Mid	1	3.88	38.8	47.1	0
Oct	1	Mid	1.02	3.83	38.3	50.8	0
Oct	2	Mid	1.02	3.65	36.5	51.5	0
Oct	3	Mid	1.02	3.62	39.9	53.1	0
Nov	1	Late	0.91	3.29	32.9	44.7	0
Nov	2	Late	0.54	2.01	20.1	32.7	0
Nov	3	Late	0.29	1.15	3.4	3.2	0
					305.8	517	0

Table 4.38 presents the results of CWR calculations for Sesamum. Total irrigation requirement is computed by adding irrigation requirement of each stages of Sesamum. and the value obtained is 517mm/dec and the effective rain is 305.8mm/dec.

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

Figure 4.16 presents the monthly variation of ETc and Irrigation requirement of Sesamum. The inference obtained from the graph is as follows:

- The maximum irrigation requirement for Sesamum is during the month of January i.e. at its mid stage and the minimum irrigation requirement is during December at its initial stage and the values obtained are 50.4mm/dec and 2.1mm/dec respectively.
- The maximum ETc of Sesamum is obtained during the month of September (mid stage) and the minimum is during November (late stage) and the values obtained are 3.88 and 1.15mm/dec.

Table 4.39 Irrigation schedule- Sesamum

CROP IRRIGATION SCHEDULE			
Total gross irrigation	100.7mm	Total rainfall	950.7mm
Total net irrigation	70.5mm	Effective rainfall	248.1mm
Total irrigation losses	0 mm	Total rain loss	702.7mm
Actual water use by crop	304.7mm	Moisture deficit at harvest	4.6mm
Potential water use by crop	304.7mm	Actual irrigation requirement	56.7mm
Efficiency irrigation schedule	100%	Efficiency rain	26.10%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Sesamum was 100.7mm for a total net irrigation of 70.5mm. The total irrigation losses were considered as zero. The actual water use by the crop was considered to be 304.7mm and the potential water use by the crop is 304.7mm.The efficiency and deficiency of the irrigation schedule was considered to be 100 and zero respectively as the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 950.7mm and 248.1mm respectively, from which the total rain loss was calculated to be 702.7mm. Moisture deficit at harvest was found to be 4.6mm. The efficiency of rain for the Sesamum was 26.10%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was found to be as 56.7mm.

Table 4.40 Crop datas -Banana

Crop data Dry crop Crop name: Banana				Planting date:06/05/2011 Harvest date:05/05/2012	
Stages(days)	initial	develop	mid	late	total
Legth(days)	120	60	180	5	365
Kc Values	0.5		1.1	1	
Rooting depth(m)	0.3			0.8	
Critical depletion(fraction)	0.35		0.35	0.35	0.35
Yield response f.	1.1	1.1	1.1	1.1	1.1
Cropheight (m)			3		

Table 4.41 Soil datas -Banana

Soil name: Sandy loam General soil data:	
Total available soil moisture (FC - WP)	37mm/meter
Maximum rain infiltration rate	95mm/day
Maximum rooting depth	90centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	18.5mm/meter

Table 4.42 Estimation of crop water requirement of Banana

Eto station: Pattambi
Rain station: Pattambi

Crop: Banana
Planting date:06/05/2011

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.97	4.76	23.8	16.7	7.1
May	2	Init	0.5	2.39	23.9	36.2	0
May	3	Init	0.5	2.21	24.3	49.4	0
Jun	1	Init	0.5	1.88	18.8	58.4	0
Jun	2	Init	0.5	1.57	15.7	65.8	0
Jun	3	Init	0.5	1.58	15.8	65.2	0
Jul	1	Init	0.5	1.57	15.7	65.6	0
Jul	2	Init	0.5	1.56	15.6	62	0
Jul	3	Init	0.5	1.55	17.1	63	0
Aug	1	Init	0.5	1.7	17	54.6	0
Aug	2	Init	0.5	1.89	18.9	54.7	0
Aug	3	Init	0.5	2.27	25	50.3	0
Sep	1	Deve	0.53	2.04	20.4	50.3	0
Sep	2	Deve	0.63	2.57	25.7	51.2	0
Sep	3	Deve	0.72	2.78	27.8	47.1	0
Oct	1	Deve	0.81	3.06	30.6	50.8	0
Oct	2	Deve	0.9	3.24	32.4	51.5	0
Oct	3	Deve	1	3.57	39.3	53.1	0
Nov	1	Mid	1.06	3.82	38.2	44.7	0
Nov	2	Mid	1.06	3.96	39.6	32.7	6.9
Nov	3	Mid	1.06	4.2	42	10.8	31.2
Dec	1	Mid	1.06	4.51	45.1	3.3	41.7
Dec	2	Mid	1.06	4.55	45.5	4.4	41.1
Dec	3	Mid	1.06	4.65	51.1	2.3	48.8
Jan	1	Mid	1.06	5.23	52.3	1.8	50.5
Jan	2	Mid	1.06	5.03	50.3	0	50.3
Jan	3	Mid	1.06	5.15	56.7	0.5	56.2
Feb	1	Mid	1.06	5.3	53	5.6	47.4
Feb	2	Mid	1.06	5.4	54	2.3	51.8
Feb	3	Mid	1.06	5.46	43.7	3.7	39.9
Mar	1	Mid	1.06	5.69	56.9	1.9	55.1
Mar	2	Mid	1.06	5.69	56.9	7.5	49.4
Mar	3	Mid	1.06	5.64	62	7	55.1
Apr	1	Mid	1.06	5.44	54.4	19.8	34.6
Apr	2	Mid	1.06	5.43	54.3	20.4	33.9
Apr	3	Mid	1.06	5.43	54.3	35.7	18.5
May	1	Late	0.97	4.76	23.8	16.7	7.1
					1341.9	1167.1	726.6

Table 4.42 presents the results of CWR calculations for Banana. Total irrigation requirement is computed by adding irrigation requirement of each stages of Banana and the value obtained is 726.6mm/dec

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

Figure 4.17 presents the monthly variation of ETc and Irrigation requirement of Banana. The inference obtained from the graph is as followed maximum irrigation requirement for Banana is during the month of January i.e. at its mid stage (56.2mm/dec) and the minimum irrigation requirement of Banana plantain obtained is zero, which is valid from second decade of May to first decade of November.

- The maximum ETc of Banana plantain is 56.9mm/dec obtained during the month of first and second decade of March (mid stage) and the minimum is during July (initial stage) and the values obtained is 15.6mm/dec.

Table 4.43 Irrigation schedule of Banana

CROP IRRIGATION SCHEDULE			
Total gross irrigation	1694mm	Total rainfall	2622.8mm
Total net irrigation	1186.2mm	Effective rainfall	155.1mm
Total irrigation losses	0 mm	Total rain loss	2467.7mm
Actual water use by crop	1336.1mm	Moisture deficit at harvest	9.5mm
Potential water use by crop	1337.2mm	Actual irrigation requirement	1182mm
Efficiency irrigation schedule	100%	Efficiency rain	5.90%
Deficiency irrigation schedule	0.00%		

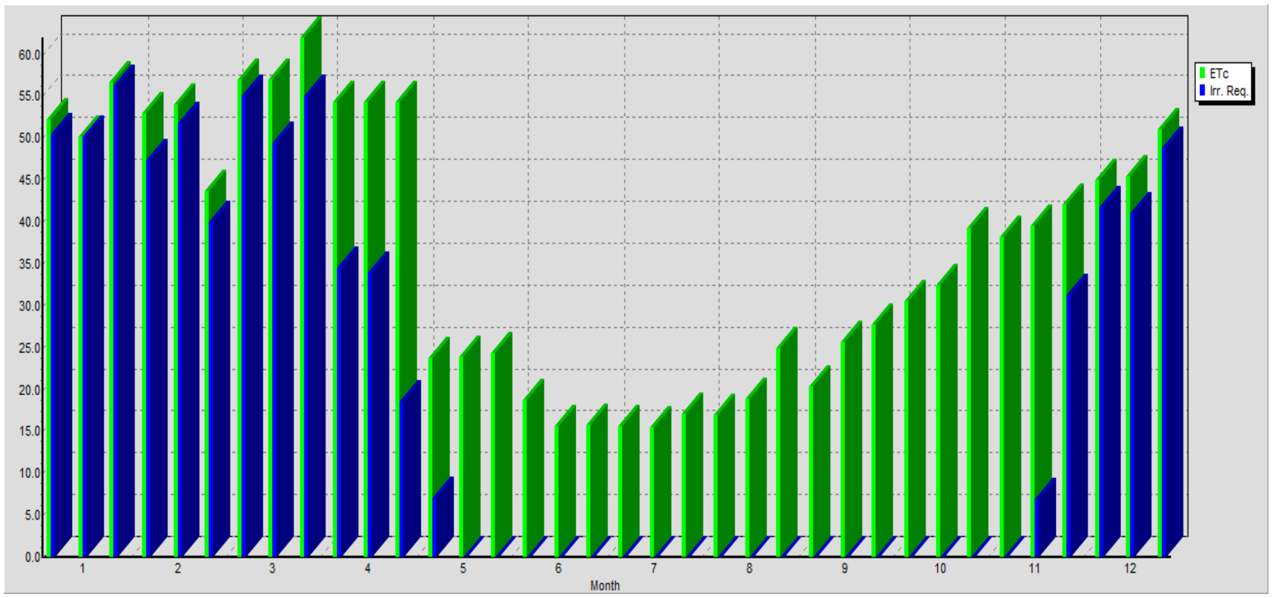


Fig 4.17 Monthly variation of ETc and Irrigation requirement of Banana

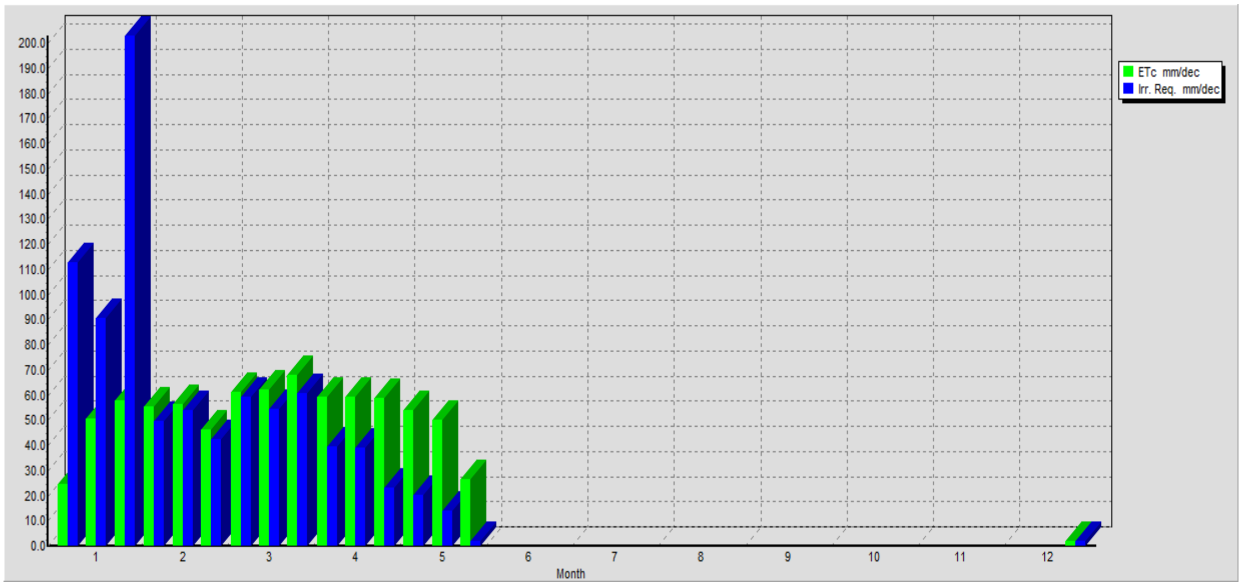


Fig. 4.18 Monthly variation of ETc and Irrigation requirement of Rice.

It was obtained from the software CROPWAT that the total gross irrigation required by Banana was 1694.6mm for a total net irrigation of 1186.2mm.The total irrigation losses were considered as zero. The actual water use by the crop was found to be 1336.1mm and the potential water use by the crop is 1337.1mm.The efficiency and deficiency of the irrigation schedule was considered to be 100 and zero respectively as the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 2622.8mm and 155.1mm respectively, from which the total rain loss was calculated to be 2467.7mm. Moisture deficit at harvest was found to be 9.5mm. The efficiency of rain for the Banana was 5.90%. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was considered to be as 1182mm.

Table 4.44 Crop data-Rice

Crop:Rice Transplanting date:27/01/2011 Harvest date:26/05/2011								
Kc dry	0.7	0.3		0.5		1.05		0.7
Kc wet	1.2	1.05		1.1		1.2		1.05
	nursery	land prep						Total
Stage		total	puddling	ini	deve	mid	late	
(days)	30	20	5	20	30	40	30	150
Rooting depth(m)			0.1				0.6	
Puddling depth(m)		0.4						
Nursery area(%)	10							
Critical depletion(fraction)	0.2			0.2		0.2	0.2	
Yield response factor				1	1.09	1.32	0.5	1.1
Crop height(m)						1		

Table 4.45 Soil data-Rice

Total available soil moisture (FC - WP)	200mm/meter
Maximum rain infiltration rate	30mm/day
Maximum rooting depth	900centimeters
Initial soil moisture depletion (% TAM)	50%
Initial available soil moisture	100mm/meter
Additional soil data for rice calculations:	
Drainable porosity (SAT - FC)	10%
Critical depletion for puddle cracking	0.6 fraction
Maximum percolation rate after puddling	3.1mm/day
Water availability at planting	5 mm WD
Maximum water depth	120mm

Table 4.45 presents the results of CWR calculations for Rice. Total irrigation requirement is computed by adding irrigation requirement of each stages of the Rice and the value obtained is 867.6mm/dec.

From the table it is clear that for all the cases the ETc value varies for different stages of the crop growth.

Table 4.46 Estimation of crop water requirement of Rice

Eto station:Pattambi				Crop:Rice			
Rain station:Pattambi				Planting date:27/01/11			
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	3	Nurs	1.2	0.53	2.1	0.8	2.1
Jan	1	Nurs/LPr	1.15	2.47	24.7	1.8	112.9
Jan	2	Nurs/LPr	1.06	5.07	50.7	0	90.7
Jan	3	Init	1.08	5.27	58	0.5	203
Feb	1	Init	1.1	5.52	55.2	5.6	49.6
Feb	2	Deve	1.1	5.64	56.4	2.3	54.1
Feb	3	Deve	1.12	5.78	46.2	3.7	42.5
Mar	1	Deve	1.13	6.11	61.1	1.9	59.2
Mar	2	Mid	1.15	6.2	62	7.5	54.5
Mar	3	Mid	1.15	6.16	67.8	7	60.8
Apr	1	Mid	1.15	5.94	59.4	19.8	39.6
Apr	2	Mid	1.15	5.94	59.4	20.4	39
Apr	3	Late	1.15	5.9	59	35.7	23.3
May	1	Late	1.1	5.39	53.9	33.4	20.5
May	2	Late	1.05	5	50	36.2	13.9
May	3	Late	1	4.45	26.7	26.9	2
					792.7	203.6	867.6

Table 4.47 Irrigation schedule of Rice

CROP IRRIGATION SCHEDULE			
Total gross irrigation	1533mm	Total rainfall	249.8mm
Total net irrigation	1073.1mm	Effective rainfall	248.9mm
Total irrigation losses	0 mm	Total rain loss	0.9mm
Actual water use by crop	679mm	Moisture deficit at harvest	0mm
Potential water use by crop	679mm	Actual irrigation requirement	430.1mm
Efficiency irrigation schedule	100%	Efficiency rain	5.90%
Deficiency irrigation schedule	0.00%		

It was obtained from the software CROPWAT that the total gross irrigation required by Rice was 1533mm for a total net irrigation of 1073.1mm. The total irrigation losses were considered as zero. The actual water use by the crop was found to be 679mm and the potential water use by the crop is 679mm.The efficiency and deficiency of the irrigation schedule was considered to be 100 and zero respectively as the field was irrigated up to field capacity. The total rainfall and effective rainfall obtained was 249.8mm and 248.9mm respectively, from which the total rain loss was calculated to be 0.9mm. Moisture deficit at harvest was found to be zero. The efficiency of rain for the Rice was 99.6. On substracting the effective rainfall from actual water use by crop, the actual irrigation requirement can be calculated which was considered to be as 430.1mm.

Flow rate requirement for decade for each crop is also given by the model. The model has also option to calculate the daily irrigation requirement for each crop and the flow rate requirement also. Deficit irrigation and rainfed irrigation can all be scheduled by using CROPWAT model. So various options of scheduling and various critical levels of depletion can be analysed and CWR can be computed by model. Thus CROPWAT has wide range applications in scheduling the irrigation requirement for any area. In the K.C.A.E.T. farm, water is flooded from the hydrant during the irrigation period. Based on the schedule exact amount of water can be applied to each block and with more efficient irrigation system like drip and sprinkler even deficit irrigation schedule can be planned for the farm using CROPWAT model. Thus wastage of water can be prevented and more efficiency can be ensured. The Table 4.48 gives the total water requirement of all the crops of the study area.

Table 4.48 The total irrigation requirement of the study area

Sl No	Crop	Total gross irrigation (mm)	Total net irrigation(mm)	Actual water use by crop(mm)	Actual irrigation requirement(mm)
1	Amaranthus	274.4	192.1	196.1	187.7
2	Snake gourd	433.5	345.5	442.5	341.5
3	Cowpea	584.6	410.5	429.6	405.9
4	Cucumber	600.2	420.1	440.7	418.2
5	Watermelon	571.2	399.9	427.4	381.7
6	Pumpkin	550.1	385.1	393.7	375.5
7	Bhindi	579.4	405.6	417.9	398.2
8	Ash gourd	715.9	501.2	525.8	486.4
9	Sesamum	100.7	70.5	304.7	56.7
10	Banana	1694.6	1186.2	1336.1	1182
11	Paddy	1533	1073.1	679	430.1

Over a period of January to December the total irrigation requirement is 4663.9mm.

Scope for future work

1. More scheduling options for each crop can be used and more detailed scheduling can be tried.
2. Deficit irrigation and full irrigation scheduling can be compared.
3. Irrigation can be scheduled for different critical levels of depletion and different frequency of application.
4. Comparison to existing system in terms of volume of water u

SUMMARY AND CONCLUSIONS

CHAPTER V

SUMMARY AND CONCLUSION

The availability of water is decreasing with increase in its demand .Water is considered as a major input for agriculture production. Earlier crop water needs were met by rain water alone but with increasing population and hence increasing food and agricultural production demands, a need for artificial application of water a has arouse. With such decrease in availability the increasing demand can be met only through scientific management of irrigation. The requirement of irrigation water depends on the quantity and duration of rain in that season. The water requirements of crops are majorly from evapotranspiration, which is extracted from root zone area. The amounts of moisture available to crops are critical during certain period of crop growth and it affects the yield.

Knowing the correct amount of water for irrigation will help not only in saving water but also in providing high yield. To calculate the precise amount of water that is to be applied use of many complicated equations is required. Development of software would make the process of calculation of depth of irrigation water requirement much easier.

For the determination of crop water requirement, Land and Water Development Division of FAO developed software named CROPWAT for the computation of water requirement and irrigation scheduling for desired crop grown in an area. The software required the values of climate, rainfall, crop and soil.

Conventionally in the K.C.A.E.T. farm, water is flooded from the hydrant during the irrigation period. This may lead to improper management of water. In the present study the CROPWAT model was used to estimate the CWR and irrigation scheduling by providing climate data taken from nearby Materiological station at

RARS,Pattambi, Crop data required for the software were taken from FAO 56 and 24, 1996.

The soil data which were the results of various experiments conducted in the K.C.A.E.T laboratory were also input to the model.The soil samples were collected from C block, B block, G block, and P block. The samples collected were air dried. Sieve analysis and sedimentation were done using the test samples and % of sand, silt and clay were found out.

Using the core cutter method bulk density was found out to be 1.8g/cm^3. The FC and PWP were gravimetrically determined with the help of pressure plate apparatus By feeding the above obtained values in the CROPWAT module, the crop water requirement of eleven crops viz Amaranthus, Snake gourd, Cowpea, Cucumber, Water melon, Pumpkin, Bhindi, Ashgourd, Sesamum, Banana and Rice were calculated and the resultswere187.7mm,341.5mm,405.9mm,418,2mm,381.7mm,375.5mm,398.2mm,486.4 mm,56.7mm ,1182m and 430.1 mm respectively. From the study it was clear that the computation of total CWR became effortless, less time consuming and more accurate.

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APPENDICES

APPENDIX I

Grain size distribution of the soil sample 1(block)(Coarse Fraction)

Mass of dry soil:599.5g

Sl. No.	IS Sieve	Particle Size D (mm)	Mass retained (g)	% retained	Cumulative % retained	Cumulative % finer
1	2mm	2mm	29	4.84	4.84	95.16
2	1mm	1mm	32	5.34	10.18	89.82
3	600µ	0.6mm	43.5	7.25	17.43	82.57
4	300µ	0.3mm	48	8.0	25.43	74.57
5	212µ	0.212mm	215.5	35.94	61.37	38.63
6	150µ	0.15mm	36	6.0	67.37	32.63
7	75µ	0.075mm	150	25.02	92.39	7.61

Grain size distribution of the soil sample 2(block)(Coarse Fraction)

Mass of dry soil:571g

Sl. No.	IS Sieve	Particle Size D (mm)	Mass retained (g)	% retained	Cumulative % retained	Cumulative % finer
1	2mm	2mm	57	9.98	9.98	90.02
2	1mm	1mm	45	7.88	17.86	82.14
3	600µ	0.6mm	62	10.86	28.72	71.28
4	300µ	0.3mm	127.5	22.34	51.06	48.94
5	212µ	0.212mm	180.5	31.61	82.67	17.33
6	150µ	0.15mm	23.5	4.11	86.78	13.22
7	75µ	0.075mm	52	9.10	95.88	4.12

Grain size distribution of the soil sample 3(block)(Coarse Fraction)

Mass of dry soil:600g

Sl. No.	IS Sieve	Particle Size D (mm)	Mass retained (g)	% retained	Cumulative % retained	Cumulative % finer
1	2mm	2mm	45.5	7.58	7.58	92.42
2	1mm	1mm	43.5	7.25	14.83	85.17
3	600µ	0.6mm	51	8.5	23.33	76.67
4	300µ	0.3mm	91.5	15.25	38.58	61.42
5	212µ	0.212mm	246.5	41.08	79.66	20.34
6	150µ	0.15mm	25	4.16	83.82	16.18
7	75µ	0.075mm	57.5	9.58	93.4	6.6

Grain size distribution of the soil sample 4(block)(Coarse Fraction)

Mass of dry soil:511.5g

Sl. No.	IS Sieve	Particle Size D (mm)	Mass retained (g)	% retained	Cumulative % retained	Cumulative % finer
1	2mm	2mm	179.5	35.09	35.09	64.91
2	1mm	1mm	77	15.05	50.14	49.86
3	600µ	0.6mm	59	11.53	61.67	38.33
4	300µ	0.3mm	68.5	13.39	75.06	24.94
5	212µ	0.212mm	59	11.53	86.59	13.41
6	150µ	0.15mm	12.5	2.44	89.03	10.97
7	75µ	0.075mm	30.5	5.96	94.99	5.01

APPENDIX II

Input and output climate data

Month/Dec	MinTemp ºC	MaxTemp ºC	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	Eto mm/day
Jan 1	20.4	34.3	61	168	8.7	19.6	4.95
2	19.9	33.3	61	146	8.8	20.1	4.76
3	19.8	33.9	60	139	8.8	20.5	4.88
Month	20.0	33.8	61	151	8.8	20.1	4.86
Feb 1	20.5	34.2	60	134	8.9	21.2	5.02
2	20.7	35.0	61	113	9.3	22.3	5.12
3	21.1	35.4	62	110	9.0	22.3	5.17
Month	20.8	34.9	61	119	9.1	21.9	5.10
Mar 1	21.7	36.4	60	106	9.1	22.9	5.39
2	22.7	36.4	64	106	8.8	22.8	5.39
3	25.5	35.9	67	106	8.3	22.2	5.34
Month	23.3	36.2	64	106	8.7	22.6	5.37
Apr 1	23.9	35.6	69	101	8.0	21.9	5.15
2	24.2	35.2	70	101	8.1	22.0	5.14
3	24.4	35.1	70	103	8.1	22.0	5.14
Month	24.2	35.3	70	102	8.1	22.0	5.14
May 1	24.4	34.2	73	103	7.7	21.2	4.89
2	24.4	33.8	74	108	7.5	20.7	4.77
3	23.9	32.9	76	98	6.9	19.6	4.43
Month	24.2	33.6	74	103	7.4	20.5	4.69
June 1	23.2	31.4	81	86	5.3	17.1	3.76
2	22.9	29.8	85	84	3.5	14.4	3.14

3	22.9	29.7	86	82	3.7	14.7	3.16
Month	23.0	30.3	84	84	4.2	15.4	3.36
July 1	22.6	29.4	85	84	3.6	14.6	3.14
2	22.6	29.3	86	89	3.5	14.5	3.11
3	22.8	29.0	85	91	3.3	14.3	3.09
Month	22.7	29.2	85	88	3.5	14.4	3.12
Aug 1	24.0	29.3	85	118	4.1	15.6	3.39
2	22.9	30.9	86	142	5.3	17.5	3.77
3	23.8	29.8	82	158	8.1	21.8	4.54
Month	23.6	30.0	84	139	5.8	18.3	3.90
Sep 1	23.0	30.3	82	94	5.6	17.9	3.83
2	23.0	30.8	80	86	6.7	19.5	4.12
3	22.9	31.0	80	74	6.0	18.3	3.87
Month	23.0	30.7	81	85	6.1	18.6	3.94
Oct 1	22.8	30.9	81	62	6.1	18.1	3.78
2	23.0	31.3	81	58	5.6	17.0	3.59
3	22.8	31.3	80	60	5.9	17.1	3.57
Month	22.9	31.2	81	60	5.9	17.4	3.65
Nov 1	23.5	31.5	78	62	6.3	17.2	3.62
2	22.1	31.9	74	79	6.9	17.7	3.75
3	21.7	32.2	71	98	7.7	18.4	3.98
Month	22.4	31.9	74	80	7.0	17.8	3.78
Dec 1	20.9	32.1	67	134	8.2	18.9	4.27
2	20.5	32.1	64	144	7.9	18.3	4.31
3	20.2	32.3	66	144	8.6	19.3	4.40
Month	20.5	32.2	66	141	8.2	18.8	4.32
Average	22.5	32.4	74	105	6.9	19.0	4.27

APPENDIX III

Input and output rainfall data

	Rain	**Eff rain**	**Rain**	**Eff rain**	**Rain**	**Eff rain**	**Rain**	**Eff rain**
	1-Dec	**1-Dec**	**2-Dec**	**2-Dec**	**3-Dec**	**3-Dec**	**Month**	**Month**
	mm	**mm**	**mm**	**Mm**	**mm**	**mm**	**mm**	**mm**
January	1.8	1.8	0	0	0.5	0.5	2.3	2.3
February	5.8	5.6	2.3	2.3	3.8	3.7	11.9	11.6
March	1.9	1.9	7.8	7.5	7.2	7	16.9	16.3
April	22.2	19.8	22.9	20.4	45.8	35.7	90.9	75.9
May	41.8	33.4	46.6	36.2	80.5	49.4	168.9	119
June	167.2	58.4	241.3	65.8	235.2	65.2	643.7	189.4
July	239.7	65.6	203.5	62	213.5	63	656.7	190.7
August	129.8	54.6	130.7	54.7	86.1	50.3	346.6	159.7
September	86.6	50.3	95.7	51.2	71.8	47.1	254.1	148.6
October	91.6	50.8	98	51.5	114	53.1	303.6	155.4
November	65	44.7	40.6	32.7	11.4	10.8	117	88.2
December	3.4	3.3	4.5	4.4	2.3	2.3	10.2	10
Total							2622.8	1167.1

APPENDIX IV

Irrigation scheduling of selected crops

Amaranthus

Eto station: Pattambi
Rain station: Pattambi
Timing:Irrigate at critical depletion
Application:Refill to field capacity
Field efficiency:70%

Crop: Amaranthus
Soil: Sandy loam
Planting date:07/12/2011
Harvest date:30/01/2012

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
7-Dec	1	Init	1.7	0.93	93	46	5.2	0	0	7.4	0.86
10-Dec	4	Init	0	1	100	35	4.3	0	0	6.1	0.24
14-Dec	8	Init	0	1	100	32	4.3	0	0	6.2	0.18
19-Dec	13	Dev	0	1	100	40	6	0	0	8.5	0.2
21-Dec	15	Dev	0	1	100	33	5.2	0	0	7.4	0.43
23-Dec	17	Dev	1.1	1	100	36	5.9	0	0	8.4	0.49
25-Dec	19	Dev	0	1	100	42	7	0	0	10	0.58
27-Dec	21	Dev	1.1	1	100	34	5.9	0	0	8.4	0.49
29-Dec	23	Dev	0	1	100	39	7	0	0	10	0.58
31-Dec	25	Dev	0	1	100	37	6.9	0	0	9.8	0.57
2-Jan	27	Mid	0	1	100	53	9.9	0	0	14.1	0.82
4-Jan	29	Mid	0	1	100	53	9.9	0	0	14.1	0.82
6-Jan	31	Mid	0	1	100	53	9.9	0	0	14.1	0.82
8-Jan	33	Mid	0	1	100	53	9.9	0	0	14.1	0.82
10-Jan	35	Mid	0	1	100	53	9.9	0	0	14.1	0.82
12-Jan	37	Mid	0	1	100	51	9.5	0	0	13.5	0.78
14-Jan	39	Mid	0	1	100	51	9.5	0	0	13.5	0.78
16-Jan	41	Mid	0	1	100	51	9.5	0	0	13.5	0.78
18-Jan	43	Mid	0	1	100	51	9.5	0	0	13.5	0.78
20-Jan	45	Mid	0	1	100	51	9.5	0	0	13.5	0.78
22-Jan	47	End	0	1	100	51	9.4	0	0	13.5	0.78
24-Jan	49	End	0	1	100	51	9.4	0	0	13.5	0.78
26-Jan	51	End	0	1	100	51	9.4	0	0	13.5	0.78
28-Jan	53	End	0	1	100	51	9.4	0	0	13.5	0.78
30-Jan	End	End	0	1	0	26					

Snake gourd

Eto station: Pattambi
Rain station: Pattambi
Timing:Irrigate at critical depletion
Application:Refill to field capacity
Field efficiency:70%

Crop: Snake gourd
Soil: Sandy loam
Planting date:31/01/2012
Harvest date:30/05/2012

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
31-Jan	1	Init	0	1	100	61	13.6	0	0	19.4	2.25
6-Feb	7	Init	0	1	100	54	12.5	0	0	17.8	0.34
11-Feb	12	Init	0	1	100	54	12.6	0	0	18	0.42
17-Feb	18	Init	1.1	1	100	55	13.1	0	0	18.7	0.36
22-Feb	23	Init	0	1	100	53	12.9	0	0	18.4	0.43
28-Feb	29	Init	0	1	100	54	13.6	0	0	19.4	0.37
5-Mar	34	Dev	0	1	100	54	13.7	0	0	19.6	0.45
10-Mar	39	Dev	0	1	100	53	13.7	0	0	19.6	0.45
15-Mar	44	Dev	0	1	100	50	13.3	0	0	19.1	0.44
20-Mar	49	Dev	0	1	100	51	13.8	0	0	19.7	0.46
25-Mar	54	Dev	0	1	100	59	16.2	0	0	23.1	0.53
30-Mar	59	Dev	0	1	100	58	16.2	0	0	23.1	0.53
5-Apr	65	Dev	0	1	100	51	14.5	0	0	20.8	0.4
10-Apr	70	Dev	0	1	100	60	17.3	0	0	24.8	0.57
16-Apr	76	Mid	0	1	100	64	19	0	0	27.2	0.52
20-Apr	80	Mid	0	1	100	64	19	0	0	27.2	0.79
26-Apr	86	Mid	0	1	100	65	19.2	0	0	27.4	0.53
30-Apr	90	Mid	0	1	100	65	19.2	0	0	27.4	0.79
6-May	96	Mid	0	1	100	62	18.2	0	0	26.1	0.5
10-May	100	Mid	0	1	100	62	18.2	0	0	26.1	0.75
16-May	106	Mid	0	1	100	60	17.8	0	0	25.5	0.49
20-May	110	Mid	0	1	100	60	17.8	0	0	25.5	0.74
30-May	End	End	0	1	0	37					

Cowpea

Eto station: Pattambi
Rain station: Pattambi
Timing:Irrigate at critical depletion
Application:Refill to field capacity
Field efficiency:70%

Crop: Cowpea
Soil: Sandy loam
Planting date:07/12/2011
Harvest date:30/01/2012

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
7-Dec	1	Init	1.7	1	100	54	6.1	0	0	8.7	1
10-Dec	4	Init	0	1	100	56	6.7	0	0	9.5	0.37
14-Dec	8	Init	0	1	100	54	6.7	0	0	9.6	0.28
18-Dec	12	Init	0	1	100	51	6.7	0	0	9.6	0.28
21-Dec	15	Init	0	1	100	49	6.8	0	0	9.7	0.37
25-Dec	19	Init	0	1	100	55	8	0	0	11.5	0.33
29-Dec	23	Init	0	1	100	52	8	0	0	11.5	0.33
2-Jan	27	Init	0	1	100	60	9.7	0	0	13.9	0.4
5-Jan	30	Init	0	1	100	46	7.6	0	0	10.9	0.42
9-Jan	34	Init	0	1	100	53	9.3	0	0	13.2	0.38
12-Jan	37	Dev	0	1	100	49	8.8	0	0	12.5	0.48
15-Jan	40	Dev	0	1	100	50	9.3	0	0	13.3	0.51
18-Jan	43	Dev	0	1	100	49	9.3	0	0	13.3	0.51
21-Jan	46	Dev	0	1	100	55	10.7	0	0	15.3	0.59
24-Jan	49	Dev	0	1	100	66	13.2	0	0	18.9	0.73
27-Jan	52	Dev	0.3	1	100	64	13.2	0	0	18.9	0.73
30-Jan	55	Dev	0	1	100	63	13.5	0	0	19.3	0.74
1-Feb	57	Dev	0	1	100	47	10.2	0	0	14.6	0.84
4-Feb	60	Dev	0	1	100	64	14.1	0	0	20.2	0.78
6-Feb	62	Mid	0	1	100	51	11.3	0	0	16.1	0.93
8-Feb	64	Mid	0	1	100	51	11.3	0	0	16.1	0.93
10-Feb	66	Mid	0	1	100	51	11.3	0	0	16.1	0.93
12-Feb	68	Mid	0	1	100	52	11.6	0	0	16.6	0.96
14-Feb	70	Mid	0	1	100	52	11.6	0	0	16.6	0.96
16-Feb	72	Mid	0	1	100	52	11.6	0	0	16.6	0.96
18-Feb	74	Mid	0	1	100	52	11.6	0	0	16.6	0.96
20-Feb	76	Mid	0	1	100	52	11.6	0	0	16.6	0.96
22-Feb	78	Mid	0	1	100	53	11.8	0	0	16.8	0.97
24-Feb	80	Mid	0	1	100	53	11.8	0	0	16.8	0.97
26-Feb	82	Mid	0	1	100	53	11.8	0	0	16.8	0.97
28-Feb	84	Mid	0	1	100	53	11.8	0	0	16.8	0.97
2-Mar	86	Mid	0	1	100	53	11.8	0	0	16.9	0.98
4-Mar	88	Mid	0	1	100	53	11.8	0	0	16.9	0.98
6-Mar	90	Mid	0	1	100	53	11.8	0	0	16.9	0.98
8-Mar	92	End	0	1	100	53	11.8	0	0	16.9	0.98
10-Mar	94	End	0	1	100	53	11.8	0	0	16.9	0.98
14-Mar	98	End	0	1	100	54	12	0	0	17.2	0.5
18-Mar	102	End	0	1	100	54	12	0	0	17.2	0.5

21-Mar	105	End	0	1	100	46	10.1	0	0	14.5	0.56
26-Mar	End	End	0	1	100	29					

Cucumber

Eto station: Pattambi
Rain station: Pattambi
Timing:Irrigate at critical depletion
Application:Refill to field capacity
Field efficiency:70%

Crop: Cucumber
Soil: Sandy loam
Planting date:16/12/2011
Harvest date:30/03/2012

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
16-Dec	1	Init	0	1	100	64	11.9	0	0	17.1	1.98
20-Dec	5	Init	0	1	100	54	10.6	0	0	15.2	0.44
25-Dec	10	Init	0	1	100	60	12.4	0	0	17.7	0.41
30-Dec	15	Init	0	1	100	57	12.4	0	0	17.7	0.41
4-Jan	20	Init	0	1	100	63	14.5	0	0	20.7	0.48
9-Jan	25	Dev	0	1	100	62	15	0	0	21.4	0.49
13-Jan	29	Dev	0	1	100	56	14.1	0	0	20.1	0.58
17-Jan	33	Dev	0	1	100	56	14.5	0	0	20.7	0.6
21-Jan	37	Dev	0	1	100	57	15.3	0	0	21.8	0.63
25-Jan	41	Dev	0	1	100	63	17.3	0	0	24.7	0.71
29-Jan	45	Dev	0	1	100	61	17.3	0	0	24.7	0.71
2-Feb	49	Dev	0	1	100	64	18.8	0	0	26.8	0.78
5-Feb	52	Mid	0	1	100	50	14.8	0	0	21.2	0.82
9-Feb	56	Mid	0	1	100	57	16.9	0	0	24.1	0.7
12-Feb	59	Mid	0	1	100	51	15.1	0	0	21.5	0.83
15-Feb	62	Mid	0	1	100	51	15.2	0	0	21.7	0.84
19-Feb	66	Mid	0	1	100	64	19.1	0	0	27.3	0.79
22-Feb	69	Mid	0	1	100	52	15.3	0	0	21.8	0.84
25-Feb	72	Mid	0	1	100	52	15.3	0	0	21.9	0.85
1-Mar	76	Mid	0	1	100	63	18.8	0	0	26.8	0.78
4-Mar	79	Mid	0	1	100	51	15	0	0	21.5	0.83
7-Mar	82	Mid	0.9	1	100	51	15	0	0	21.5	0.83
10-Mar	85	Mid	0	1	100	54	16	0	0	22.8	0.88
14-Mar	89	Mid	0	1	100	57	16.8	0	0	24	0.7
18-Mar	93	End	0	1	100	57	16.8	0	0	24	0.7
22-Mar	97	End	0	1	100	64	18.9	0	0	27	0.78
26-Mar	101	End	0	1	100	58	17.1	0	0	24.4	0.71
30-Mar	End	End	0	1	0	43					

Water melon

Eto station: Pattambi
Rain station: Pattambi
Timing:Irrigate at critical depletion
Application:Refill to field capacity
Field efficiency:70%

Crop: Water melon
Soil: Sandy loam
Planting date:23/12/11
Harvest date:11/04/12

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
23-Dec	1	Init	1.1	0.93	93	53	10	0	0	14.3	1.65
28-Dec	6	Init	0	1	100	41	9	0	0	12.8	0.3
2-Jan	11	Init	0	1	100	44	10.6	0	0	15.1	0.35
8-Jan	17	Init	0	1	100	46	12.4	0	0	17.8	0.34
13-Jan	22	Dev	0	1	100	41	12.1	0	0	17.3	0.4
19-Jan	28	Dev	0	1	100	47	15.4	0	0	22	0.42
24-Jan	33	Dev	0	1	100	47	16.8	0	0	24	0.56
29-Jan	38	Dev	0	1	100	47	17.9	0	0	25.5	0.59
2-Feb	42	Dev	0	1	100	42	16.8	0	0	23.9	0.69
6-Feb	46	Dev	0	1	100	43	18.1	0	0	25.8	0.75
10-Feb	50	Dev	0	1	100	41	18.1	0	0	25.8	0.75
14-Feb	54	Mid	0	1	100	43	19.1	0	0	27.2	0.79
18-Feb	58	Mid	0	1	100	43	19.1	0	0	27.2	0.79
22-Feb	62	Mid	0	1	100	46	20.3	0	0	29	0.84
26-Feb	66	Mid	0	1	100	46	20.4	0	0	29.2	0.84
2-Mar	70	Mid	0	1	100	47	20.9	0	0	29.8	0.86
6-Mar	74	Mid	0	1	100	48	21.3	0	0	30.4	0.88
10-Mar	78	Mid	0	1	100	48	21.3	0	0	30.4	0.88
15-Mar	83	End	0	1	100	49	21.8	0	0	31.2	0.72
20-Mar	88	End	0	1	100	49	21.8	0	0	31.2	0.72
25-Mar	93	End	0	1	100	44	19.4	0	0	27.7	0.64
30-Mar	98	End	0	1	100	44	19.4	0	0	27.7	0.64
9-Apr	108	End	0	1	100	41	18	0	0	25.7	0.3
11-Apr	End	End	0	1	100	9					

Pumpkin

Eto station: Pattambi
Rain station: Pattambi
Timing:Irrigate at critical depletion
Application:Refill to field capacity
Field efficiency:70%

Crop: Pumpkin
Soil: Sandy loam
Planting date:10/12/2011
Harvest date:19/03/2012

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
10-Dec	1	Init	0	1	100	61	11.6	0	0	16.5	1.91
16-Dec	7	Init	0	1	100	56	11.8	0	0	16.9	0.33
21-Dec	12	Init	0	1	100	50	11.5	0	0	16.4	0.38
28-Dec	19	Init	0	1	100	56	14.2	0	0	20.3	0.33
3-Jan	25	Dev	0.9	1	100	57	15.8	0	0	22.6	0.44
8-Jan	30	Dev	0	1	100	51	15.2	0	0	21.7	0.5
13-Jan	35	Dev	0	1	100	57	18.1	0	0	25.8	0.6
18-Jan	40	Dev	0	1	100	58	19.4	0	0	27.7	0.64
23-Jan	45	Dev	0.3	1	100	62	21.8	0	0	31.1	0.72
27-Jan	49	Dev	0.3	1	100	51	18.8	0	0	26.8	0.78
1-Feb	54	Mid	0	1	100	63	23.5	0	0	33.5	0.78
6-Feb	59	Mid	0	1	100	59	21.9	0	0	31.3	0.73
10-Feb	63	Mid	0	1	100	54	19.9	0	0	28.4	0.82
14-Feb	67	Mid	0	1	100	52	19.1	0	0	27.3	0.79
18-Feb	71	Mid	0	1	100	52	19.1	0	0	27.3	0.79
22-Feb	75	Mid	0	1	100	55	20.3	0	0	29.1	0.84
26-Feb	79	Mid	0	1	100	55	20.4	0	0	29.2	0.84
2-Mar	83	End	0	1	100	55	20.2	0	0	28.8	0.83
6-Mar	87	End	0	1	100	54	19.9	0	0	28.4	0.82
10-Mar	91	End	0	1	100	54	19.9	0	0	28.4	0.82
16-Mar	97	End	0	1	100	62	22.8	0	0	32.6	0.63
19-Mar	End	End	0	1	100	24					

Bhindi

Eto station: Pattambi
Rain station: Pattambi
Timing:Irrigate at critical depletion
Application:Refill to field capacity
Field efficiency:70%

Crop: Bhindi
Soil: Sandy loam
Planting date:16/12/2011
Harvest date:15/03/2012

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
16-Dec	1	Init	0	1	100	73	9.5	0	0	13.6	1.57
19-Dec	4	Init	0	1	100	69	9	0	0	12.9	0.5
22-Dec	7	Init	0	1	100	69	9.2	0	0	13.1	0.51
25-Dec	10	Init	0	1	100	69	9.3	0	0	13.2	0.51
28-Dec	13	Init	0	1	100	60	8.1	0	0	11.6	0.45
31-Dec	16	Dev	0	1	100	68	9.3	0	0	13.2	0.51
2-Jan	18	Dev	0	1	100	57	7.8	0	0	11.1	0.64
4-Jan	20	Dev	0	1	100	56	7.8	0	0	11.1	0.64
6-Jan	22	Dev	0	1	100	56	7.8	0	0	11.1	0.64
8-Jan	24	Dev	0	1	100	56	7.8	0	0	11.1	0.64
10-Jan	26	Dev	0	1	100	55	7.8	0	0	11.1	0.64
12-Jan	28	Dev	0	1	100	62	8.7	0	0	12.4	0.72
14-Jan	30	Dev	0	1	100	61	8.7	0	0	12.4	0.72
16-Jan	32	Dev	0	1	100	61	8.7	0	0	12.4	0.72
18-Jan	34	Dev	0	1	100	60	8.7	0	0	12.4	0.72
20-Jan	36	Dev	0	1	100	60	8.7	0	0	12.4	0.72
22-Jan	38	Dev	0	1	100	70	10.2	0	0	14.5	0.84
24-Jan	40	Dev	0	1	100	70	10.2	0	0	14.5	0.84
26-Jan	42	Dev	0	1	100	69	10.2	0	0	14.5	0.84
28-Jan	44	Dev	0	1	100	69	10.2	0	0	14.5	0.84
30-Jan	46	Mid	0	1	100	69	10.2	0	0	14.5	0.84
1-Feb	48	Mid	0	1	100	71	10.5	0	0	15.1	0.87
3-Feb	50	Mid	2.9	1	100	54	8	0	0	11.4	0.66
5-Feb	52	Mid	0	1	100	74	10.9	0	0	15.6	0.9
7-Feb	54	Mid	2.9	1	100	54	8	0	0	11.4	0.66
9-Feb	56	Mid	0	1	100	74	10.9	0	0	15.6	0.9
11-Feb	58	Mid	0	1	100	74	11	0	0	15.7	0.91

13-Feb	60	Mid	1.1	1	100	67	10	0	0	14.2	0.82
15-Feb	62	Mid	0	1	100	75	11.1	0	0	15.9	0.92
17-Feb	64	Mid	1.1	1	100	67	10	0	0	14.2	0.82
19-Feb	66	Mid	0	1	100	75	11.1	0	0	15.9	0.92
21-Feb	68	Mid	0	1	100	75	11.2	0	0	15.9	0.92
23-Feb	70	Mid	1.9	1	100	63	9.3	0	0	13.3	0.77
25-Feb	72	Mid	0	1	100	76	11.2	0	0	16	0.93
27-Feb	74	Mid	1.9	1	100	63	9.3	0	0	13.3	0.77
1-Mar	76	End	0	1	100	75	11.2	0	0	15.9	0.92
3-Mar	78	End	0.9	1	100	68	10.1	0	0	14.5	0.84
5-Mar	80	End	0	1	100	75	11.1	0	0	15.8	0.92
7-Mar	82	End	0.9	1	100	68	10.1	0	0	14.5	0.84
9-Mar	84	End	0	1	100	75	11.1	0	0	15.8	0.92
11-Mar	86	End	0	1	100	72	10.7	0	0	15.2	0.88
14-Mar	89	End	0	1	100	78	11.5	0	0	16.4	0.63
15-Mar	End	End	0	1	0	0					

Ash gourd

Eto station: Pattambi
Rain station: Pattambi
Timing:Irrigate at critical depletion
Application:Refill to field capacity
Field efficiency:70%

Crop: Ash gourd
Soil: Sandy loam
Planting date:10/12/2011
Harvest date:13/04/2012

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
10-Dec	1	Init	0	1	100	64	11.9	0	0	17	1.97
15-Dec	6	Init	0	1	100	57	11.2	0	0	16	0.37
20-Dec	11	Init	0	1	100	54	11.2	0	0	16	0.37
25-Dec	16	Init	0	1	100	58	12.6	0	0	17.9	0.42
30-Dec	21	Init	0	1	100	55	12.6	0	0	17.9	0.42
4-Jan	26	Dev	0	1	100	63	14.9	0	0	21.2	0.49
9-Jan	31	Dev	0	1	100	62	15.4	0	0	21.9	0.51
13-Jan	35	Dev	0	1	100	56	14.4	0	0	20.6	0.6
17-Jan	39	Dev	0	1	100	56	14.9	0	0	21.3	0.62
21-Jan	43	Dev	0	1	100	58	15.6	0	0	22.3	0.65
25-Jan	47	Dev	0	1	100	63	17.7	0	0	25.2	0.73
29-Jan	51	Dev	0	1	100	61	17.7	0	0	25.2	0.73
2-Feb	55	Dev	0	1	100	64	18.9	0	0	27.1	0.78
5-Feb	58	Mid	0	1	100	50	14.8	0	0	21.2	0.82
9-Feb	62	Mid	0	1	100	57	16.9	0	0	24.1	0.7
12-Feb	65	Mid	0	1	100	51	15	0	0	21.5	0.83
15-Feb	68	Mid	0	1	100	51	15.1	0	0	21.6	0.83
19-Feb	72	Mid	0	1	100	64	19	0	0	27.2	0.79
22-Feb	75	Mid	0	1	100	51	15.2	0	0	21.8	0.84
25-Feb	78	Mid	0	1	100	52	15.3	0	0	21.8	0.84
1-Mar	82	Mid	0	1	100	63	18.7	0	0	26.7	0.77
4-Mar	85	Mid	0	1	100	51	15	0	0	21.4	0.83
7-Mar	88	Mid	0.9	1	100	51	15	0	0	21.4	0.83
10-Mar	91	Mid	0	1	100	54	15.9	0	0	22.8	0.88
14-Mar	95	Mid	0	1	100	59	17.4	0	0	24.8	0.72
18-Mar	99	Mid	0	1	100	59	17.4	0	0	24.8	0.72
21-Mar	102	Mid	0	1	100	53	15.7	0	0	22.4	0.87

25-Mar	106	End	0	1	100	57	16.7	0	0	23.9	0.69
29-Mar	110	End	0	1	100	57	16.7	0	0	23.9	0.69
2-Apr	114	End	0	1	100	63	18.6	0	0	26.6	0.77
6-Apr	118	End	0	1	100	57	16.9	0	0	24.1	0.7
10-Apr	122	End	0	1	100	57	16.9	0	0	24.1	0.7
13-Apr	End	End	0	1	0	0					

Sesamum

Eto station: Pattambi
Rain station: Pattambi
Crop: Sesamum
Timing:Irrigate at critical depletion
Soil: Sandy loam
Application:Refill to field capacity
Planting date:06/08/2011
Field efficiency:70%
Harvest date:23/11/2011

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
2-Oct	58	Mid	0	1	100	63	23.2	0	0	33.1	0.07
12-Oct	68	Mid	0	1	100	61	22.6	0	0	32.3	0.37
2-Nov	89	Mid	0	1	100	67	24.7	0	0	35.3	0.19
23-Nov	End	End	0	1	0	13					

Banana

Eto station: Pattambi	
Rain station: Pattambi	Crop: Banana
Timing:Irrigate at critical depletion	Soil: Sandy loam
Application:Refill to field capacity	Planting date:06/05/2011
Field efficiency:70%	Harvest date:05/05/2012

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
6-May	1	Init	0	0.77	77	83	9.3	0	0	13.2	1.53
7-May	2	Init	20.9	1	100	42	4.8	0	0	6.8	0.79
8-May	3	Init	0	1	100	42	4.8	0	0	6.8	0.79
9-May	4	Init	0	1	100	41	4.8	0	0	6.8	0.79
10-May	5	Init	0	1	100	41	4.8	0	0	6.8	0.79
12-May	7	Init	0	1	100	40	4.8	0	0	6.8	0.39
14-May	9	Init	0	1	100	40	4.8	0	0	6.8	0.39
16-May	11	Init	0	1	100	39	4.8	0	0	6.8	0.39
18-May	13	Init	0	1	100	38	4.8	0	0	6.8	0.39
20-May	15	Init	0	1	100	38	4.8	0	0	6.8	0.39
25-May	20	Init	0	1	100	50	6.6	0	0	9.5	0.22
29-May	24	Init	0	1	100	49	6.6	0	0	9.5	0.27
1-Jun	27	Init	0	1	100	45	6.3	0	0	9	0.35
5-Jun	31	Init	0	1	100	40	5.6	0	0	8.1	0.23
9-Jun	35	Init	0	1	100	38	5.6	0	0	8.1	0.23
16-Jun	42	Init	0	1	100	41	6.3	0	0	9	0.15
20-Jun	46	Init	0	1	100	40	6.3	0	0	9	0.26
26-Jun	52	Init	0	1	100	38	6.3	0	0	9	0.17
30-Jun	56	Init	0	1	100	38	6.3	0	0	9	0.26
6-Jul	62	Init	0	1	100	36	6.3	0	0	9	0.17
10-Jul	66	Init	0	1	100	35	6.3	0	0	9	0.26
21-Jul	77	Init	0	1	100	41	7.8	0	0	11.1	0.12
31-Jul	87	Init	0	1	100	39	7.8	0	0	11.1	0.13
11-Aug	98	Init	0	1	100	41	8.7	0	0	12.4	0.13
21-Aug	108	Init	0	1	100	44	9.8	0	0	14	0.16

26-Aug	113	Init	0	1	100	40	9.1	0	0	13	0.3
30-Aug	117	Init	0	1	100	39	9.1	0	0	13	0.38
11-Sep	129	Dev	0	1	100	44	10.7	0	0	15.3	0.15
16-Sep	134	Dev	0	1	100	41	10.3	0	0	14.7	0.34
20-Sep	138	Dev	0	1	100	41	10.3	0	0	14.7	0.43
26-Sep	144	Dev	0	1	100	43	11.1	0	0	15.9	0.31
30-Sep	148	Dev	0	1	100	42	11.1	0	0	15.9	0.46
6-Oct	154	Dev	0	1	100	45	12.2	0	0	17.5	0.34
10-Oct	158	Dev	0	1	100	45	12.2	0	0	17.5	0.51
16-Oct	164	Dev	0	1	100	46	13	0	0	18.5	0.36
20-Oct	168	Dev	0	1	100	46	13	0	0	18.5	0.54
25-Oct	173	Dev	0	1	100	37	10.7	0	0	15.3	0.35
29-Oct	177	Dev	0	1	100	37	10.7	0	0	15.3	0.44
1-Nov	180	Dev	0	1	100	37	11	0	0	15.7	0.6
5-Nov	184	Mid	0	1	100	39	11.5	0	0	16.4	0.47
9-Nov	188	Mid	0	1	100	39	11.5	0	0	16.4	0.47
12-Nov	191	Mid	0	1	100	40	11.7	0	0	16.8	0.65
15-Nov	194	Mid	0	1	100	40	11.9	0	0	17	0.65
19-Nov	198	Mid	0	1	100	40	11.9	0	0	17	0.49
22-Nov	201	Mid	0	1	100	42	12.4	0	0	17.7	0.68
25-Nov	204	Mid	0	1	100	43	12.6	0	0	18	0.69
29-Nov	208	Mid	0	1	100	43	12.6	0	0	18	0.52
2-Dec	211	Mid	0	1	100	45	13.2	0	0	18.9	0.73
5-Dec	214	Mid	0	1	100	46	13.5	0	0	19.3	0.74
8-Dec	217	Mid	0	1	100	40	11.8	0	0	16.9	0.65
11-Dec	220	Mid	0	1	100	46	13.6	0	0	19.4	0.75
14-Dec	223	Mid	0	1	100	39	11.4	0	0	16.3	0.63
17-Dec	226	Mid	2.3	1	100	39	11.4	0	0	16.3	0.63
20-Dec	229	Mid	0	1	100	46	13.7	0	0	19.5	0.75
23-Dec	232	Mid	1.1	1	100	43	12.8	0	0	18.3	0.7
26-Dec	235	Mid	0	1	100	47	13.9	0	0	19.9	0.77
29-Dec	238	Mid	0	1	100	47	13.9	0	0	19.9	0.77
1-Jan	241	Mid	0	1	100	49	14.5	0	0	20.7	0.8
4-Jan	244	Mid	0	1	100	50	14.8	0	0	21.1	0.82
6-Jan	246	Mid	0	1	100	35	10.5	0	0	14.9	0.86
8-Jan	248	Mid	0	1	100	35	10.5	0	0	14.9	0.86
10-Jan	250	Mid	0	1	100	35	10.5	0	0	14.9	0.86
13-Jan	253	Mid	0	1	100	51	15.1	0	0	21.5	0.83
16-Jan	256	Mid	0	1	100	51	15.1	0	0	21.5	0.83
19-Jan	259	Mid	0	1	100	51	15.1	0	0	21.5	0.83
22-Jan	262	Mid	0	1	100	52	15.3	0	0	21.9	0.85
25-Jan	265	Mid	0	1	100	52	15.5	0	0	22.1	0.85

28-Jan	268	Mid	0	1	100	51	15.2	0	0	21.7	0.84
31-Jan	271	Mid	0	1	100	52	15.5	0	0	22.1	0.85
2-Feb	273	Mid	0	1	100	36	10.6	0	0	15.2	0.88
4-Feb	275	Mid	0	1	100	36	10.6	0	0	15.2	0.88
6-Feb	277	Mid	0	1	100	36	10.6	0	0	15.2	0.88
8-Feb	279	Mid	0	1	100	36	10.6	0	0	15.2	0.88
10-Feb	281	Mid	0	1	100	36	10.6	0	0	15.2	0.88
12-Feb	283	Mid	0	1	100	37	10.8	0	0	15.4	0.89
14-Feb	285	Mid	0	1	100	37	10.8	0	0	15.4	0.89
16-Feb	287	Mid	0	1	100	37	10.8	0	0	15.4	0.89
18-Feb	289	Mid	0	1	100	37	10.8	0	0	15.4	0.89
20-Feb	291	Mid	0	1	100	37	10.8	0	0	15.4	0.89
22-Feb	293	Mid	0	1	100	37	10.9	0	0	15.6	0.9
24-Feb	295	Mid	0	1	100	37	10.9	0	0	15.6	0.9
26-Feb	297	Mid	0	1	100	37	10.9	0	0	15.6	0.9
28-Feb	299	Mid	0	1	100	37	10.9	0	0	15.6	0.9
2-Mar	301	Mid	0	1	100	38	11.4	0	0	16.3	0.94
4-Mar	303	Mid	0	1	100	38	11.4	0	0	16.3	0.94
6-Mar	305	Mid	0	1	100	38	11.4	0	0	16.3	0.94
8-Mar	307	Mid	0	1	100	38	11.4	0	0	16.3	0.94
10-Mar	309	Mid	0	1	100	38	11.4	0	0	16.3	0.94
12-Mar	311	Mid	0	1	100	38	11.4	0	0	16.3	0.94
14-Mar	313	Mid	0	1	100	38	11.4	0	0	16.3	0.94
16-Mar	315	Mid	0	1	100	38	11.4	0	0	16.3	0.94
18-Mar	317	Mid	0	1	100	38	11.4	0	0	16.3	0.94
20-Mar	319	Mid	0	1	100	38	11.4	0	0	16.3	0.94
22-Mar	321	Mid	0	1	100	38	11.3	0	0	16.1	0.93
24-Mar	323	Mid	0	1	100	38	11.3	0	0	16.1	0.93
26-Mar	325	Mid	0	1	100	38	11.3	0	0	16.1	0.93
28-Mar	327	Mid	0	1	100	38	11.3	0	0	16.1	0.93
30-Mar	329	Mid	0	1	100	38	11.3	0	0	16.1	0.93
1-Apr	331	Mid	0	1	100	37	11.1	0	0	15.8	0.92
4-Apr	334	Mid	0	1	100	37	10.9	0	0	15.5	0.6
6-Apr	336	Mid	0	1	100	37	10.9	0	0	15.5	0.9
8-Apr	338	Mid	0	1	100	37	10.9	0	0	15.5	0.9
10-Apr	340	Mid	0	1	100	37	10.9	0	0	15.5	0.9
12-Apr	342	Mid	0	1	100	37	10.9	0	0	15.5	0.9
14-Apr	344	Mid	0	1	100	37	10.9	0	0	15.5	0.9
16-Apr	346	Mid	0	1	100	37	10.9	0	0	15.5	0.9
18-Apr	348	Mid	0	1	100	37	10.9	0	0	15.5	0.9
20-Apr	350	Mid	0	1	100	37	10.9	0	0	15.5	0.9
22-Apr	352	Mid	0	1	100	37	10.9	0	0	15.5	0.9

24-Apr	354	Mid	0	1	100	37	10.9	0	0	15.5	0.9
26-Apr	356	Mid	0	1	100	37	10.9	0	0	15.5	0.9
28-Apr	358	Mid	0	1	100	37	10.9	0	0	15.5	0.9
30-Apr	360	Mid	0	1	100	37	10.9	0	0	15.5	0.9
5-May	End	End	0	1	0	32					

Rice

Eto station: Pattambi Rain station: Pattambi						Crop: Rice Planting date:27/01/2011					
	Timing						**Application**				
Pre puddling :	Irrigate at fixed % depletion of FC						Refill to fixed % saturation				
Puddling :	Irrigate at fixed mm water depth						Refill to fixed water depth				
Growth stages:	Irrigate at fixed mm water depth						Refill to fixed water depth				
Date	Day	Stage	Rain	Ks	Eta	Puddl	Percol.	Depl.SM	Net Gift	Loss	Depl.SAT
			mm	fract.	%	state	mm	mm	mm	mm	mm
7-Jan	-19	PrePu	0.9	0.91	91	Prep	0	40	90.6	0	40
21-Jan	-5	PrePu	0	1	100	Prep	0	17	40	0	40
22-Jan	-4	Puddl	0	1	100	Prep	17.2	0	86.2	0	36.2
25-Jan	-1	Puddl	0	1	100	OK	7.7	0	54.3	0	4.3
31-Jan	5	Init	0	1	100	OK	3.1	0	101.6	0	1.6
12-Feb	17	Init	0	1	100	OK	3.1	0	98	0	-2
24-Feb	29	Dev	0	1	100	OK	3.1	0	101.3	0	1.3
7-Mar	40	Dev	0.9	1	100	OK	3.1	0	96.3	0	-3.7
19-Mar	52	Mid	0	1	100	OK	3.1	0	103.6	0	3.6
31-Mar	64	Mid	0	1	100	OK	3.1	0	104.1	0	4.1
15-Apr	79	Mid	0	1	100	OK	3.1	0	102.1	0	2.1
2-May	96	End	0	1	100	OK	3.1	0	95.1	0	-4.9
26-May	End	End	0	1	0	OK	0	0			

ESTIMATION OF CROP WATER REQUIREMENT AND IRRIGATION SCHEDULING OF KCAET INSTRUCTIONAL FARM USING CROPWAT MODEL

By

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Sabeena Shahul

PROJECT REPORT

**Submitted in partial fulfillment of the
requirement for the degree**

***Bachelor of Technology
in
Agricultural Engineering***

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Irrigation & Drainage Engineering

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ABSTRACT

Water is considered as a major input for agriculture production, earlier crop water needs were met by rain water alone. But increasing population demands enhanced food and agricultural production. This has made irrigation inevitable. The primary objective of irrigation is to provide plants with sufficient water to obtain optimum yields and a high quality harvested product. The scientific management of irrigation system is necessary to conserve water.

Flooded irrigation system without proper scheduling mainly adopted in K.C.A.E.T. Instructional farm is less efficient and causes immense water loss. In order to compensate for this problem a study was undertaken in the K.C.A.E.T. Instructional farm to schedule irrigation using the CROPWAT model. The crop water requirements of eleven major crops were calculated and irrigation scheduling was done. The total water requirement was found to be 4663.9mm.