CHAPTER ONE

INTRODUCTION

1.1.General:

Globally, it is well debated fact that the water productivity in agriculture needs to be raised in order to meet the increasing demand for food, which will double by 2050. Thus, on one hand, failure to develop and implement the technologies to enhance water productivity will result in use of more water in future to sustain the present level of agricultural production and on the other hand, use of water in excess of that required for crop growth will have a significant negative impact on ecosystem and livelihood of the region (FAO, 2006). Keeping view of the above, it is imperative to enhance the water productivity in agriculture. To accomplish this, there are broadly two options such as a) to improve productivity at the farm level through better management and use of improved varieties having drought resistance and higher yield potential and b) to optimize the use of land resources, irrigation and rainfed farming technologies and judicious management of surface and ground water resources. All this can be achieved by using appropriate tools to predict water productivity under different irrigation regimes or deficit irrigation approaches for different crops. The complexity of crop responses to water deficits led to the use of empirical production functions as the most practical option to assess crop yield response to water. However, the production functions developed using regression equations or empirical methods are purely location specific and these black box models have limited applicability to different crops, locations and management practices. Therefore use of physics based crop simulation models were preferred over the regression equations. Crop models developed so far rely on the physics based concept of soil, plant water and climatic interactions and these models have been used by different researchers.

Objectives:

General Objective:

The General objective is to improve the water management system for

Aljunyed sugarcane scheme using Aqua Crop model developed by FAO.

Specific Objectives:

The specific objectives of the study are;

1. To simulate Crop Water Productivity Aljunyed sugarcane scheme, using AquaCrop model developed by FAO, with the following data

CHAPTER TWO

LITERATURE REVIEW

2.1. Sugar cane:

Sugar cane knows noble cane. It is believed that sugar cane grew up in South China, South Pacific Islands or New Guinea, Malaysia and the first of the sugar extracted from sugar cane are the Indians and sugar cane spread its plants from ancient time in area between latitudes 20 north and 20 south, but the proportion of the demand for sugar globally that spread cultivation of sugar cane to latitude 35 ˚ N and 35 ˚ S, and even the latitude of 37 ˚ N. in the south of Spain..

Identifies the cultivation of sugar cane economically the climate factors mainly due to the crop growth duration is relatively long, ranging from 9-24 months. The planting of sugar cane in India since 1000 years BC, and then go to Iran and the Middle East in 600 AD, and to the Mediterranean, reaching Egypt, Morocco, Spain and Sagllya in the thirteenth century AD and later spread its cultivation in the rest of the world with favorable climatic conditions for its growth. Sugar cane reached the New World in the fifteenth century with the discovery of Columbus to America, and began its cultivation in Brazil in 1500 and in Cuba in 1772 in the United States of America in 1800

Figure(2.1): Sugar Cane

2.1.1.Production areas in the world

Sugar cane is grown commercially in more than 58 countries, located mostly in the tropical region, including India, Brazil, Cuba, China, Mexico and the United States, Pakistan, Australia and Colombia. In Africa sugar cane planting in South Africa, Egypt, Mauritius, Natal and Sudan. The most important Arab countries that produce sugar cane are Egypt, Sudan and Morocco. And have reached the global area of sugar cane in the years 1999 and 2000 and 2001 about 19.405 million and 19.186 million and 19.245 million hectares, respectively. The global production stood at 1274697000 and 1258531000 and 1254857000 tons, respectively. Producing countries of Latin America about 50% of world production of sugar cane.

In the Arab world, the average area of sugar cane in the period from 1985 to 1995 about 210,500 hectares and production is about 17,135,180 tons

2.1.2. Production areas in Sudan

Before start planting sugar cane in extensive trade of sugar production in Sudan, the crop is grown in small areas around Khartoum and Berber, and some areas of the Blue Nile and Equatoria for domestic consumption in the form of cane, and the production of small amounts of molasses by some factories in Khartoum.

Then started experimental for the cultivation of sugar cane for sugar production in the early fifties in Mangala, but commercial production did not begin due to the economic situation in Sudan and its low prices worldwide.

Did not begin commercial production of sugar cane and sugar industry in Sudan, until in 1960 when Aljunyed sugar factory was founded, which began production capacity of 60000 tons of sugar. And due to the success of Aljunyed sugar factory established New Halfa Sugar Factory in 1965 with a capacity of 60000 tons also, in the seventies the sugar industry in Sudan, witnessed a big leap by establishing factories Sennar and Aslayah stone and Kenana, which started production in the seasons of 75 / 1976, 1979, 1980 and 1980 / 1981 by productivity energy reached 110,000 and 110,000 and 330,000 tons respectively. The average area of sugar cane in Sudan, about 117,464 feddan in the eighties, and 140,435 feddan in the nineties. In 2000 and 2001 the area amounted to 128,000 and 130,000 feddan, respectively. The total production of sugar cane reached 2860859 tons on average in the period from the mid seventies to mid eighties and 3252851 tons in the period from the mid-eighties to mid nineties. The average production for the three seasons from 1999 to 2001 amounted to 5.101 million tons, reduce to 3,306,998 tons and raised to 3,393,192 tons in 2001-2002 and 2002-2003 seasons, respectively.

Sudan has characteristics led to the success of the sugar cane in it are fallow :

1. the abundance of fertile land in the middle mudflats.
2. The abundance of irrigation water and rainfall rates, like that of a part of the crop water needs, thus easing the pressure on irrigation systems and reduces production costs.
3. Sudan has a weather-appropriate for the growth of sugar cane, a bright warm weather at the stage of vegetative growth and a relatively cold winter and dry in the stage of maturity of the crop. And also the harvest season long and dry helps to the high concentration of sugar in the cane, raising the efficiency of factories in the extract, and reduces cost.
4. Provide trained employment and non trained employment to work in factories and in the sugar cane fields.
5. Availability of infrastructure, especially in central Sudan (Al-Jazeera and the States of the Blue Nile and White Nile), paved roads, storage facilities and maintenance workshops.
6. Low cost production in Sudan compared to other sugar cane production areas in the world.
7. Near the areas where sugar cane production and processing of the main centers of consumption in the Sudan, as well as the relative proximity of the ports of export in Port Sudan and Suakin

2.1.3.The economic importance and use

Sugar cane is the most important crop contains a high concentration of sugar in its sap. It is considered the cheapest source of energy in the same unit area compared to other sugar crops.

And is extracted from sugar cane by-products after the task of extracting the sugar, a substance such as molasses which is dark color and dense texture, containing 35% sucrose and 15% reducing sugars.

The molasses is an important industrial chemical used in the following terms:

1. Production of alcohol which is used for industrial purposes
2. Used as fuel for tractors in some countries in Asia.
3. Acetone and butanol is made from molasses
4. Many kinds of yeast made from molasses, including yeast bread
5. The molasses is used widely in animal feed directly or mixed with some other material and is also used in the preparation of silage. Also use the upper parts of the cane stalks staple of animals either alone or mixed with molasses.
6. Mixed molasses with urea and the mixture is used as a substitute for protein in animal feed.
7. Molasses is also used for the production of carbon dioxide, vinegar, acetic acid, citric acid and organic solvents and perfumes

2.3.3.1Sugar projects in Sudan

1- Aljunyed Sugar Project
2- New Halfa Sugar Project
3- Sennar Sugar Project
4- Aslalayah Sugar Project
5- Kenana Sugar Project

2.3.4. Environmental conditions

Sugar cane grows in a wide range of soil types provided that the good soil drainage to a depth of 60 cm in order to grow roots well. Soil layers where there is a solid at a depth close to hinder the growth of the roots. To achieve good production should be planted cane in the soil of good construction. Acidic lands are not suitable and lead to lower productivity because of lack of calcium in it. Also heavy clay soil and poor drainage hinder the absorption of potassium is an important element of each sugar crops. Cane sugar from the salt-tolerant crops, but the degree of tolerance depends on the variety grown. Cane sugar from crops with high nutritional requirements for this should be high soil fertility and generally the most appropriate types of soil for sugar cane is a good loam soil drainage and salt-free and high fertility. Also a water level of the soil (water table) must be down to the roots growing well. Heavy clay soils are not suitable for sugar cane because of poor drainage and its ability to solidity as a result of agricultural operations involving the use of heavy machinery. Also crop does not success in the sandy land because of not retaining water, exposing the crop to water stress as well as the ease of the fall of the plants and the lack of sugar content in the crop grown there. Alkaline soil is also not suitable for cane sugar

2.3.4.1Temperature and light

Sugar cane need to high temperature and bright sun. The most suitable temperature for germination and growth of between 32 º C and 38 º C. And low temperature to less than 21 º C leads to a delay or failure of germination and low tillers and low productivity. The crop requires a long season and hot during the vegetative growth and the weather is relatively cool and dry in the process of maturation and harvesting.

In the humid tropics the crop matured during the year. In areas under tropical and due to low temperature, the crop matures in two years.

Sugar cane from short day plants. And in the northern hemisphere (Sudan), plant flowering in November, while in the southern hemisphere flowering in June. The flowering undesirable phenomenon in sugar cane because it shorten the season of vegetative growth and lead to low content sugar in cane and blanks in the stems. In addition to the length of the day, the flowering is influenced by temperature and level of nutrition and height of the area where the cane is grown and the variety.

And may be delay flowering in the first season in several ways, including :

1. Spraying with chemicals such as (Diaquat) or (Ethrel) as in Kenana project.
2. Cultivation of varieties non-flowering or late flowering.
3. Deprive the crop from water.
4. Use high doses of nitrogen.

2.1.5. Water requirements

Sugar cane requires a large amount of water. The average rainfall is 1525 mm the appropriate year. When crop production requires irrigation for

11,000 cubic meters of water per feddan per year. The thirsty have a direct affect on the growth of stems and on the productivity of the plant therefore needs a large amount of water throughout the period of vegetative growth and dry in the process of maturity because it helps the high concentration of sugar in the stems. And high rainfall or heavy irrigation in the crop mature stage harmful because it leads to delay maturity and low sugar concentration and growth of tillers in the late stage that contributing to the reduce in sugar concentration and low productivity.

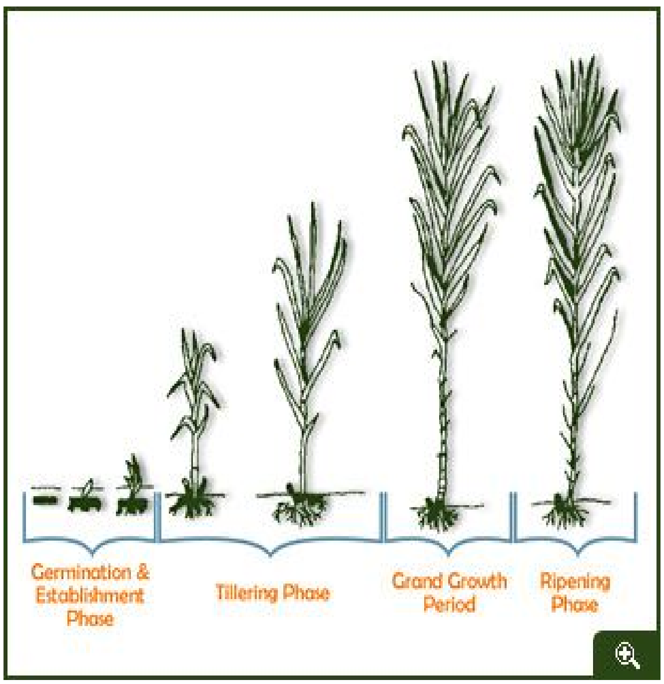


Figure (2.2): Stages growth for Sugarcane (Kuyper, L., 1952).

2.1.6. Varieties

The variety NCO310 was prevailing in the Sudan but it exposes to smut disease, which has spread widely in Aljunyed project with degree become threatens cane cultivation in the project. So replace this variety with CO527-resistant to smut disease, which competes in the productivity variety NCO310 then confirmed variety CO6806, which is characterized by resistance to smut disease, higher productivity and delayed flowering, which prolongs the period of vegetative growth and leads to increased productivity.

At present, varieties of sugar confirmed in all projects in Sudan are the variety CO6806, a red color and variety NCO527 a white color. Also new varieties approved, but did not spread widely and are currently grown in small area in Kenana project for propagation its seeds, including varieties CO997 and B47419 and B63349 and KNH80-412 and CO775.

2.2. Aqua crop modal

The Crop Systems model (CropSyst) (Stockle et al., 2003) is a process based simulation model designed to predict the performance of multiple cropping systems across genotype, soil, weather and management combinations. Decision Support System of Agro Technology Transfer (DSSAT) (Jones *et al.*, 2003) comprises nine different crop modules including cereal crops *viz.* rice, wheat and maize which simulated different processes pertaining to the effect of soil, crop phenotype, weather and nutrient management options. By simulating probable outcomes of crop management strategies, DSSAT offers options for new crops, products, and practices for adoption. The World Food Studies crop growth model (WOFOST) is a mechanistic model in which the crop growth is simulated using the underlying processes of photosynthesis and respiration. The model describes crop growth as biomass accumulation in combination with phenological development (van Ittersum et al., 2003). However, most of these models require an extended number of variables and input parameters, which are not easily available for the diverse range of crops and sites around the world. Some models use generic data base with an assigned parameter values corroborating experimental data generated from the study region for calibration and validation purposes. Moreover, accurate modeling of crop response to water plays an important role in optimizing crop water productivity in agriculture (Geerts *et al.* 2009). There are a plethora of models that simulate the growth and development of maize and other cereal crops. The CERES-Maize (Crop Environment Resource Synthesis) model is a deterministic model designed to simulate maize growth, soil, water and temperature and nitrogen dynamics at a field scale (Jones *et al.*, 1986). The input data required by most of these models are difficult to obtain or require detailed empirical measurements to establish hybrid-specific genetic coefficients as inputs to run the model and these can be suitably applied to the locations for which these are calibrated. Besides this, the models require more number of input parameters which is difficult to generate from field experiments and the crop growth engines are not water driven, *i.e.* separate module to account for crop growth responses under variable water supply situations is not available. Keeping in view of these limitations, a crop water productivity model Aqua Crop was developed by the Land and Water Division of FAO and released for use during 2009 (Steduto *et al.,* 2009; Raes *et al.,* 2009). AquaCrop is a water-driven crop model to simulate yield response to water of several herbaceous crops. It is designed to balance simplicity, accuracy and robustness, and is particularly suited to address conditions where water is a key limiting factor in crop production. The AquaCrop model has been parameterised and validated for simulating maize yield response to water (Hsiao *et al.* 2009; Heng *et al.* 2009). Although AquaCrop is based on complex crop physiological processes, it uses a relatively small number of explicit and mostly intuitive parameters with simplicity and accuracy (Steduto *et al.,* 2009; Raes *et al.,* 2009). Some of the advantages of AquaCrop are: a) it is widely applicable with acceptable accuracy; b) it requires only commonly available input (*i.e.* climate, soil, crop and field data); c) it allows easy verification of simulation results with simple field observations. In an attempt to compare performance of AquaCrop, CropSyst, and WOFOST Models, Todorovic *et al.* (2009) simulated sunflower (*Helianthus annuus L.*) growth under different water regimes in a Mediterranean environment. These three models differ in the level of complexity describing the crop development in the main growth modules driving the simulation of biomass growth, and in the number of input parameters. AquaCrop is exclusively based on the water-driven growth module, in which the transpiration is converted into biomass through water productivity (WP) parameter. The CropSyst model is based on both water and radiation driven modules, while WOFOST simulates crop growth using a carbon driven approach and fraction of intercepted radiation. The models were calibrated on data from a full irrigation treatment in 2007, and were validated on a full irrigation treatment in 2005 and several deficit irrigation (DI) treatments, including regulated deficit irrigation (RDI) and rain-fed (RF) conditions. Although AquaCrop required less input information than CropSyst and WOFOST, it performed at par with them in simulating both biomass and yield. Use of minimal data input and water-driven crop growth module of AquaCrop resulted in simulated yield in line with the data intensive and radiation driven CropSyst and WOFOST models. Therefore, it can be recommended that under conditions of limited input information and yield predictions under variable water supply situations, the AquaCrop model should be preferred over other models and the use of simpler models should be encouraged.

2.2.1.Governing equations and concepts of FAO AquaCrop model

AquaCrop model is based on the crop growth engine which is basically water driven, in which, the crop growth and production are driven by the amount of water used through consumptive use of the plant. Among the empirical function approaches, FAO Irrigation and Drainage Paper n. 33 (Doorenbos and Kassam, 1979) represented an important source to determine the yield response to water of field, vegetable and tree crops, through the following equation

$$\left[\frac{Yx-Y}{Yx}\right] = K_y\left[\frac{ETx-ET}{ETx}\right] \qquad (2.1)$$

Where, Yx and Y are the maximum and actual yield, ETx and ET are the maximum and actual evapotranspiration, and Ky is the proportionality factor between relative yield loss and relative reduction in evapotranspiration. There was a constant scientific and experimental progress in crop-water relations from 1979 till date, which led to a revision framework that treats separately field crops from tree crops. For the field crops, it was suggested to develop a model of proper structure and conceptualization that would evolve from Eq.1 and be designed for planning, management and scenario simulations. The result is the AquaCrop model which differs from the main existing models for its balance between accuracy, simplicity and robustness. AquaCrop is a FAO's crop water productivity simulation model. AquaCrop evolves from the previous Doorenbos and Kassam (1979) approach (Eq. 1) by separating (i) the ET into soil evaporation (E) and crop transpiration (Tr) and (ii) the final yield (Y) into biomass (B) and harvest index (HI). The separation of ET into E and Tr avoids the confusing effect of the non-productive consumptive use of water (E), especially during incomplete ground cover. The separation of Y into B and HI allows the distinction of the basic functional relations between environment and B from those between environment and HI and also avoids the confusing effects of water stress on B and on HI. The changes led to the following equation for the AquaCrop model

$$B \times \square WP = \square \sum Tr \qquad (2.2)$$

Where, Tr is the crop transpiration (in mm) and WP is the water productivity parameter (kg of biomass per m2 and per mm of cumulated water transpired over the time period in which the biomass is produced). The main change from Eq. 1 to AquaCrop is in the time scale used for each one. In the case of Eq. 1, the relationship is used seasonally or for long periods (of the order of months), while in the case of Eq. 2 the relationship is used for daily time steps, a period that is closer to the time scale of crop responses to water deficits. A schematic representation of the evolution of AquaCrop is shown in Figure (2.1).

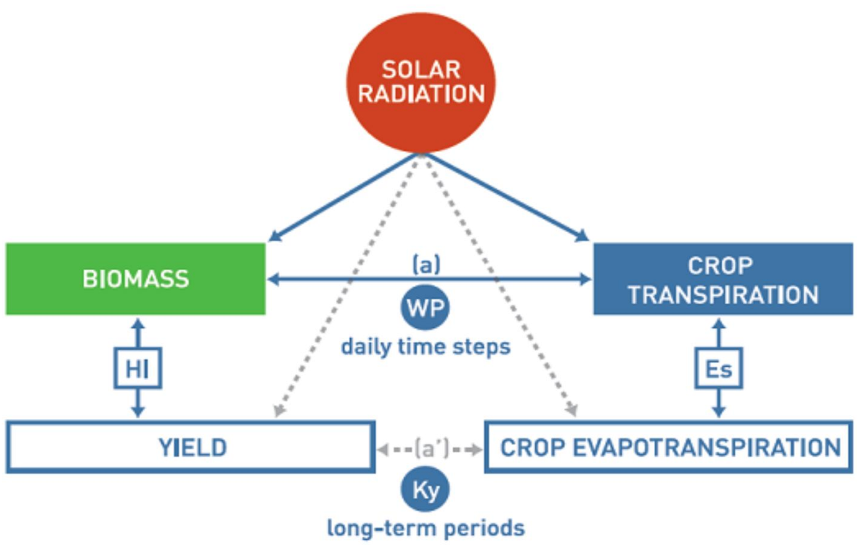


Figure (2.3). A schematic representation of the evolution of AquaCrop

Equation 1 is based on two intermediary steps *i.e.* separation of soil evaporation (E) from crop transpiration (Tr) and the attainment of yield

(Y) from biomass (B) and harvest index (HI). AquaCrop has a structure that is based on the soil-plant-atmosphere continuum. It includes the soil, with its water balance; the plant, with its development, growth and yield processes; and the atmosphere, with its thermal regime, rainfall, evaporative demand and carbon dioxide concentration. Additionally, some management aspects are explicitly considered (*e.g.*, irrigation, fertilization, etc.), as they will affect the soil water balance, crop development and final yield.

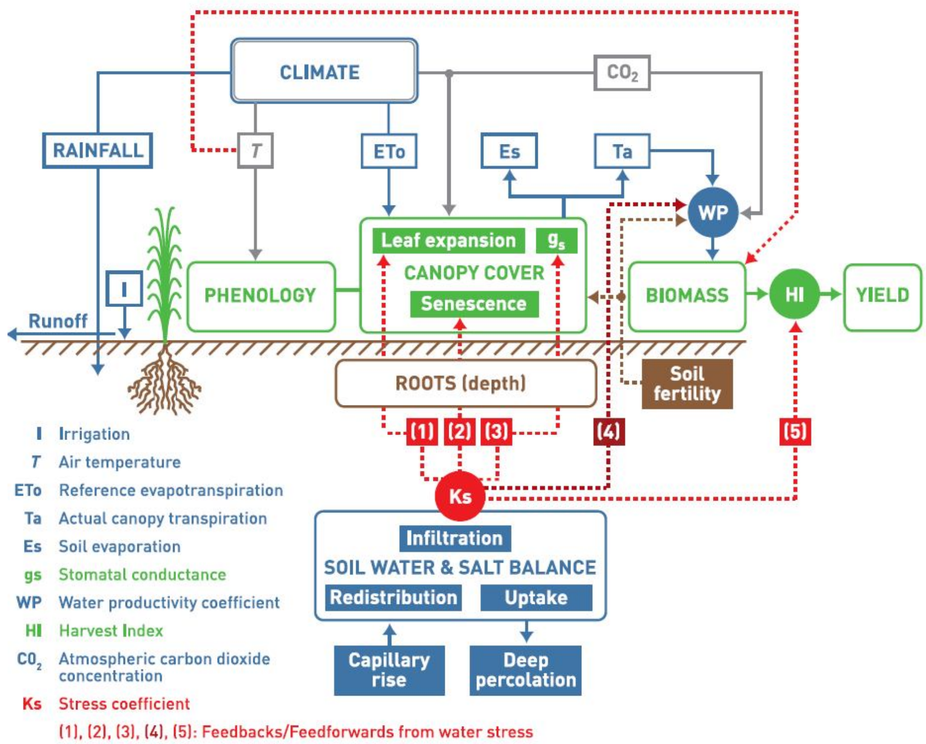
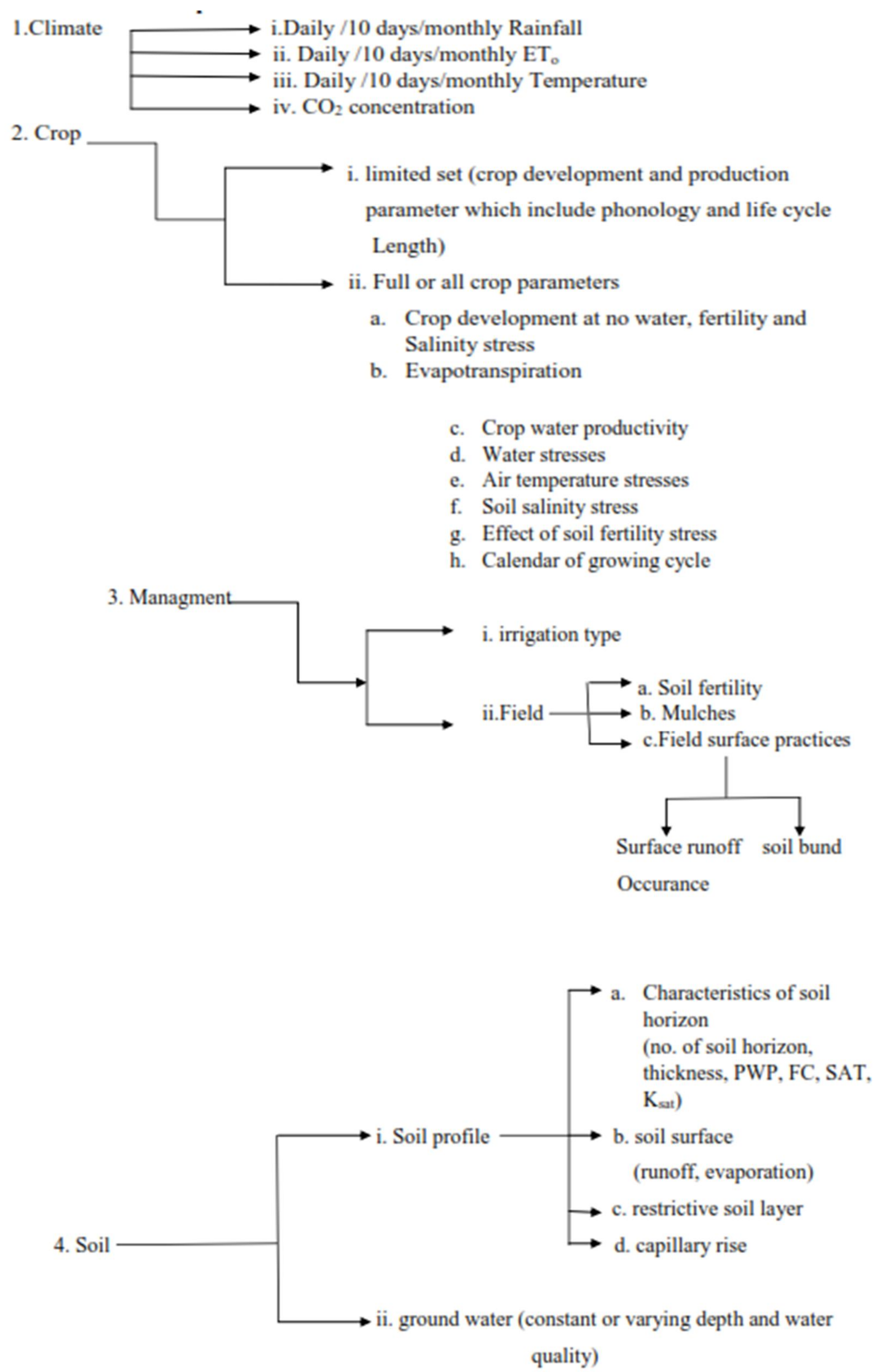


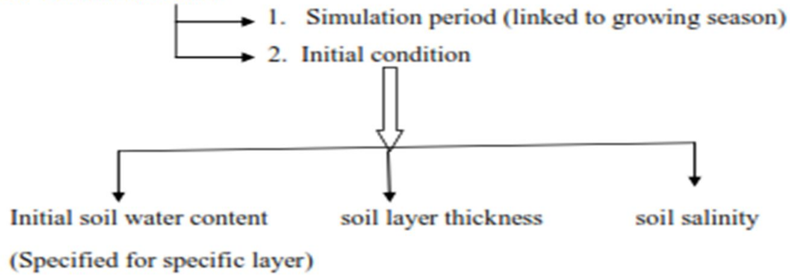
Figure (2.4). Flowchat of Aqua Crop indicating the main components of soil-plant-atmosphere continuum

2.2.2. Input data requirement of AquaCrop Model

A. Environment and Crop Data :-



B. Simulation data



CHAPTER THREE

MATERIAL AND METHODS

3.1. Case Study.

Aljunyed scheme :- The project is located in N 14°51.55 E 33°15.62 about 150 km southeast Of Khartoum on the eastern bank of the Blue Nile figure (3.1) Project was founded in Aljunyed area late fifties for the production of cotton and then converted to sugar cane production in 1962.

3.1.1. Size and design capacity

The project covers an area of 27,500 feddan distributed as farms (Hawashat) to the farmers who grow cotton. Farmers do all the agricultural operations of Planting and care of the crop until harvest. The management of the project Follows the government and provides all other services starting from preparation of land and provision of seed cane and other inputs of fertilizers and pesticides and all the infrastructure of irrigation methods and machinery, warehouses and roads. Also government owned sugar factory. At the end of the season the government buys cane from farmers, after deducting the cost of production.

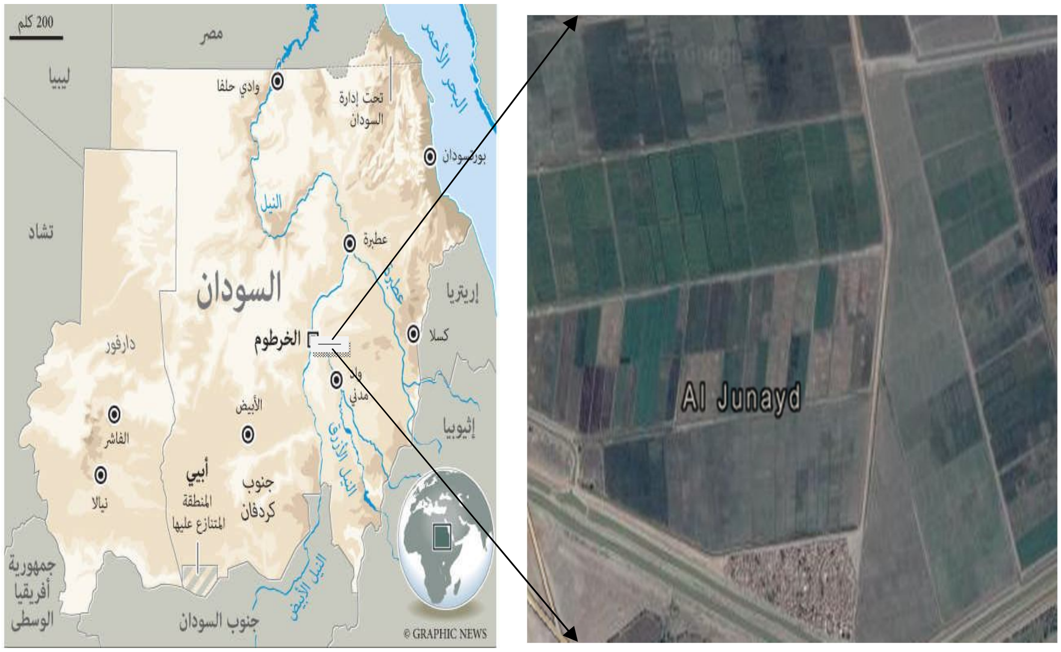


Figure (3.1):The Location and General Layout of the Aljunyed Scheme.

3.1.2. Experimental Work:

Excessive experimental and field measurements (in Aljunyed area) have been carried out at the field of Hagu and Nasr during period from 15st July 2012 till end of August 2013 (rain season). The monitored crop is Sugar cane, with two different Soil to predict Biomass (Ton/Ha) and Yield (Ton/Ha), considering the following aspects:

1. Climatic daily data taken from Aljunyed meteorological station for the period from 15st July 2012to 7th August 2013 table (3.1)
2. The growth stages of Sugar cane have been monitored from sowing date, vegetation, flowering, yield formation and Harvesting.
3. After harvesting the actual yield (Ton/Ha) of Sugar cane, for each soil, has been weighted.
4. Water quality of applied irrigation water has been measured and analyses.

3.2. Input data

Environment condition

3.2.1. Climate data

Meteorological Data:

From the climatic daily data taken from Aljunyed meteorological station ,during period from 1st of July 2012 to 31th of December 2013, maximum temperature is 45.81 C^{o} ,occurred on 29,30th May, while the minimum temperature is 9.91 C^{o} ,occurred on 16th December,. The mean relative humidity is about 32%. The mean wind speed is 1.97 m/s at 2 m height. Solar radiation ranges between 5.01 Mj/m^2, on 2th August, and 30.16 Mj/m^2 on 9th April. The peak of effective rain fall is 84.91mm/day occurred on 2th August with total effective rain fall of 313 mm and ETo Table (1) appendix .

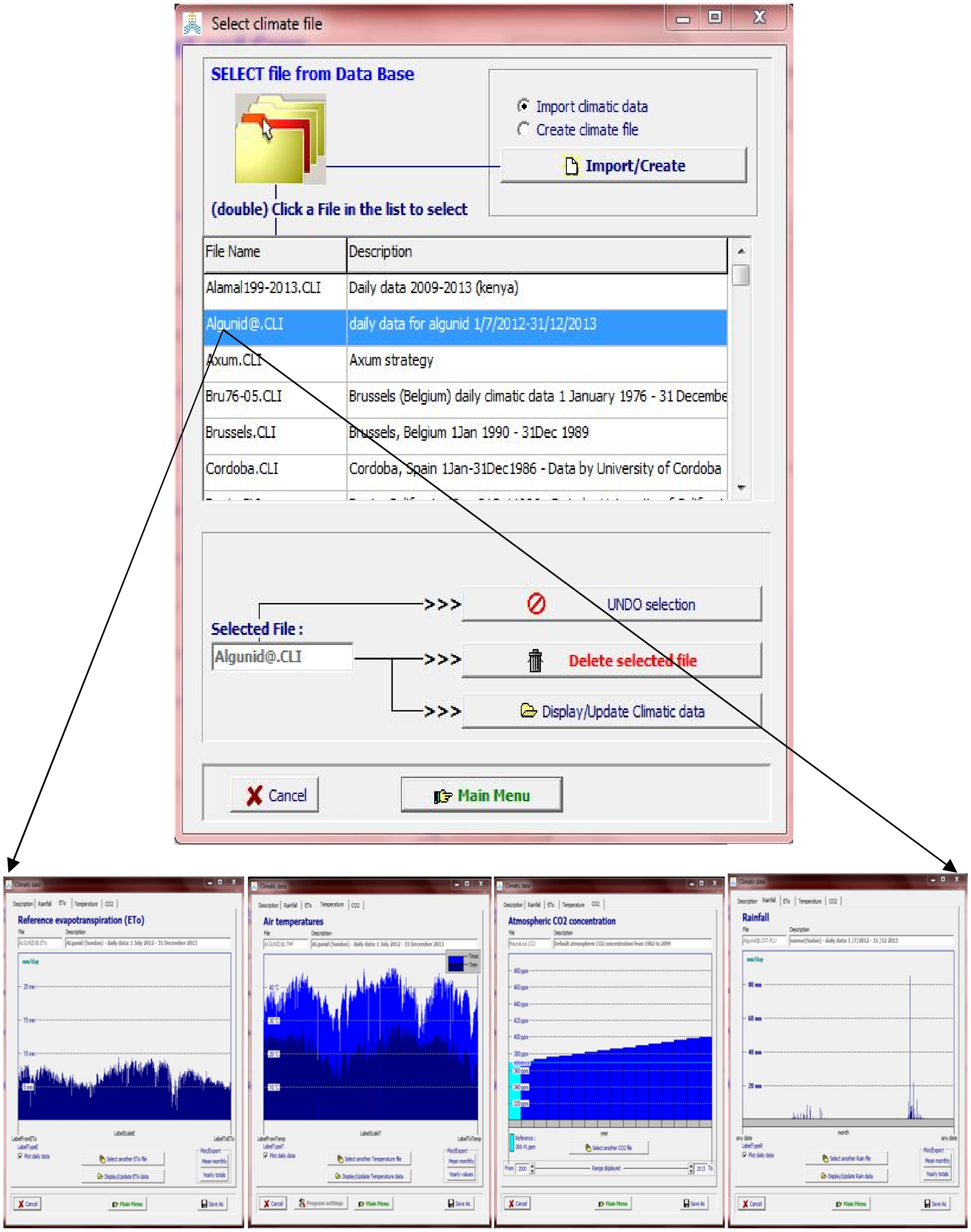


Figure (3.2): Climate date from Aljunyed.

3.2. 2. The crop:

Excessive experimental and field measurements have been carried during period from 15st July 2012 till 7th August 2013 (rain season) in "Aljunyed" area to monitor growth of Sugar cane crop at different soil.

The output of Aqua Crop model is to predict Biomass and Yield and compare them with actual Biomass and yield weighted by the two soils(sandy clay –sand clay loam)16 scenarios have been developed to predict biomass and yield together with two other scenarios of rainfed irrigation that have been developed to predict biomass and yield. Also the influence of water stresses has been monitored on biomass and yield of Sugar cane crop.

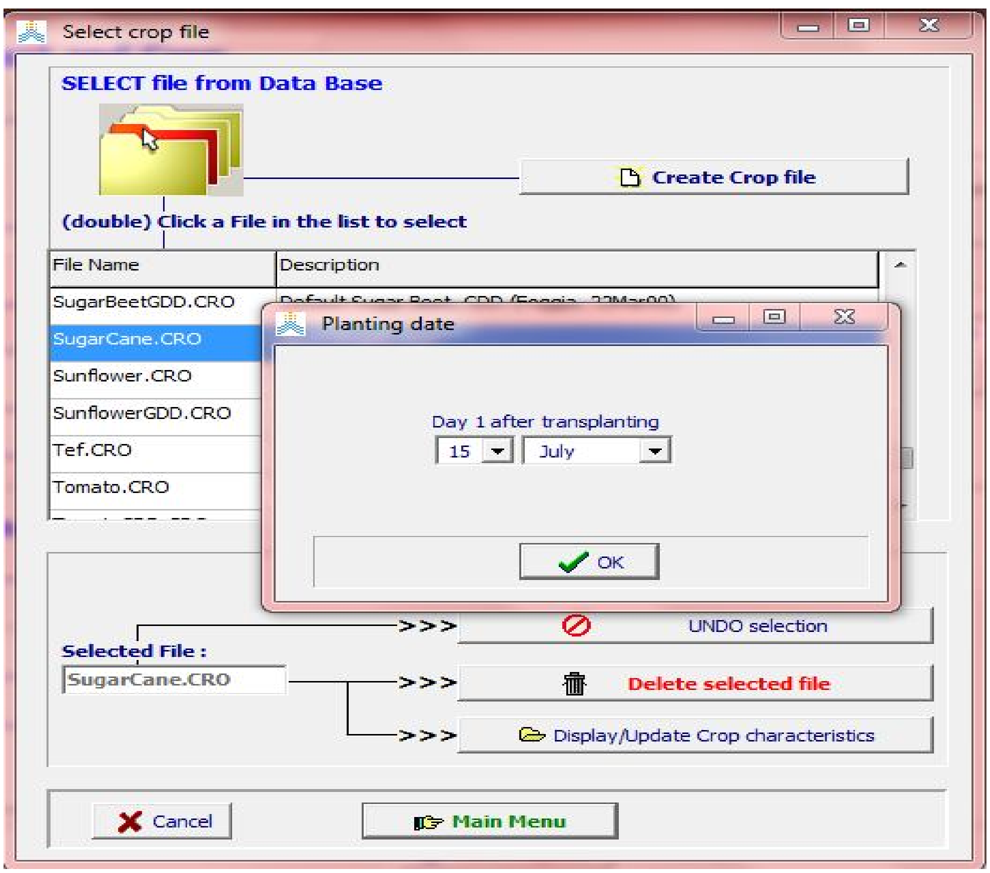


Figure (3.3) :- sugar cane sowing date .

(Aljunyed '' Nasr'):

The sowing Date was on 15th July 2012 with initial moisture content 100%. "Aljunyed" applied 27 irrigations in fixed depths at fixed times. The field measurements obtained (*Input Data*) were as follows :-

1. The plant density was 140000 plants/ha.
2. Maximum canopy cover was 95% occurred after 26 days.
3. Senescence started after 64 days from sowing date
4. Maximum roots depth was 0.70 m.
5. Overall growth cycle was 389 days
6. The soil was sand clay (with permanent wilting point (PWP) about27%, maximum field moisture content (FC) about 39% .

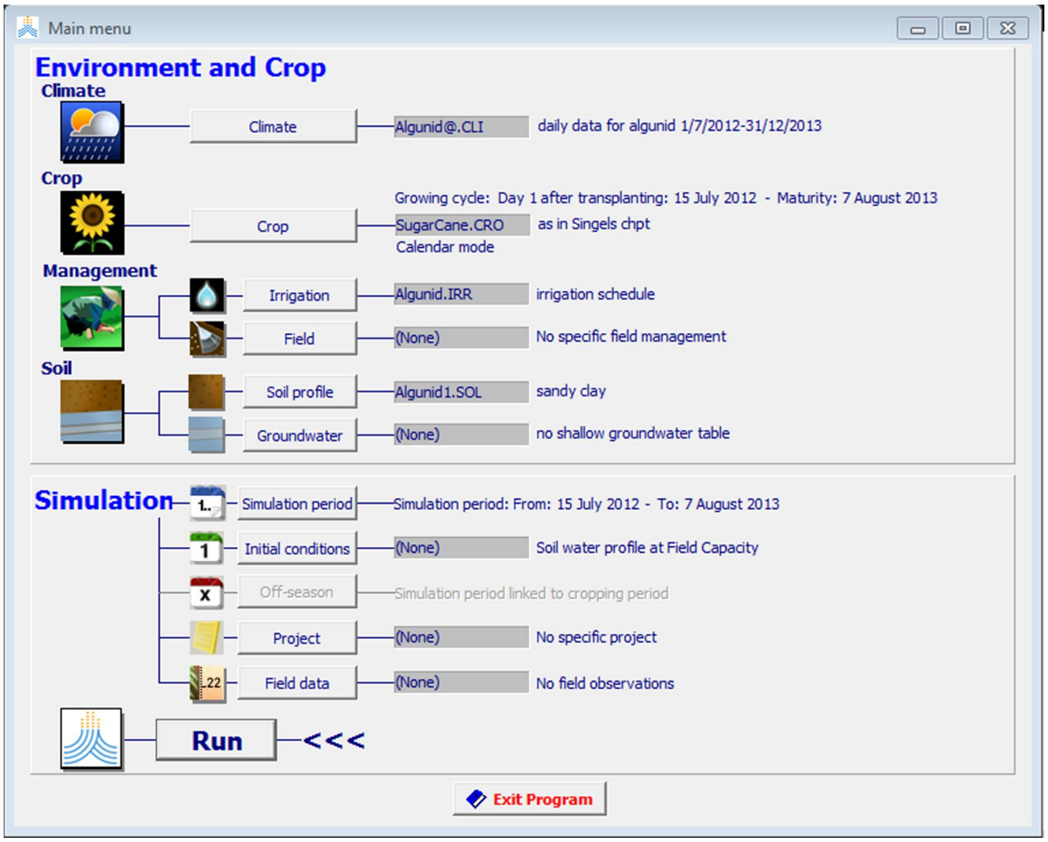


Figure.(3.4): Main menu of Aqua crop model showing input data of Field

3.2.3.Manag meant:

Figure (3.8)

3.2.4. Soil profile:

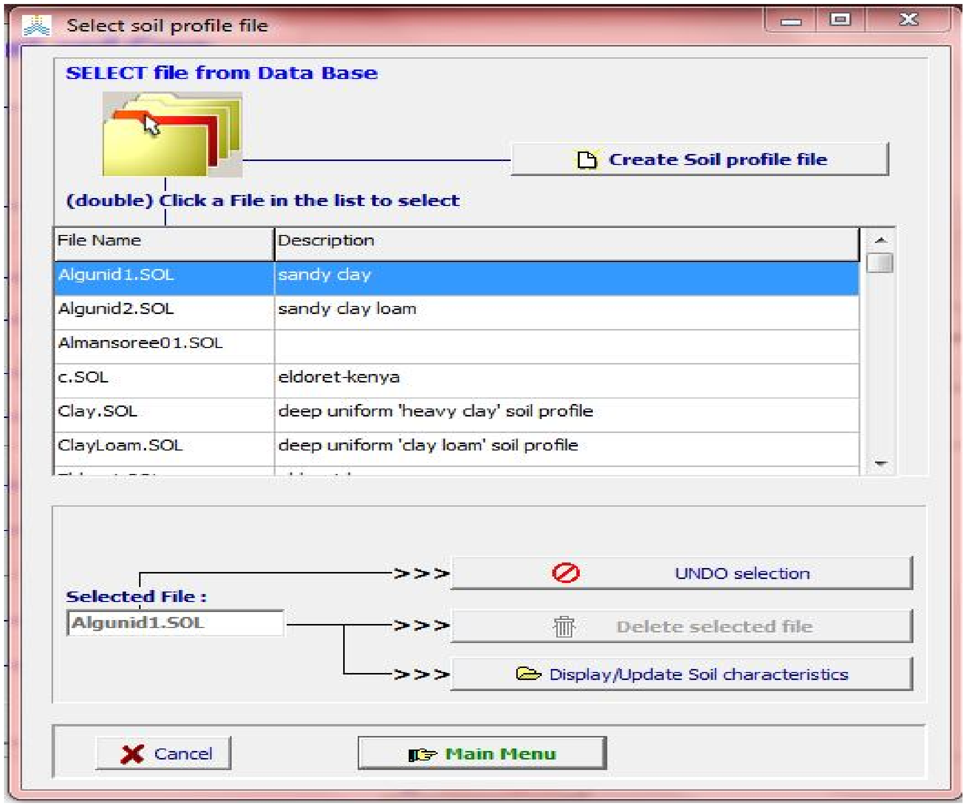


Figure.(3.5):soil profile for Nasr area .

3.2.5 Simulation Period:

The simulation period was from 15th July 2012 to 7th December 2013 with initial moisture content 100%.

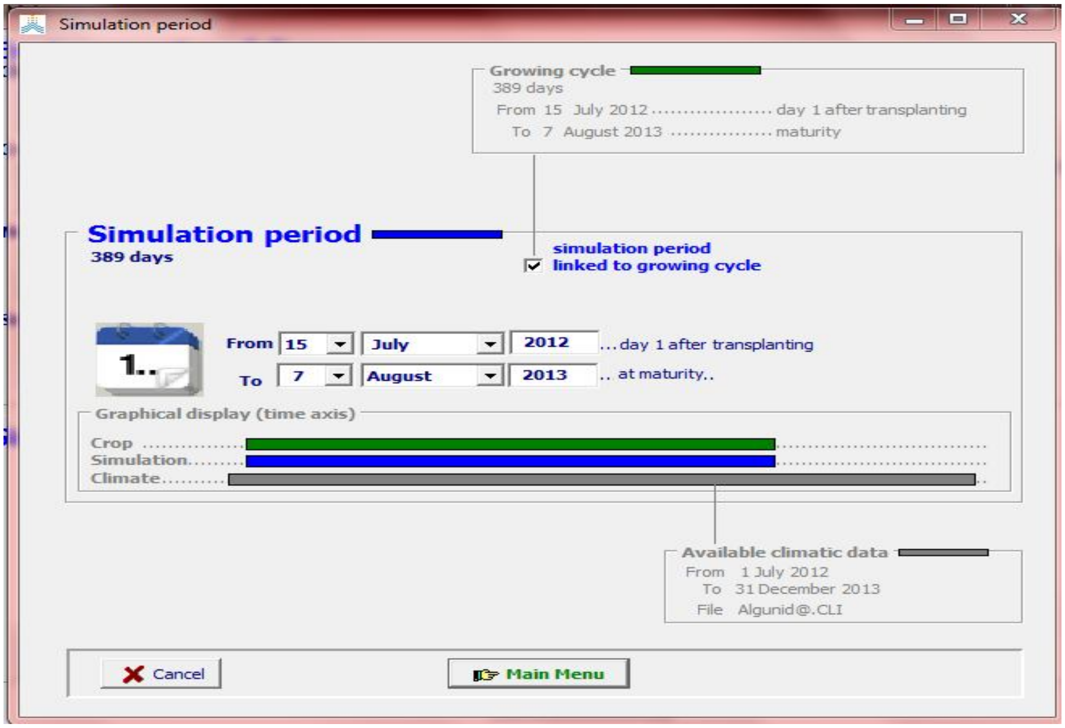


Figure.(3.6):simulation the growth stages for sugar cane

(Aljunyed ''Hagu''):

The sowing Date was on 15th July 2012 with initial moisture content 100%.

"Aljunyed" applied (27) irrigations in fixed depths at fixed times.

The field measurements obtained (*Input Data*) were as follows:-

1. The plant density was (140000) plants/ha.
2. Maximum canopy cover was 95% occurred after 26 days.
3. Senescence started after 64 days from sowing date
4. Maximum roots depth was 0.70 m.
5. Overall growth cycle was 389 days
6. The soil was sand clay loam (with permanent wilting point (PWP) about20%, maximum field moisture content (FC) about (32%) .

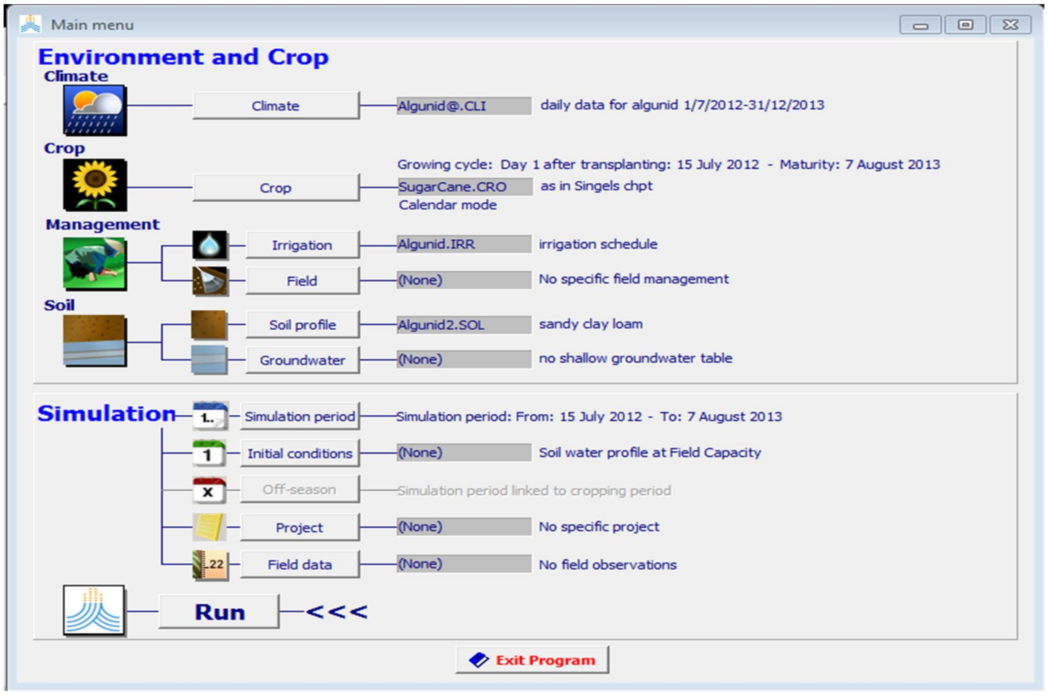


Figure (3.7): Main menu of Aqua crop model showing input data of Hagu area .

3.2. 3.1.Irrigationsystem:

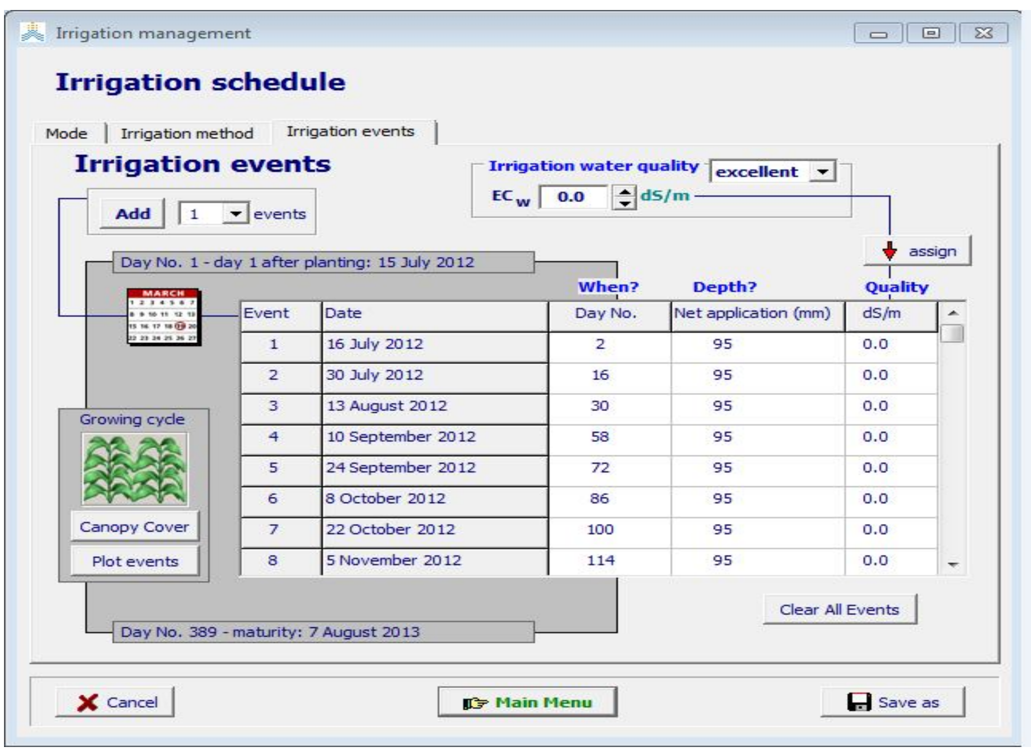


Figure (3.8):Main Irrigation system Fixed schedule (after 14 day)

Soil profile :-

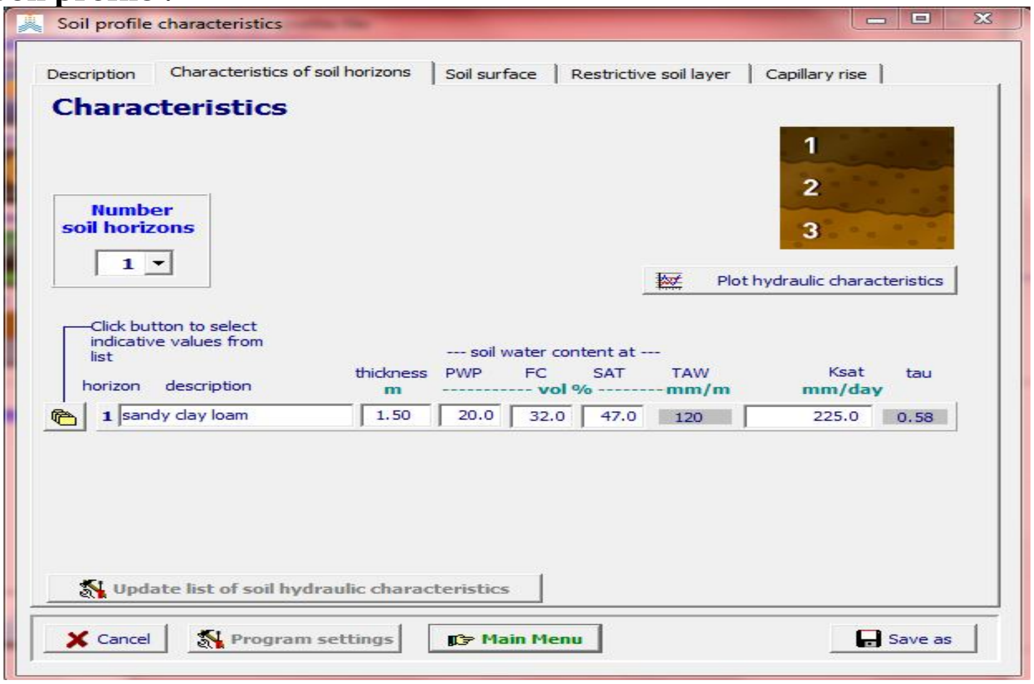


Figure (3.9):-soil profile from Hagu area .

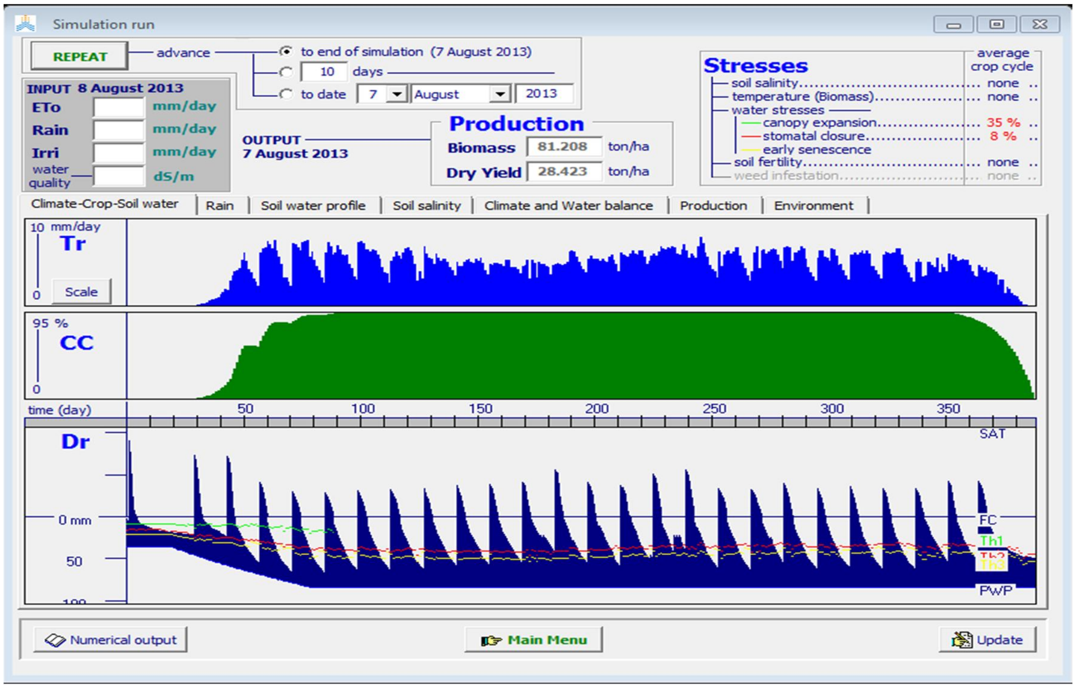
3.3. Aqua Crop Model Testing:-

The Model Output Data for (Hagu): are as follows

i. The biomass was 81.208ton/ha.

ii.The yield was equal to 2 ton/ha.

iii. Canopy expansion was 35% and Stomatal closure was 8% .Figure (3.10)



Figure(3.10): Simulation run of Aqua crop model showing output data of Hagu (Biomass, Yield, Stresses, Transpiration, Root zone depletion and Canopy cover).

The Model Output Data for Nassir Area:-

i. The biomass was equal to28.271Ton/ha

ii. The yield was equal to 9.895 ton/ha.

iii. canopy expansion was 86% and

Stomatal closure was 40%. Figure (3.11).

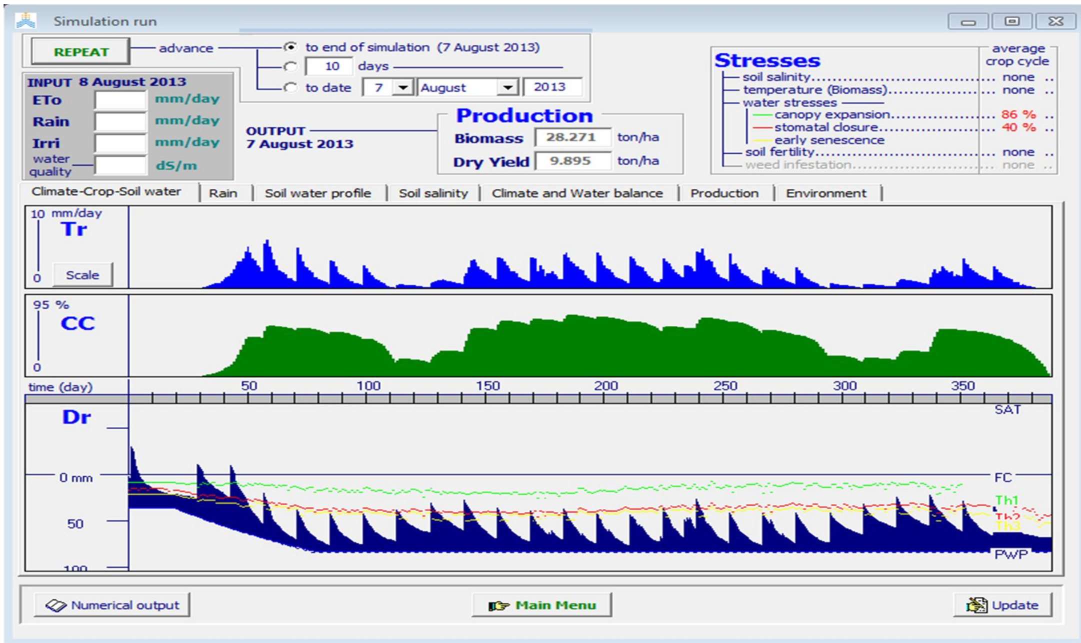


Figure (3.11): Simulation run of Aqua crop model showing output data of Field (Biomass, Yield, Stresses, Transpiration, Root zone depletion and Canopy cover)

The Actual Measurements: yield was equal to 44.Ton/ha

AquaCrop Model Testing:

The Aqua crop model has been tested using the measured data obtained from (Nasr) and (Hagu) in table (3.2)

Sours: - global weather data

Table (3.1): Aqua Crop model testing Predicted by model (Ton/H)

Station	**Yield productivity (ton/ha)**
Hagu	28.423
Nasr	9.895
Total productivity	38.318
Actual Measurements	44.8
Accuracy	85.5%

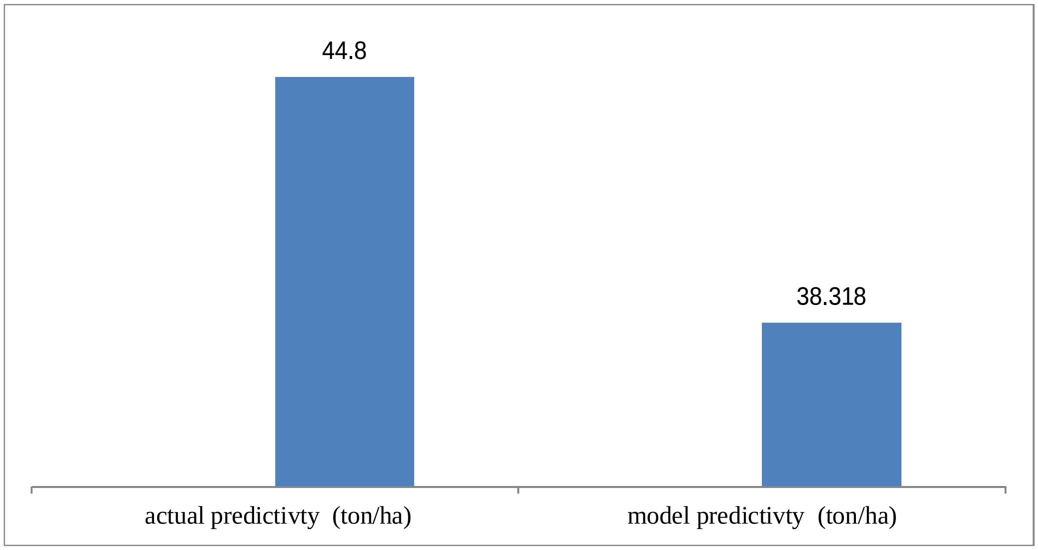


Figure (3.12): compared actually productivity (yield) Model testing

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1Aqua Crop Model Applications Using Different Scenarios:

16 scenarios have been considered in data analysis using Aqua Crop software. For each scenario the following outputs have been determined:

Main outputs*:*

1. Biomass of sugar cane (Ton/ha)
2. Yield of sugar cane (Ton/ha)

Other outputs:

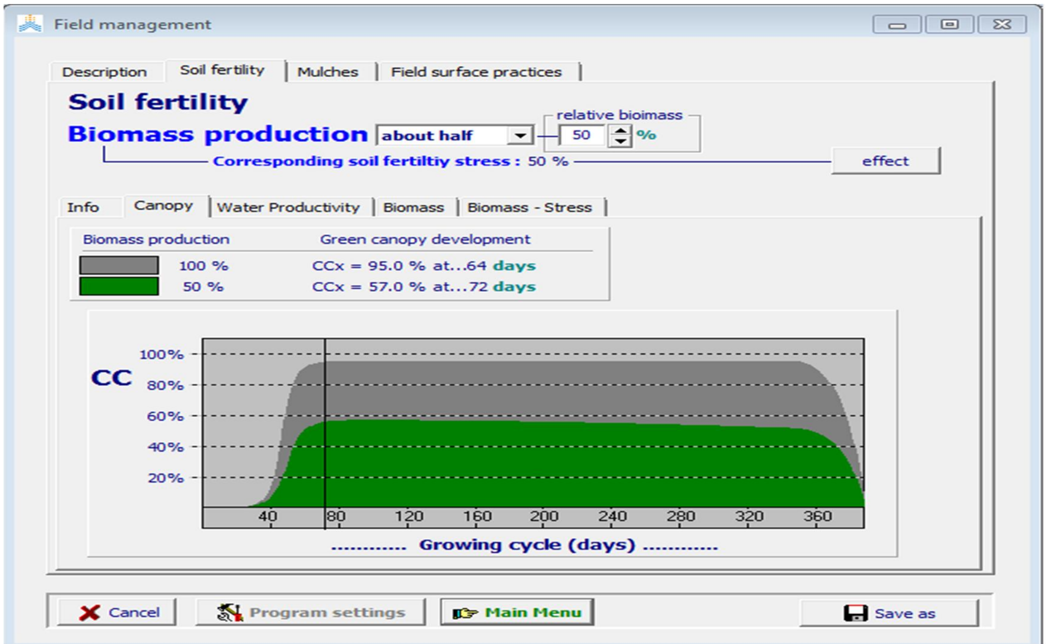
1. Stresses (soil fertility - canopy expansion - stomatal closure)
2. Crop growth cycle

NO	Scenario	NO	Scenario
	Increase(50)to(75)		Decrease(75)to(50)
1	fertility , mulch, rainfall, irrigation	9	Fertility
2	Fertility	10	Mulch
3	Mulch	11	Rainfall
4	Rainfall	12	Irrigation
5	Irrigation	13	mulch and irrigation
6	mulch and irrigation	14	irrigation and rain
7	irrigation and rain	15	rain and mulch
8	rain and mulch	16	fertility , mulch, rainfall, irrigation

4.1.1.a. Soil Fertility Level Scenarios:

Aqua crop presents six types of soil fertility levels, but the following three levels of soil fertility have been considered:

1. About half: soil fertility level 50%.
2. Moderate: soil fertility level 75%



Figure(4.1): Abut half of Soil Fertility Level.

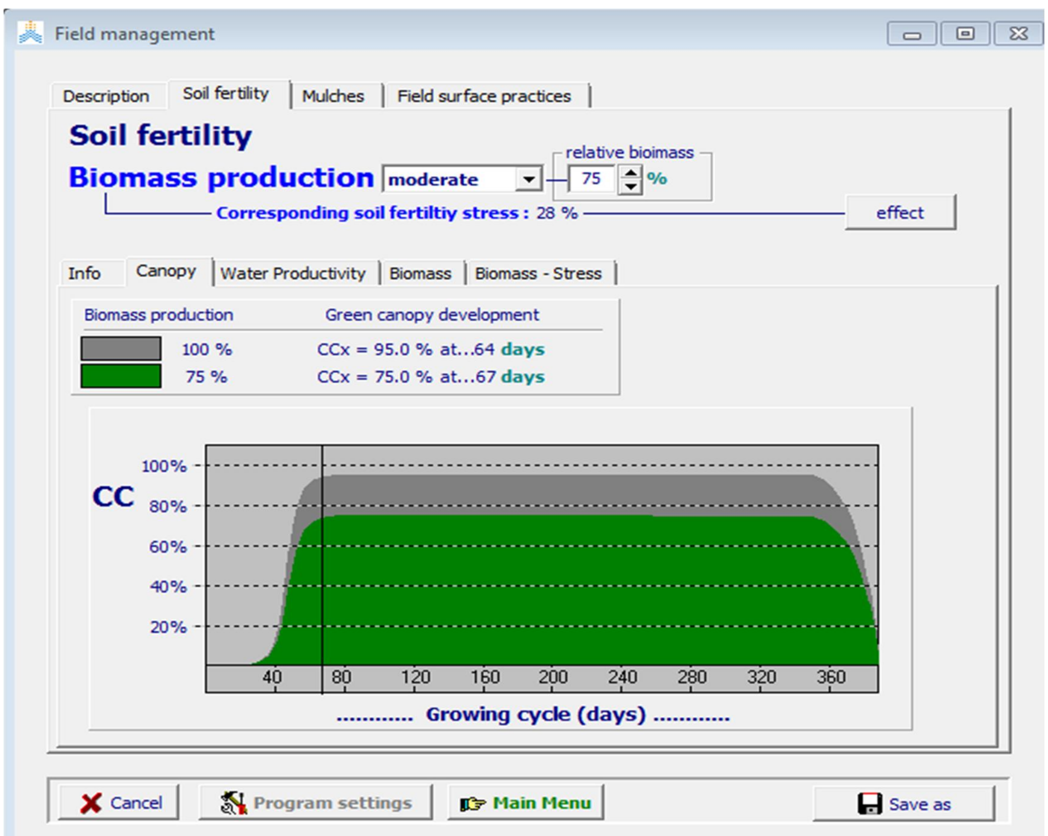


Figure (4.2): Moderate Soil Fertility Level.

4.1.2.b. Soil Mulch Level Scenarios:

Aqua crop presents six types of soil Mulch levels, but the following three levels of soil Mulch have been considered:

1. About half: soil fertility level 50%.
2. Significant: soil Mulch level 75%.

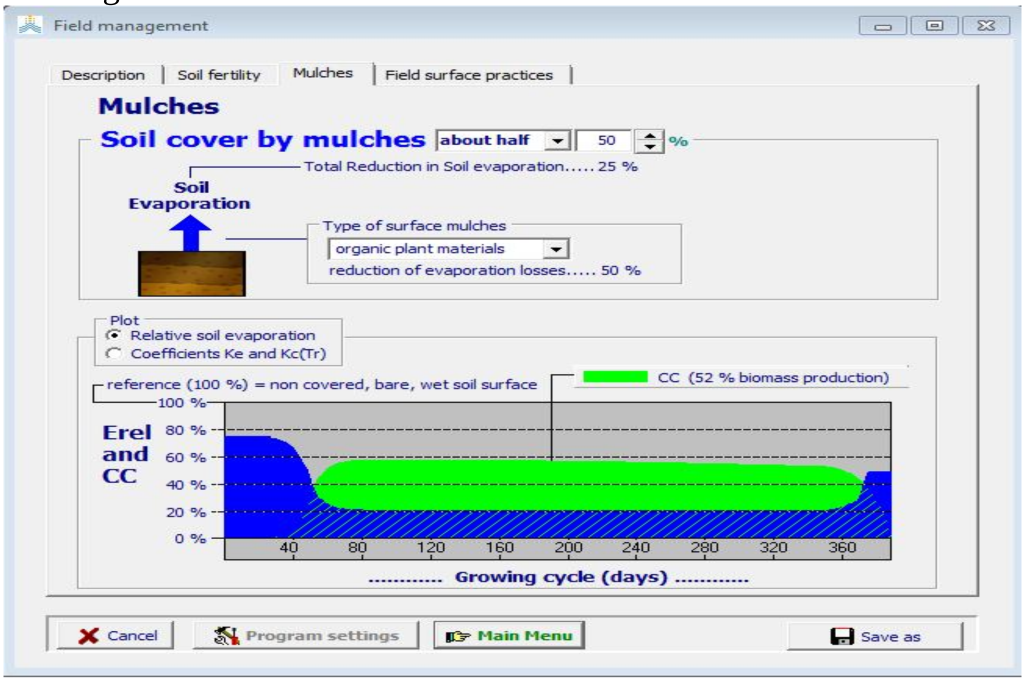


Figure (4.3): Abut half Soil Fertility Level.

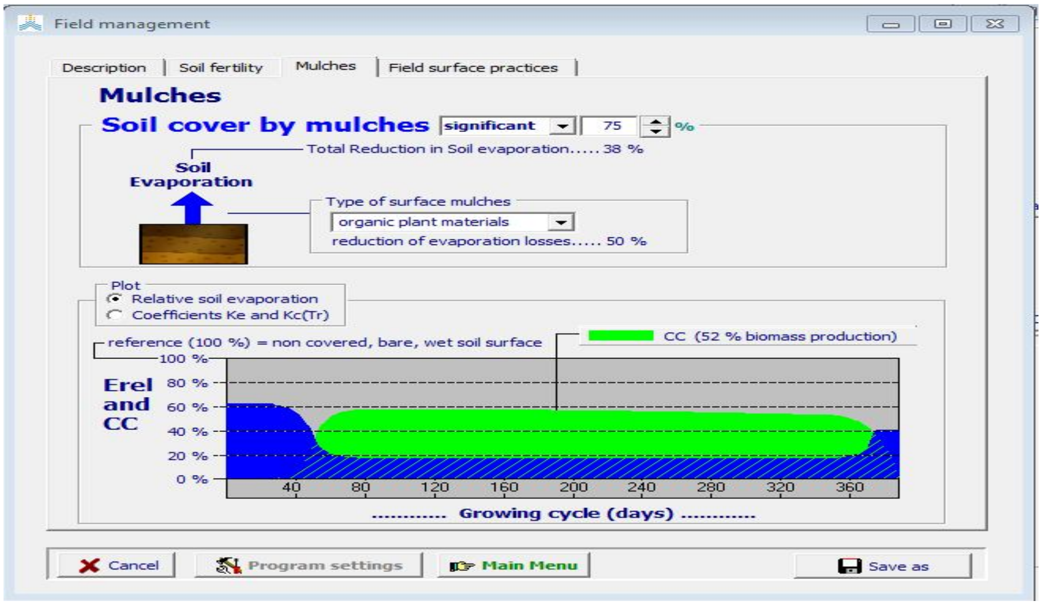


Figure (4.4): Moderate Soil Fertility Level.

4.1.3. C. Irrigation Scenarios:

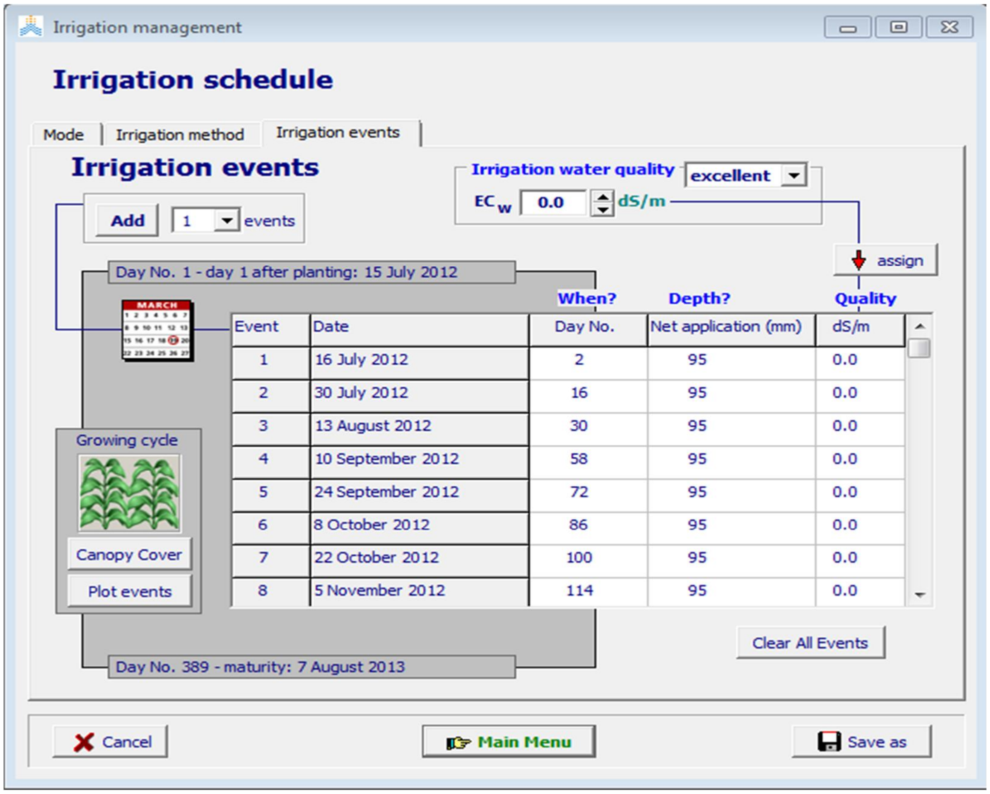
Irrigation Options:

The following irrigation options have been considered: (Figure)

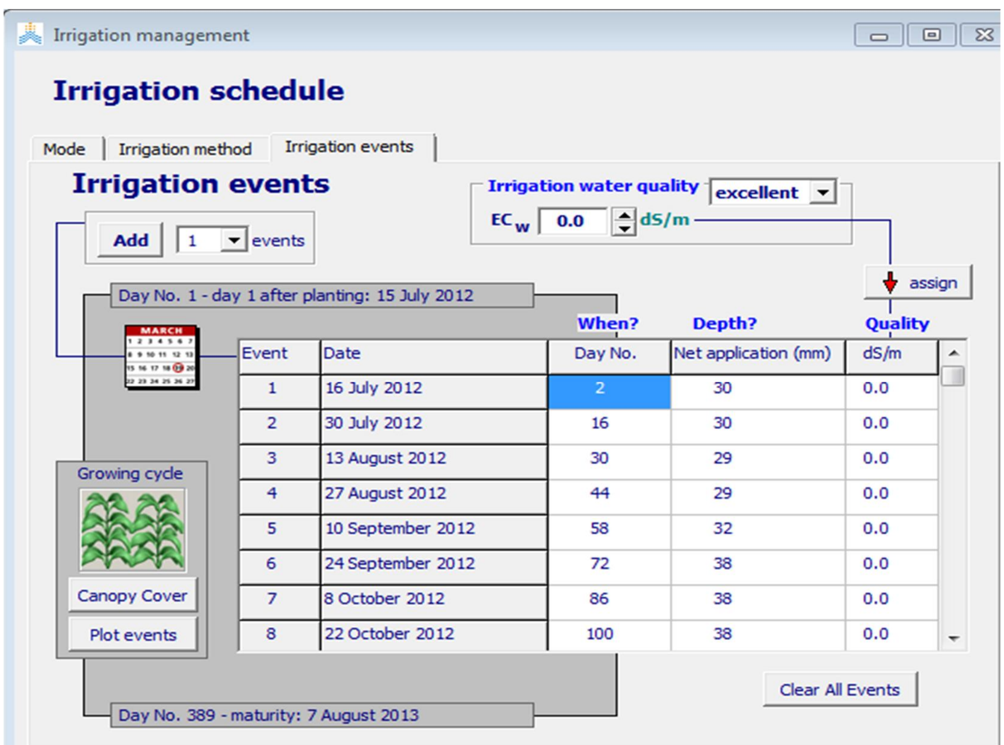
1. The application irrigation system depending need esteem50% effective rain fall
2. The application irrigation system depending needier crop esteem75 % effective rain fall.

Table (4.1): Water Requirements for sugar cane at 4 stages of sugar cane crop

Stage \ Net irrigation requirement	Net (50%)	Net(75%)
Germenation (mm)	56.29	51.68
Tillering (mm)	78.47	64.51
Grand Period or Boom Stage (mm)	764.1	759.75
Maturity (mm)	40.53	29.71-



Figure(4.5): Actual Irrigation Option.



Figure(4.6): Water Application ETc (50%)Irrigation Option.

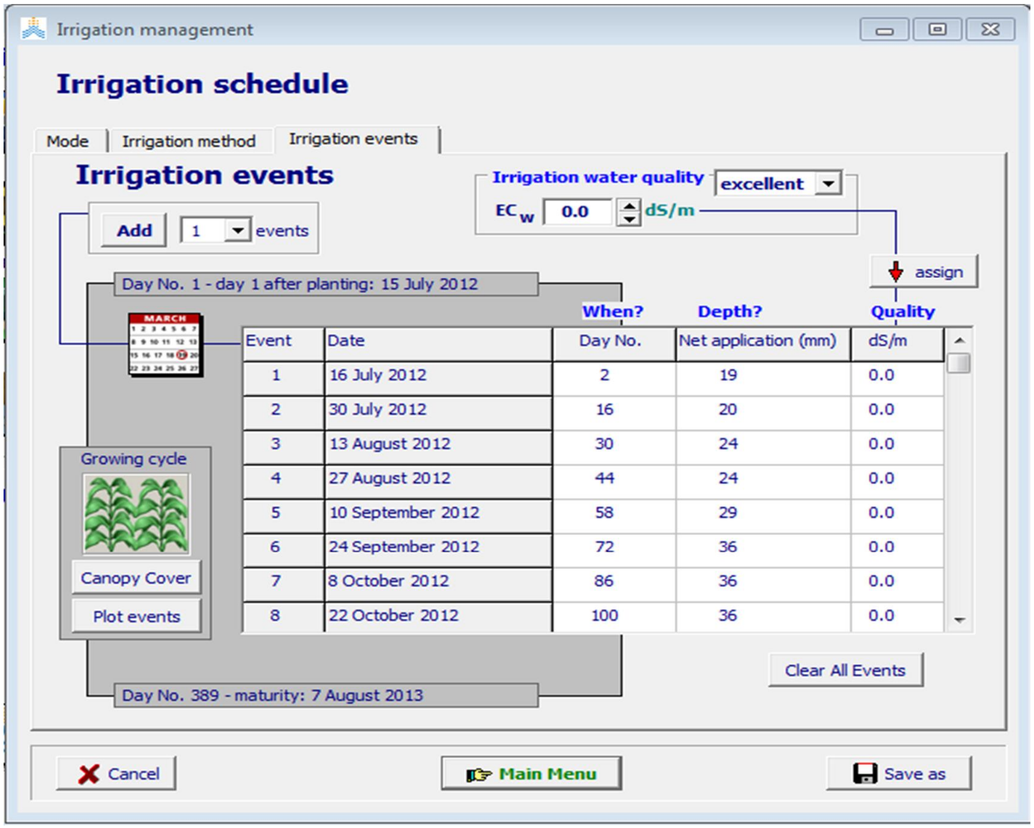


Figure (4.7): Water Application ETc (75%) Irrigation Option.

4.1.4. D. Effective Rainfall Scenarios:

The following two scenarios have been considered: (Table and Figure) Actual effective rainfall for Aljunid meteorological station during period 1st July 2012 to 31th December2013, with total rainfall 254.9mm. (100%).

1. 50% decrease of actual effective rainfall for Aljunid meteorological station, with total rainfall 312.88 mm.

2. 75% increase of actual effective rainfall for Aljunid meteorological station, with total rainfall 312.88 mm.

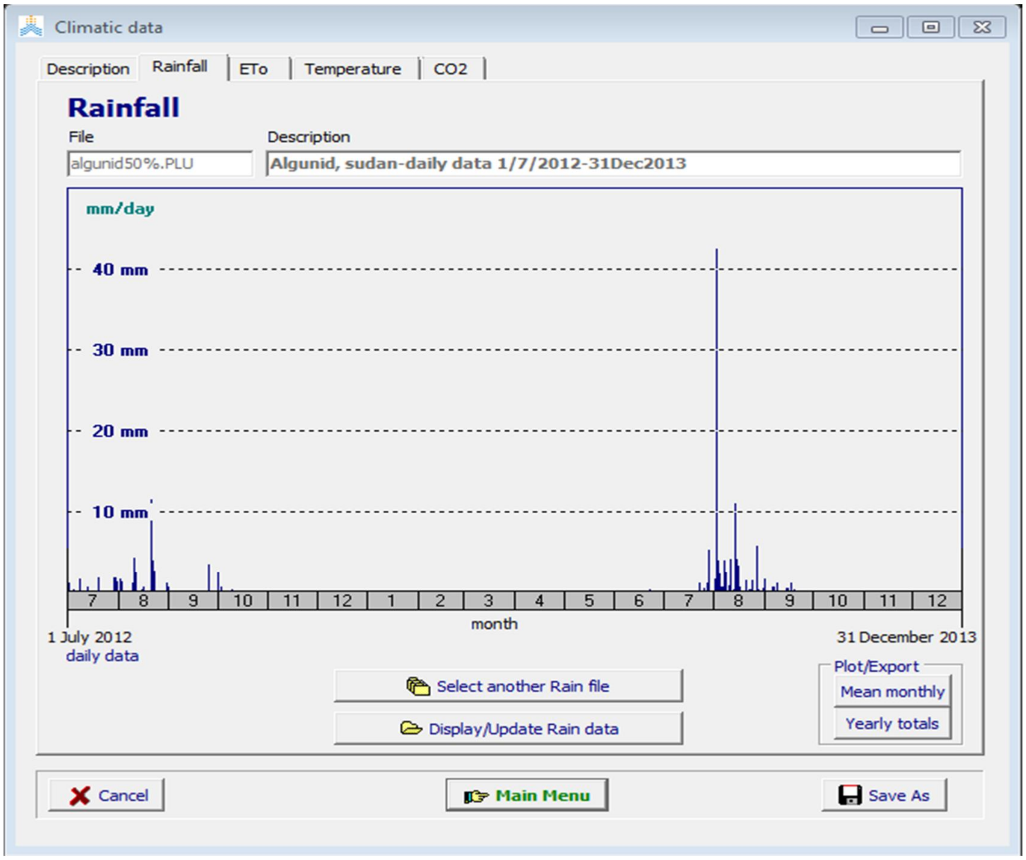
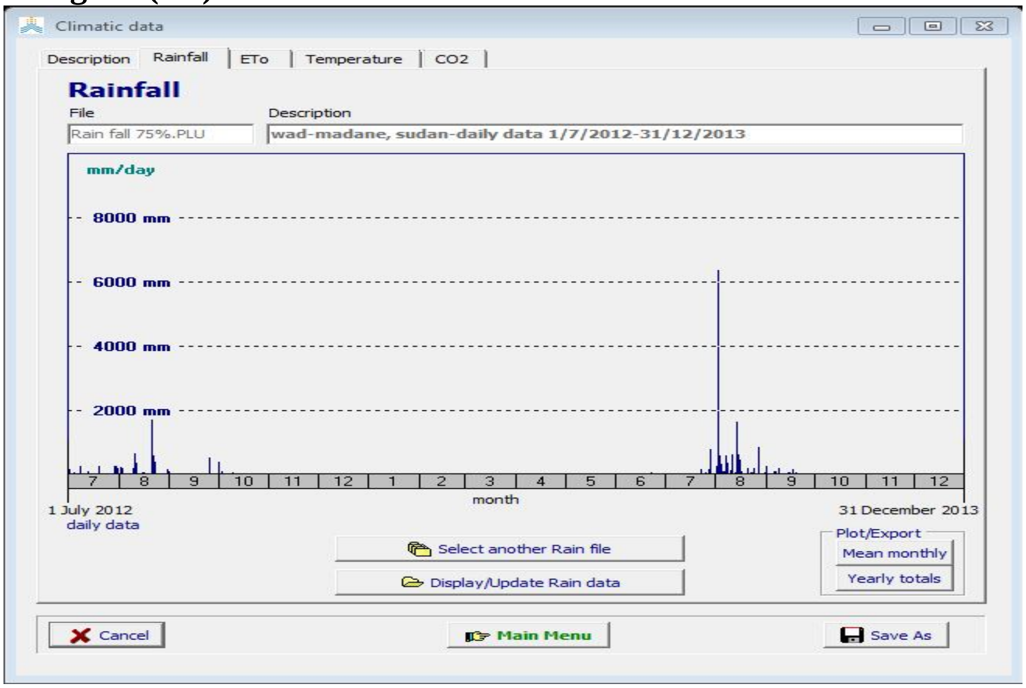


Figure (4.8): 50 % of Actual Effective Rainfall.



Figure(4.9): 75% of Actual Effective Rainfall.

Table (4.3): Biomass and yield Predicted by the model (1)

	Fertility 50 %	Mulch 50%	Rain 50 %	Irrigation 50%	Fertility 50 %	Mulch 50 %	Rain 50 %	Irrigation 75 %
	Predicted by the model				Predicted by the model			
	Nasr		Hagu		Nasr		Hagu	
Biomass(Ton/ha)	20.853		27.569		13.601		21.699	
Yield (Ton/ha)	7.298		9.649		4.760		7.595	
Canopyexpansion (%)	88		87		84		88	
stomatal closure(%)	42		43		38		43	
Soil fertility (%)	49		49		49		49	

Table (4.4): Biomass and yield (Predicted by the model)(2)

	Fertility 50 %	Mulch 50 %	Rain 75 %	Irrigation 50 %	Fertility 50 %	Mulch 50 %	Rain 75 %	Irrigation 75%
	Predicted by the model				Predicted by the model			
	Nasr		Hagu		Nasr		Hagu	
Biomass(Ton/ha)	21.432		27.705		23.885		32.303	
Yield (Ton/ha)	7.501		9.697		8.360		11.306	
Canopy expansion (%)	88		87		63		71	
stomatal closure(%)	42		43		36		33	
Soil fertility (%)	49		49		49		49	

Table(4.5): Biomass and yield Predicted by the model(3)

	Fertility	Mulch	Rain	Irrigation	Fertility	Mulch	Rain	Irrigation
	50 %	75 %	50 %	50 %	50 %	75%	50 %	75%
	Predicted by the model				Predicted by the model			
	Nasr		Hagu		Nasr		Hagu	
Biomass(Ton/ha)	22.863		28.211		19.294		23.421	
Yield (Ton/ha)	8.002		9.874		6.753		8.197	
Canopyexpansion (%)	88		86		87		88	
stomatal closure(%)	43		42		41		43	
soil fertility(%)	51		51		51		51	

Table(4.6): Biomass and yield Predicted by the model(4)

	Fertility	Mulch	Rain	Irrigation	Fertility	Mulch	Rain	Irrigation
	50 %	75 %	75%	50%	50 %	75%	75 %	75 %
	Predicted by the model				Predicted by the model			
	Nasr		Hagu		Nasr		Hagu	
Biomass(Ton/ha)	23.039		28.354		28.969		32.458	
Yield (Ton/ha)	8.064		9.924		10.139		11.360	
Canopy expansion (%)	88		86		71		70	
Stomata closure (%)	42		42		35		32	
Soil fertility (%)	51		51		51		51	

Table (4.7): Biomass and yield Predicted by the model (5)

<table>
<tr><td rowspan="4"></td><td>Fertility</td><td>Mulch</td><td>Rain</td><td>Irrigation</td><td>Fertility</td><td>Mulch</td><td>Rain</td><td>Irrigation</td></tr>
<tr><td>75 %</td><td>50 %</td><td>50 %</td><td>50 %</td><td>75%</td><td>50 %</td><td>50 %</td><td>75 %</td></tr>
<tr><td colspan="4">Predicted by the model</td><td colspan="4">Predicted by the model</td></tr>
<tr><td colspan="2">Nasr</td><td colspan="2">Hagu</td><td colspan="2">Nasr</td><td colspan="2">Hagu</td></tr>
<tr><td>Biomass(Ton/ha)</td><td colspan="2">22.018</td><td colspan="2">30.151</td><td colspan="2">14.125</td><td colspan="2">22.714</td></tr>
<tr><td>Yield (Ton/ha)</td><td colspan="2">7.706</td><td colspan="2">10.553</td><td colspan="2">4.944</td><td colspan="2">7.950</td></tr>
<tr><td>Canopy expansion (%)</td><td colspan="2">87</td><td colspan="2">88</td><td colspan="2">84</td><td colspan="2">88</td></tr>
<tr><td>Stomata closure (%)</td><td colspan="2">40</td><td colspan="2">45</td><td colspan="2">37</td><td colspan="2">42</td></tr>
<tr><td>Soil fertility (%)</td><td colspan="2">28</td><td colspan="2">28</td><td colspan="2">28</td><td colspan="2">28</td></tr>
</table>

Table(4.8): Biomass and yield Predicted by the model(6)

<table>
<tr><td rowspan="4"></td><td>Fertility</td><td>Mulch</td><td>Rain</td><td>Irrigation</td><td>Fertility</td><td>Mulch</td><td>Rain</td><td>Irrigation</td></tr>
<tr><td>75%</td><td>50%</td><td>75%</td><td>50%</td><td>75 %</td><td>50 %</td><td>75%</td><td>75%</td></tr>
<tr><td colspan="4">Predicted by the model</td><td colspan="4">Predicted by the model</td></tr>
<tr><td colspan="2">Nasr</td><td colspan="2">Hagu</td><td colspan="2">Nasr</td><td colspan="2">Hagu</td></tr>
<tr><td>Biomass(Ton/ha)</td><td colspan="2">22.655</td><td colspan="2">30.189</td><td colspan="2">34.602</td><td colspan="2">39.827</td></tr>
<tr><td>Yield (Ton/ha)</td><td colspan="2">7.929</td><td colspan="2">10.566</td><td colspan="2">12.111</td><td colspan="2">13.939</td></tr>
<tr><td>Canopyexpansion (%)</td><td colspan="2">87</td><td colspan="2">88</td><td colspan="2">75</td><td colspan="2">75</td></tr>
<tr><td>stomatal closure (%)</td><td colspan="2">41</td><td colspan="2">45</td><td colspan="2">35</td><td colspan="2">35</td></tr>
<tr><td>soil fertility(%)</td><td colspan="2">28</td><td colspan="2">28</td><td colspan="2">28</td><td colspan="2">28</td></tr>
</table>

Table(4.9): Biomass and yield Predicted by the model (7)

	Fertility 75%	Mulch 75 %	Rain 50 %	Irrigation 50%	Fertility 75 %	Mulch 75%	Rain 50%	Irrigation 75 %
	Predicted by the model				Predicted by the model			
	Nasr		Hagu		Nasr		Hagu	
Biomass(Ton/ha)	25.062		31.862		15.627		24.738	
Yield (Ton/ha)	8.772		11.152		5.469		8.658	
Canopy expansion (%)	88		88		85		88	
Stomatal closure (%)	43		47		40		44	
Soil fertility (%)	28		28		28		28	

Table(4.10): Biomass and yield Predicted by the model (8)

	Fertility 75%	Mulch 75 %	Rain 75%	Irrigation 50%	Fertility 75 %	Mulch 75 %	Rain 75 %	Irrigation 75%
	Predicted by the model				Predicted by the model			
	Nasr		Hagu		Nasr		Hagu	
Biomass(Ton/ha)	40.239		46.484		36.622		41.350	
Yield (Ton/ha)	14.84		16.269		12.818		14.472	
Canopy expansion (%)	73		72		74		75	
stomata closure (%)	35		32		35		34	
Soil fertility (%)	28		28		28		28	

Yield and biomass prediction under different scenarios at (75%) increasing.

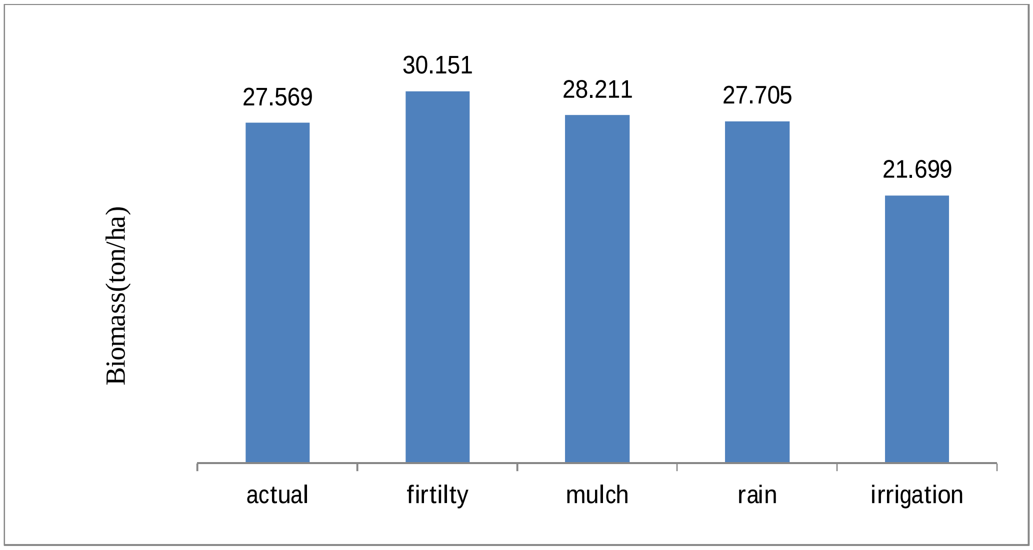


Figure (4.10.a) (Hagu) : Biomass productivity under all irrigation and nitrogen levels

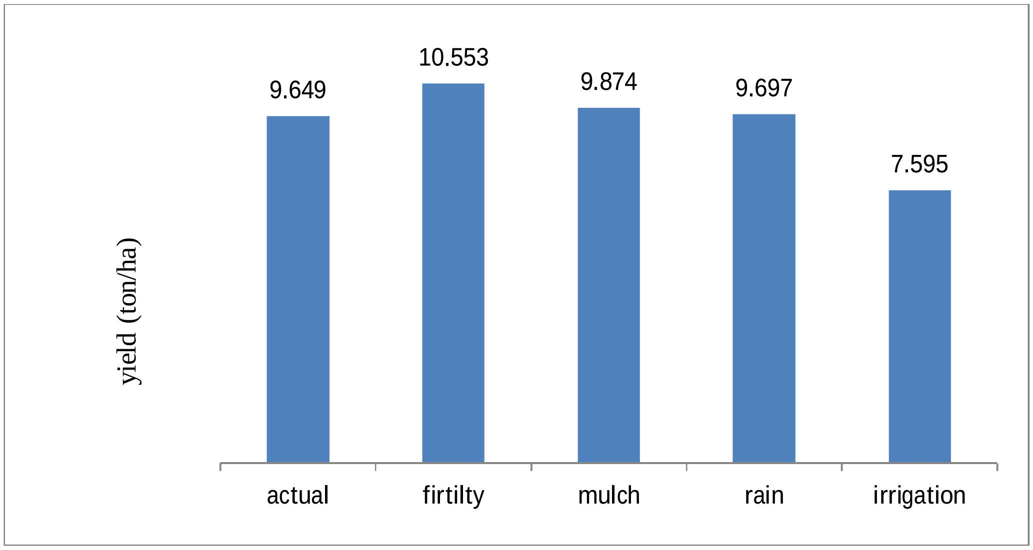


Figure (4.10.a) (Hagu): Yield productivity under all irrigation and nitrogen levels.

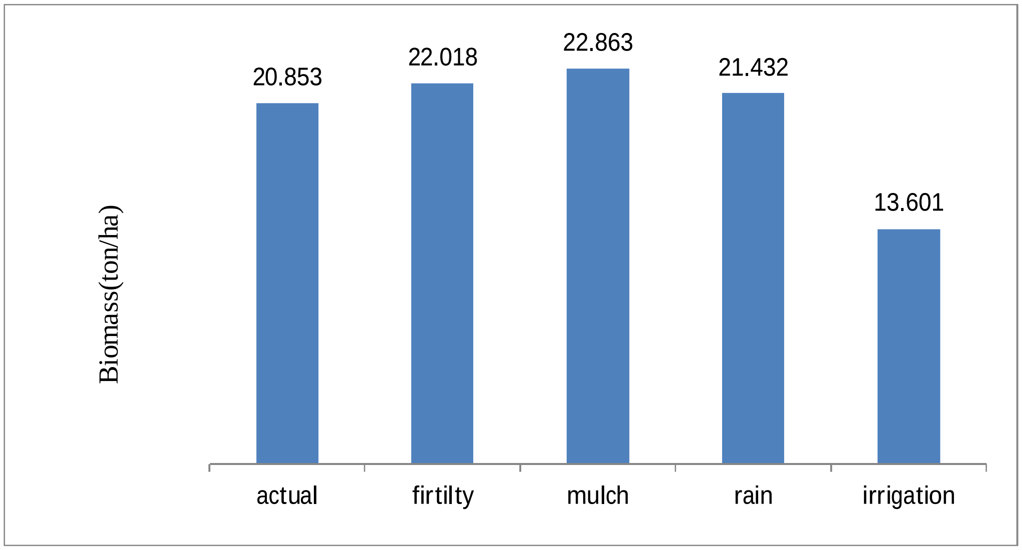


Figure (4.10.a)(Nasr): Biomass productivity under all irrigation and nitrogen levels

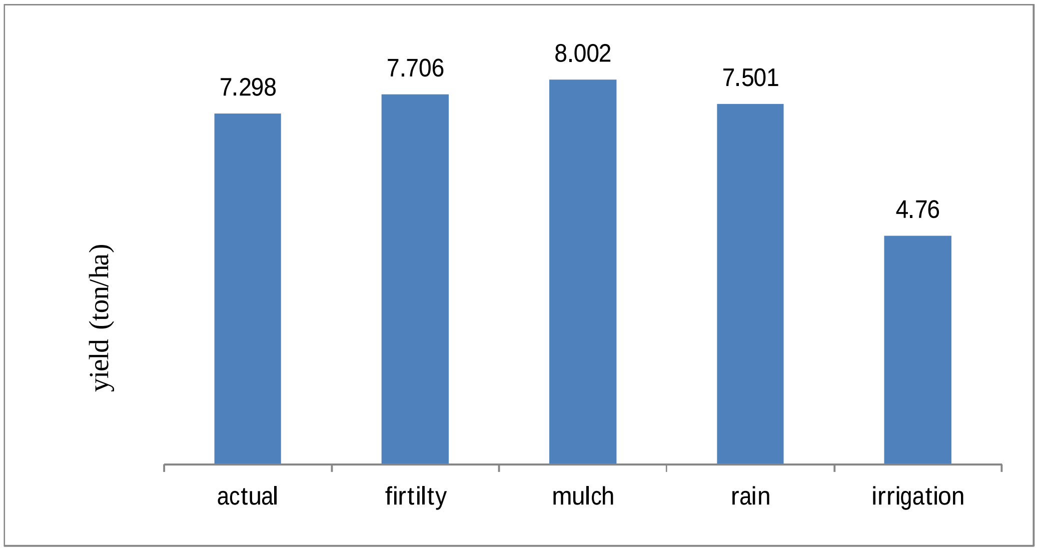


Figure (4.10.a) (Nasr): Yield productivity under all irrigation and nitrogen levels

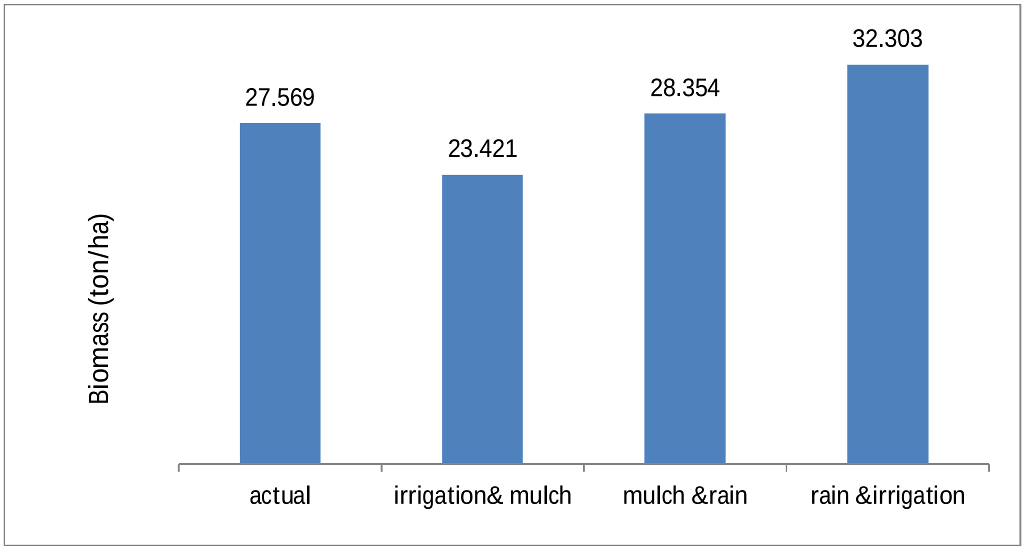


Figure (4.10.a) (Hagu): Biomass productivity under all irrigation and nitrogen levels

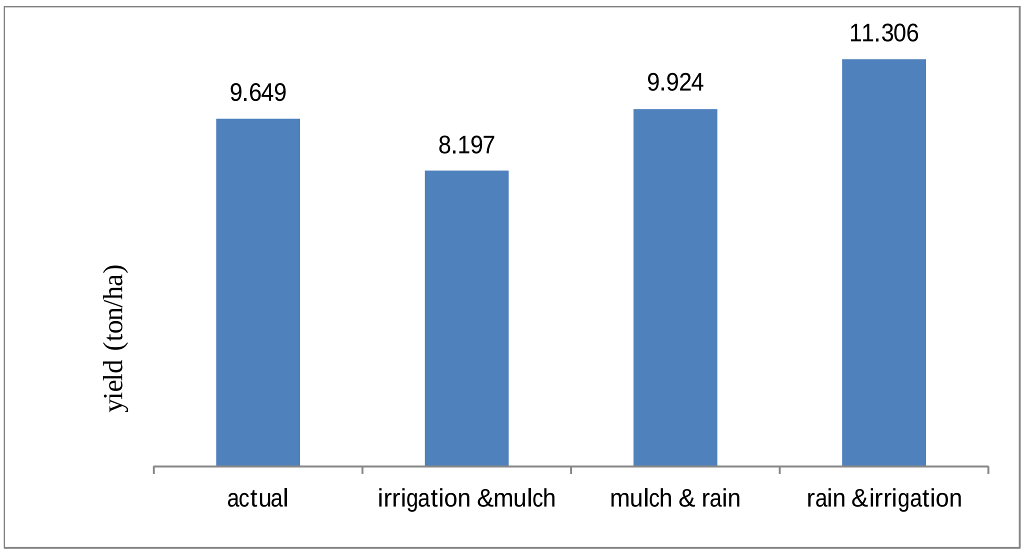


Figure (4.10.a)(Hagu): Yield productivity under all irrigation and nitrogen levels

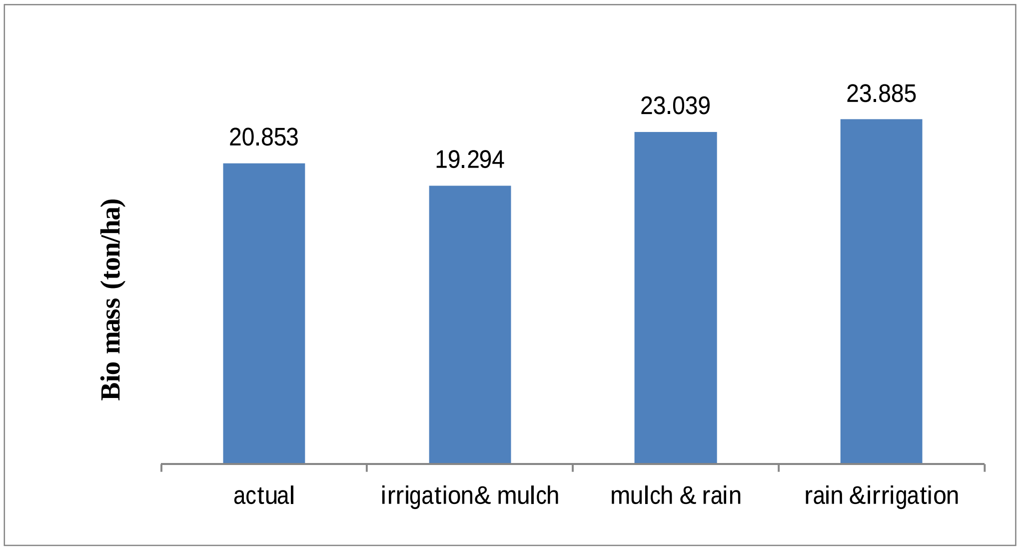


Figure (4.10.a)(Nasr): Biomass productivity under all irrigation and nitrogen levels

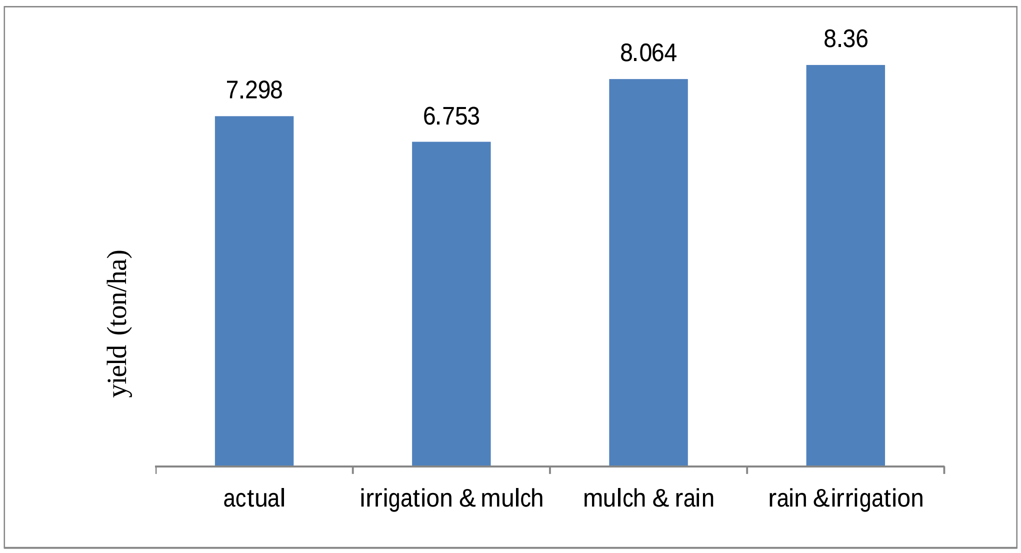


Figure (4.10.a)(Nasr): Yield productivity under all irrigation and nitrogen levels

Yield and biomass prediction under different scenarios at Decreased to **(50)**

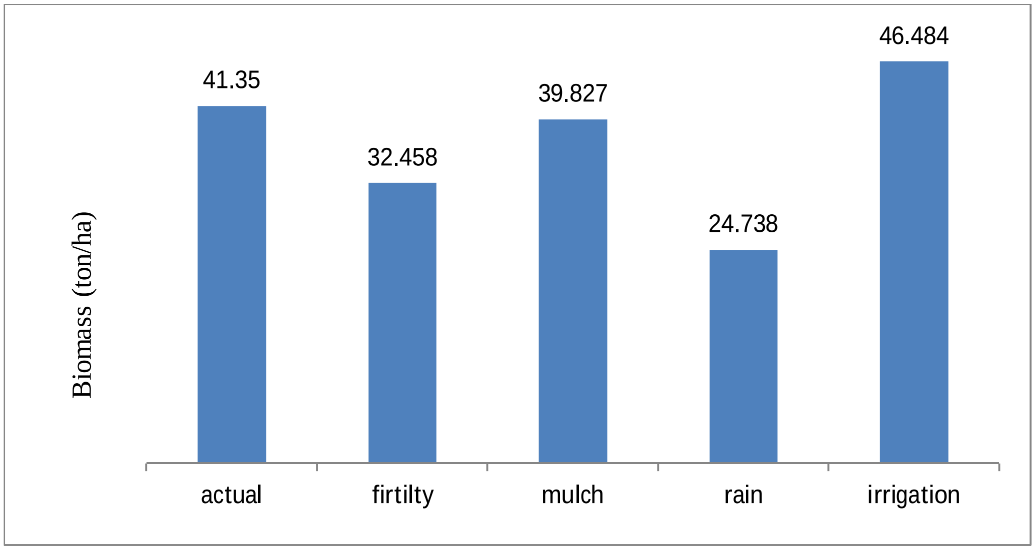


Figure (4.15.d) (Hagu): crop biomass prediction with decreased soil mulch levels (other parameters are fixed)

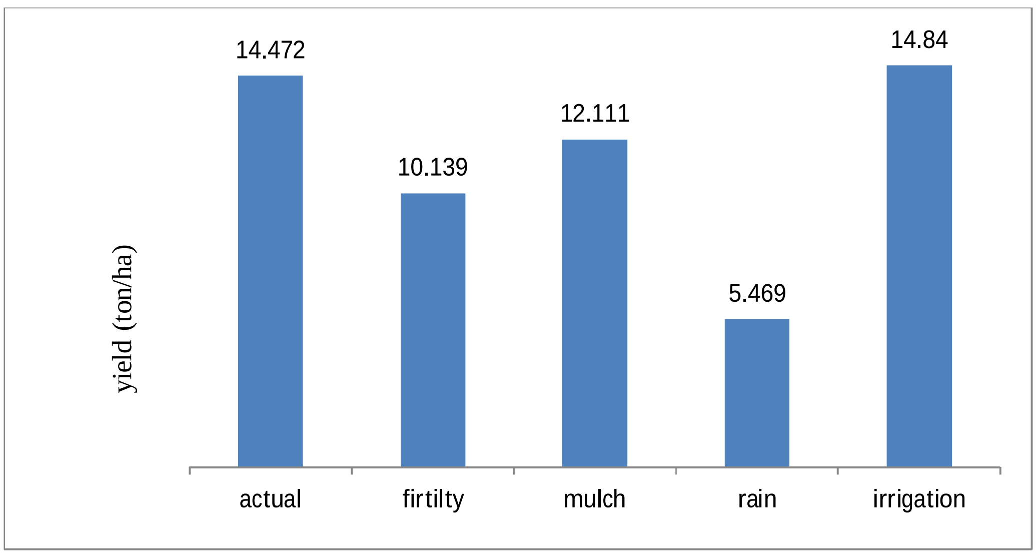


Figure (4.10.a) (Hagu): Yield productivity under all irrigation and nitrogen levels

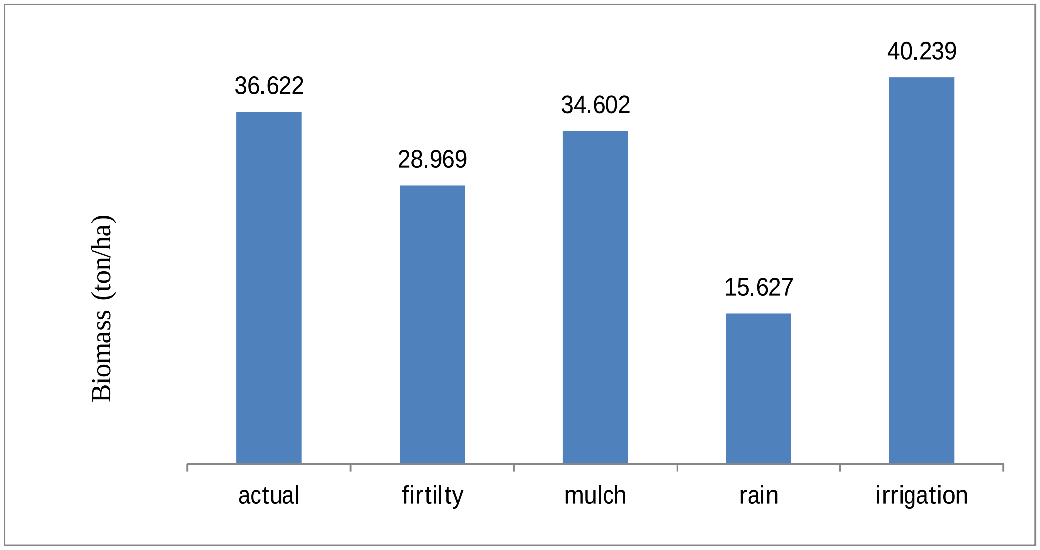


Figure (4.10.a) (Nasr): Biomass productivity under all irrigation and nitrogen levels

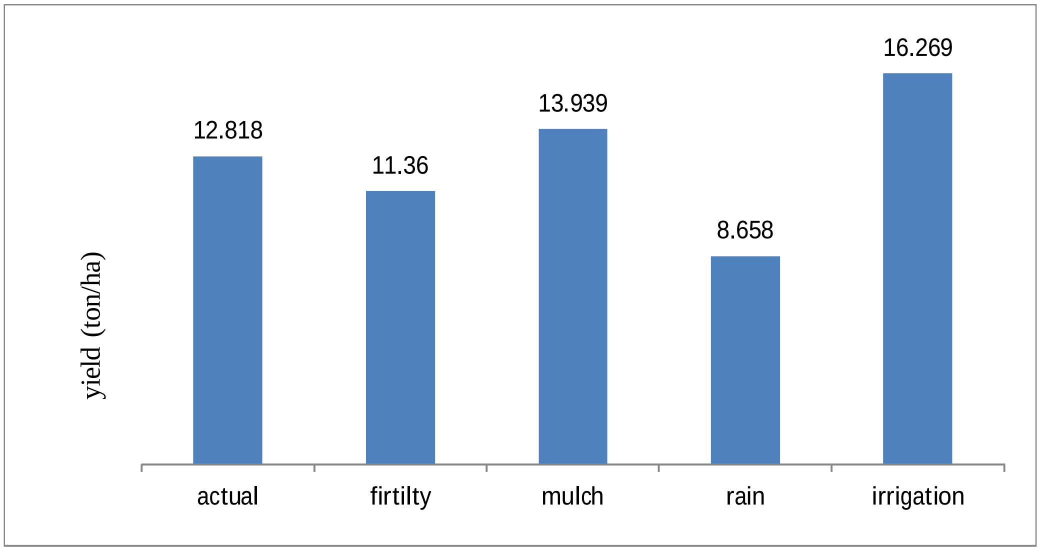


Figure (4.10.a) (Nasr): Yield productivity under all irrigation and nitrogen levels

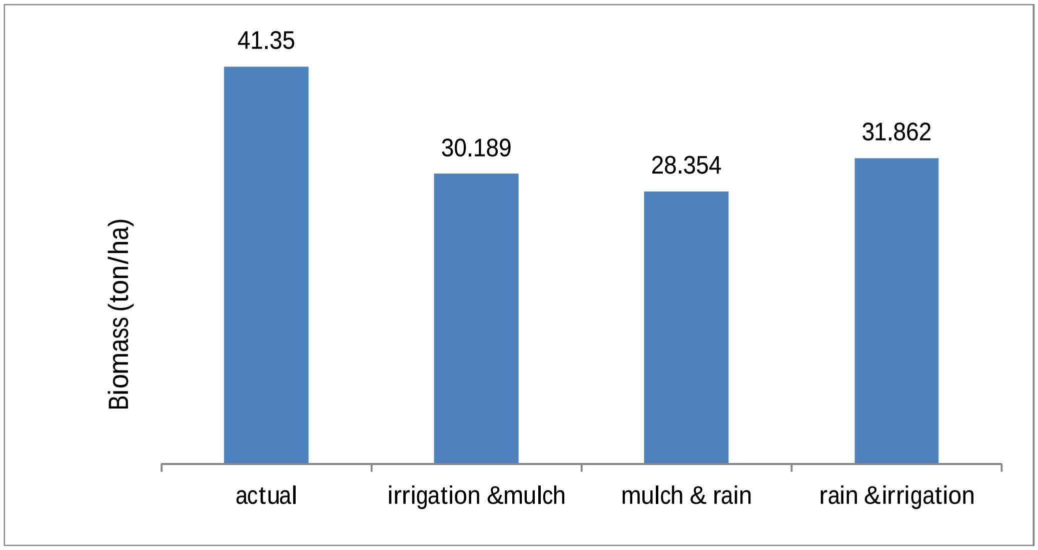


Figure (4.10.a) (Hagu): Biomass productivity under all irrigation and nitrogen levels

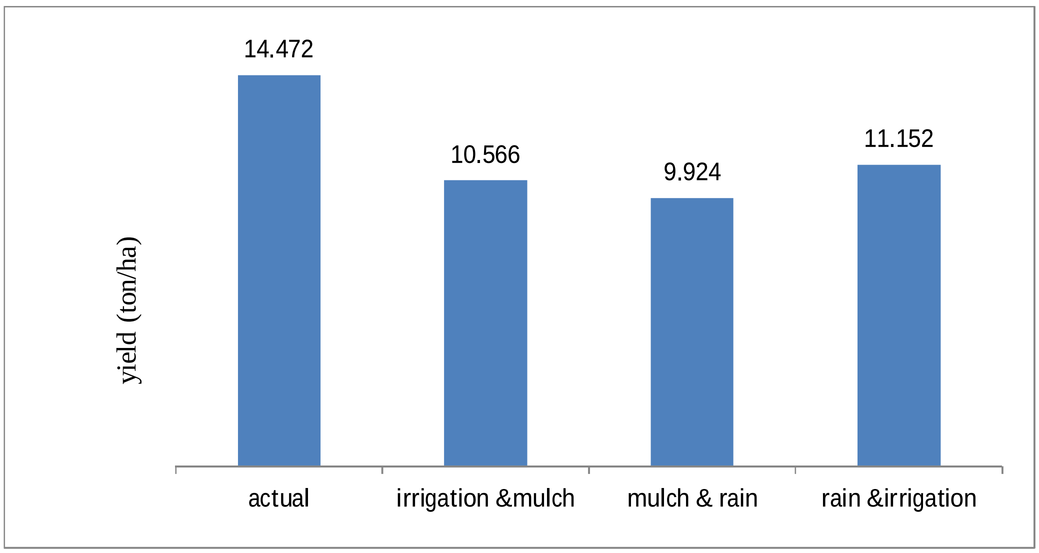


Figure (4.10.a) (Hagu): Yield productivity under all irrigation and nitrogen levels .

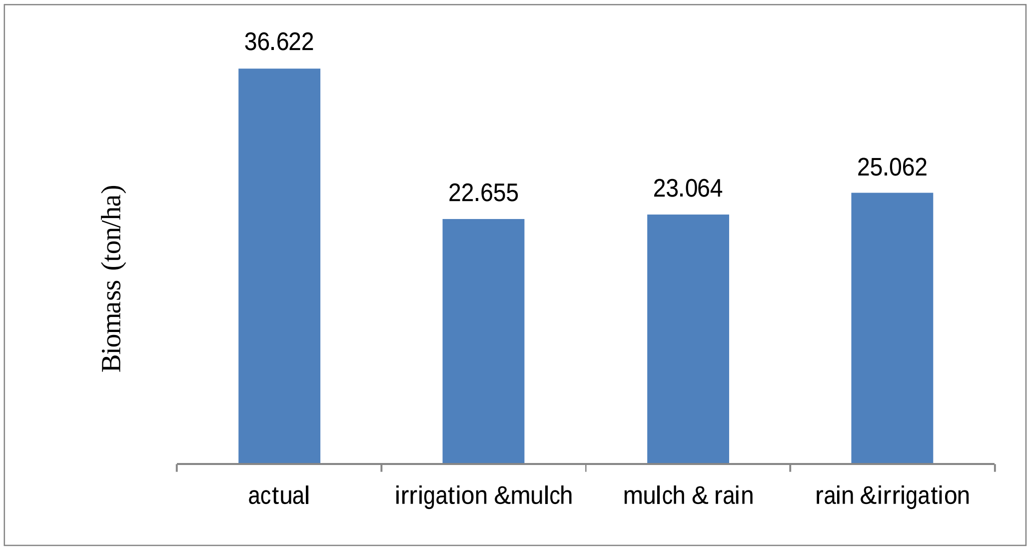


Figure (4.10.a) (Nasr): Biomass productivity under all irrigation and nitrogen levels

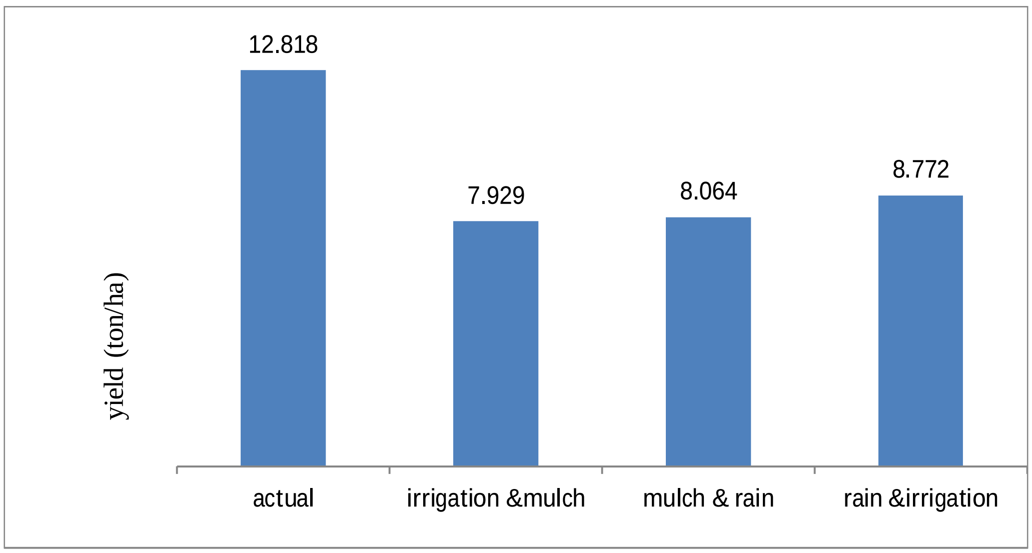


Figure (4.10.a) (Nasr): Yield productivity under all irrigation and nitrogen levels.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

The Aqua Crop model had been used to monitor the growth of Sugar Cane Crop in study area within aljunyed scheme ("Hagu and Nassir) regarding its yield and biomass respectively considering different parameters such as; the Mulch , Rain , soil fertility level and water application options.

To test the accuracy of the Aqua Crop model, its predictions of yield and biomass have been compared to the actual measured weights of yield at the end of the season, for Hagu and Nasr . From the 16 scenarios considered in the Aqua Crop model, the following results have been obtained:

1. Biomass and yield increased when soil fertility level increased.
2. Biomass and yield decreased when irrigation increased.
3. For 87% of the 16 scenarios, biomass and yield increased when actual effective rainfall increased, 75% when fertility level increased , 62% when mulch increased level and 50% when irrigation increased.
4. For 75% of the 16 scenarios, yield increased when actual effective rainfall increased.
5. Maximum biomass (62.753 Ton/ha) occurred at (50%) net requirement option with moderate (75%) soil fertility and (75%) of actual effective rainfall moderate (75%) soil mulch.
6. Minimum biomass (29.294 Ton/ha) occurred at (75%) net requirement option with about half (50%) soil fertility and 50% of actual effective rain fall moderate (75%) soil mulch.

7. Maximum yield (55.079 Ton/ha) occurred at (50%) net requirement irrigation option with moderate (75%) soil fertility and 50% of actual effective rain fall moderate(75%) soil mulch.
8. Minimum yield (18.361Ton/ha) occurred at (50%) soil fertility and 50% of actual effective rainfall About half (50%) soil mulch.
9. The one irrigation applied in the beginning in rainfed scenario proved to be very essential to produce significant amount of yield and biomass for sugar cane crop.

Recommendations:

AquaCrop model can be used as a planning tool or to assist in management decisions for both irrigated and rainfed agriculture. (Model should be run on daily basis)

1. AquaCrop Model can be used as planning tool: given the average meteorological data .
2. For the study area, type of crop grown, soil profile, simulation period, Initial.
3. Conditions and ground water level, to predict crop yield and biomass for different scenarios of irrigation options and soil fertility levels.

AquaCrop Model can be used in management decisions: given the measured meteorological data for the agriculture field, type of crop grown and daily monitoring for crop behavior, daily moisture content measurements, simulation period, initial conditions for the beginning of agricultural season and ground water level, to predict the maximum crop yield and biomass by selecting the appropriate irrigation option and soil fertility level.

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Appendices

Appendix (1): Meteorological Data from Aljunyed Station Season (2012-2013)

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
01/07/2012	34.57	24.32	18.92	57.66	2.71	0.82	4.40
02/07/2012	30.08	24.83	16.45	65.01	2.50	2.33	4.70
03/07/2012	35.74	23.60	24.28	56.56	2.27	0.00	6.50
04/07/2012	34.32	25.07	23.53	54.96	3.40	0.00	7.10
05/07/2012	34.55	23.86	23.03	56.39	2.87	0.68	6.60
06/07/2012	32.97	23.61	19.23	56.16	2.92	0.00	6.00
07/07/2012	32.71	24.17	20.25	57.37	2.82	0.00	6.00
08/07/2012	36.40	24.72	27.20	49.33	3.13	0.21	8.00
09/07/2012	32.68	24.55	18.25	57.59	3.07	3.35	5.80
10/07/2012	37.13	22.19	26.83	51.89	2.44	0.00	7.30
11/07/2012	37.83	24.51	26.37	48.56	2.69	0.00	7.80
12/07/2012	37.34	25.74	23.42	52.07	2.82	0.00	7.30
13/07/2012	36.69	24.86	26.45	53.60	2.45	1.35	7.30
14/07/2012	35.97	25.88	18.84	50.44	2.58	0.00	6.30
15/07/2012	36.88	25.59	17.24	48.82	2.59	0.00	6.30
16/07/2012	35.08	25.63	25.23	52.63	3.31	0.00	7.50
17/07/2012	38.40	23.82	22.08	50.05	3.09	0.00	7.50
18/07/2012	37.47	24.87	24.15	44.95	3.43	0.00	8.20
19/07/2012	35.83	25.10	19.85	49.39	2.54	0.00	6.40
20/07/2012	40.03	25.42	27.14	44.61	1.91	3.50	7.60
21/07/2012	38.34	26.88	27.10	43.67	2.61	0.00	8.10
22/07/2012	35.60	26.29	26.62	48.20	3.39	0.00	8.10
23/07/2012	33.44	24.74	19.30	53.12	3.03	0.00	6.30
24/07/2012	37.04	24.49	27.56	47.18	2.80	0.00	8.00
25/07/2012	39.08	25.53	24.20	45.50	2.74	0.00	7.80
26/07/2012	37.16	25.27	24.71	48.99	3.44	0.00	8.10
27/07/2012	36.21	24.29	27.53	48.05	3.51	0.00	8.30
28/07/2012	36.62	24.30	24.41	47.41	3.27	0.01	7.80
29/07/2012	38.81	25.80	24.40	41.62	2.29	0.31	7.50
30/07/2012	35.06	24.87	20.15	55.04	3.03	3.50	6.50
31/07/2012	34.77	23.83	25.46	58.55	2.72	2.55	6.80
01/08/2012	34.46	24.95	17.60	59.43	2.31	0.02	5.40
02/08/2012	30.57	24.95	5.01	64.96	1.01	3.12	2.00
03/08/2012	35.01	23.77	23.08	64.40	2.38	2.60	6.10
04/08/2012	33.13	23.67	25.09	61.89	2.42	0.00	6.20
05/08/2012	35.34	22.77	26.11	55.93	2.24	0.01	6.70
06/08/2012	35.06	25.17	19.86	56.50	2.77	0.03	6.20
07/08/2012	35.12	24.07	23.25	53.10	2.66	0.16	6.70
08/08/2012	32.81	24.84	22.84	56.67	2.67	0.00	6.30
09/08/2012	35.85	24.12	22.62	52.92	2.42	0.18	6.60
10/08/2012	32.41	24.80	22.08	59.09	2.71	2.48	6.10
11/08/2012	37.60	23.47	20.36	57.34	1.73	8.57	5.70
12/08/2012	36.73	24.43	23.44	56.35	1.51	4.72	6.00
13/08/2012	32.89	25.07	10.83	62.15	1.84	0.09	3.80

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
14/08/2012	33.01	23.27	21.74	58.59	2.35	0.01	5.80
15/08/2012	36.69	22.39	26.66	53.25	1.92	0.14	6.80
16/08/2012	38.34	25.11	20.82	52.31	2.24	0.72	6.50
17/08/2012	33.76	25.44	21.93	57.17	2.69	1.09	6.30
18/08/2012	36.59	22.77	26.93	55.41	2.22	0.00	7.00
19/08/2012	38.30	24.48	26.95	50.62	2.31	0.00	7.50
20/08/2012	38.94	24.41	26.22	45.64	2.24	0.28	7.60
21/08/2012	35.39	24.53	23.07	61.00	2.11	22.84	6.10
22/08/2012	34.36	23.84	26.54	67.95	1.59	7.90	6.00
23/08/2012	32.29	23.46	26.68	67.54	2.14	5.30	6.10
24/08/2012	34.86	21.82	26.57	56.76	2.16	0.00	6.60
25/08/2012	35.54	23.76	26.03	52.13	2.59	0.00	7.10
26/08/2012	38.48	23.02	27.20	41.04	1.90	0.00	7.30
27/08/2012	35.85	24.74	26.14	46.01	2.80	0.00	7.60
28/08/2012	38.16	24.08	26.63	39.63	2.45	0.00	7.90
29/08/2012	38.24	25.53	26.69	44.31	2.64	0.00	8.00
30/08/2012	39.69	24.59	26.92	36.51	2.04	0.04	7.70
31/08/2012	39.69	25.46	20.51	39.87	2.07	2.38	6.80
01/09/2012	36.60	25.09	19.96	52.05	2.56	1.29	6.40
02/09/2012	38.30	23.41	23.95	41.47	2.02	0.14	7.00
03/09/2012	40.61	25.30	26.45	40.39	2.11	0.01	7.70
04/09/2012	38.24	25.57	26.23	46.16	2.43	0.01	7.60
05/09/2012	40.65	25.46	26.41	37.23	1.75	0.00	7.20
06/09/2012	41.15	26.93	25.71	42.03	2.39	0.00	8.10
07/09/2012	36.75	25.12	25.75	50.15	2.99	0.00	7.70
08/09/2012	38.93	24.01	25.77	46.04	2.44	0.00	8.20
09/09/2012	38.75	24.92	26.36	41.33	2.07	0.00	7.50
10/09/2012	41.73	25.56	26.42	30.65	1.58	0.00	7.30
11/09/2012	40.56	25.53	25.55	45.21	1.96	0.00	7.40
12/09/2012	41.44	25.34	25.25	41.58	1.79	0.00	7.30
13/09/2012	42.83	25.65	26.18	39.07	1.94	0.00	7.80
14/09/2012	41.88	25.90	24.28	40.46	1.87	0.00	7.30
15/09/2012	41.70	26.21	19.68	42.65	2.00	0.18	6.70
16/09/2012	39.10	23.90	26.02	41.13	2.13	0.11	7.50
17/09/2012	39.44	22.67	25.86	37.45	1.75	0.00	7.10
18/09/2012	39.76	24.38	25.69	38.38	2.12	0.00	7.60
19/09/2012	41.27	25.04	25.06	38.29	2.12	0.00	7.70
20/09/2012	33.19	24.84	18.81	46.07	2.25	0.01	5.80
21/09/2012	42.20	23.72	25.60	35.27	1.55	0.00	7.10
22/09/2012	43.34	24.46	25.86	29.43	1.51	0.00	7.20
23/09/2012	42.87	25.58	25.63	32.63	1.76	0.00	7.50
24/09/2012	43.24	25.55	25.46	36.42	1.49	0.00	7.10
25/09/2012	40.01	25.77	22.86	40.19	1.92	0.00	6.90
26/09/2012	33.69	24.45	23.79	48.55	2.39	6.90	6.50

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
27/09/2012	38.96	22.53	22.51	46.08	1.62	0.00	6.20
28/09/2012	40.89	24.02	25.09	41.81	1.73	0.00	7.00
29/09/2012	41.41	24.85	24.55	40.44	1.76	0.00	7.10
30/09/2012	42.65	25.00	24.74	36.03	1.70	0.10	7.20
01/10/2012	38.64	25.19	15.97	47.50	1.78	5.05	5.40
02/10/2012	39.78	24.63	19.07	42.47	1.84	0.04	6.20
03/10/2012	39.58	24.28	23.53	43.03	1.31	1.42	6.10
04/10/2012	41.91	24.15	24.00	36.27	1.24	0.36	6.30
05/10/2012	43.23	26.23	24.73	29.17	1.34	0.00	6.70
06/10/2012	42.08	25.30	24.29	33.89	1.51	0.00	6.80
07/10/2012	41.73	25.08	19.41	33.42	1.36	0.00	5.90
08/10/2012	43.98	26.07	21.67	29.26	1.07	0.05	5.90
09/10/2012	41.44	28.60	20.69	27.88	1.70	0.26	7.00
10/10/2012	41.26	27.29	22.45	34.91	1.60	0.75	6.60
11/10/2012	41.98	25.84	22.22	32.60	1.04	0.17	5.70
12/10/2012	41.63	24.08	23.96	21.36	1.07	0.00	5.80
13/10/2012	41.41	25.00	23.61	27.63	1.50	0.00	6.60
14/10/2012	40.66	24.15	23.58	36.05	1.37	0.00	6.20
15/10/2012	42.15	22.80	23.85	26.44	0.95	0.00	5.60
16/10/2012	42.48	19.59	23.98	21.89	0.90	0.00	5.50
17/10/2012	41.22	20.45	23.90	23.46	1.27	0.00	6.10
18/10/2012	41.15	20.30	23.79	22.19	1.09	0.00	5.70
19/10/2012	42.32	22.62	23.37	24.96	1.24	0.00	6.10
20/10/2012	43.12	22.62	23.52	21.30	0.87	0.00	5.40
21/10/2012	43.37	20.95	23.15	21.15	0.99	0.00	5.60
22/10/2012	39.78	24.13	22.71	22.78	1.97	0.03	7.00
23/10/2012	39.97	26.97	22.47	22.82	2.08	0.00	7.20
24/10/2012	40.12	24.66	22.98	20.43	1.83	0.00	6.90
25/10/2012	38.15	22.06	22.84	11.62	1.76	0.00	6.30
26/10/2012	38.66	21.14	23.19	13.36	1.63	0.00	6.30
27/10/2012	39.66	21.85	22.79	20.81	1.39	0.00	6.00
28/10/2012	39.74	23.17	22.45	26.34	1.63	0.00	6.30
29/10/2012	40.02	23.70	22.47	24.26	1.54	0.00	6.20
30/10/2012	40.22	19.74	22.83	18.32	1.26	0.00	5.70
31/10/2012	40.25	19.88	22.79	16.47	1.29	0.00	5.70
01/11/2012	39.92	20.32	22.00	19.71	1.10	0.00	5.30
02/11/2012	40.60	25.78	21.72	18.52	1.02	0.00	5.20
03/11/2012	39.68	24.33	20.78	28.62	1.80	0.00	6.40
04/11/2012	36.05	24.69	16.10	44.97	1.53	0.00	4.80
05/11/2012	36.24	20.97	16.84	35.92	1.55	0.00	5.10
06/11/2012	38.85	21.18	20.82	36.31	1.44	0.00	5.60
07/11/2012	37.66	24.37	21.26	17.73	1.68	0.00	6.10
08/11/2012	37.34	21.24	21.29	22.29	1.54	0.00	5.70
09/11/2012	36.98	19.44	21.07	21.53	1.37	0.00	5.40

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
10/11/2012	37.27	21.11	21.11	18.94	1.73	0.00	6.00
11/11/2012	37.98	21.95	20.89	22.47	1.97	0.00	6.50
12/11/2012	37.53	22.91	20.76	22.41	2.14	0.00	6.70
13/11/2012	37.50	21.94	20.94	22.74	1.93	0.00	6.30
14/11/2012	36.61	21.12	20.88	24.68	1.84	0.00	6.00
15/11/2012	36.30	19.69	21.02	18.78	1.62	0.00	5.70
16/11/2012	37.05	18.00	21.19	17.75	1.38	0.00	3.60
17/11/2012	38.37	20.25	20.95	15.19	1.82	0.00	6.30
18/11/2012	39.12	21.49	20.51	16.07	1.86	0.00	6.40
19/11/2012	38.49	22.54	20.73	14.14	2.10	0.00	6.80
20/11/2012	36.40	19.06	21.18	13.09	1.78	0.00	6.00
21/11/2012	37.26	19.01	20.71	21.19	1.52	0.00	5.50
22/11/2012	37.04	19.52	20.68	25.01	1.50	0.00	5.40
23/11/2012	36.84	19.62	20.48	24.38	1.71	0.00	4.90
24/11/2012	35.26	19.67	20.65	19.69	1.95	0.00	6.00
25/11/2012	33.79	17.61	20.41	23.05	1.82	0.00	5.60
26/11/2012	34.14	17.58	20.20	33.31	1.66	0.00	5.20
27/11/2012	33.95	17.77	19.93	24.92	1.81	0.00	5.50
28/11/2012	32.02	17.06	20.12	20.59	1.92	0.00	5.50
29/11/2012	32.01	16.20	20.26	25.78	1.66	0.00	5.10
30/11/2012	34.59	15.90	20.04	22.90	1.50	0.00	5.10
01/12/2012	35.52	18.50	19.74	20.60	1.70	0.00	5.50
02/12/2012	36.62	18.19	20.09	20.06	1.48	0.00	5.30
03/12/2012	35.25	18.74	19.84	29.39	1.56	0.00	5.20
04/12/2012	35.47	17.81	19.71	29.97	1.26	0.00	4.70
05/12/2012	36.53	18.03	19.44	32.05	1.23	0.00	4.70
06/12/2012	37.54	19.60	19.39	26.90	1.42	0.00	5.20
07/12/2012	37.45	19.91	19.33	27.99	1.56	0.00	5.40
08/12/2012	36.19	20.87	19.50	28.03	1.81	0.00	5.60
09/12/2012	35.23	18.65	19.54	27.38	1.62	0.00	5.20
10/12/2012	35.03	18.64	19.22	36.67	1.68	0.00	5.10
11/12/2012	34.92	20.93	19.30	30.72	1.92	0.00	5.60
12/12/2012	34.66	19.27	19.09	35.29	1.86	0.00	5.40
13/12/2012	34.59	20.03	19.01	33.90	2.13	0.00	5.70
14/12/2012	32.86	18.88	19.28	31.84	2.14	0.00	5.60
15/12/2012	32.25	18.11	19.40	35.11	1.94	0.00	5.20
16/12/2012	30.76	17.17	19.62	29.53	2.01	0.00	5.30
17/12/2012	31.30	15.15	19.57	30.23	1.79	0.00	5.00
18/12/2012	31.73	15.83	19.22	39.28	1.85	0.00	4.90
19/12/2012	31.84	16.66	18.63	32.65	2.03	0.00	5.20
20/12/2012	31.69	17.16	18.79	33.33	2.00	0.00	5.20
21/12/2012	30.61	15.84	18.76	29.88	1.96	0.00	5.10
22/12/2012	30.27	15.99	19.16	24.40	1.91	0.00	5.10
23/12/2012	31.97	15.24	19.07	27.25	1.59	0.00	4.80

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
24/12/2012	30.77	16.58	18.93	21.60	2.16	0.00	5.60
25/12/2012	27.39	14.95	19.44	18.42	2.48	0.00	5.60
26/12//2012	26.69	12.23	19.69	31.35	2.02	0.00	4.70
27/12/2012	29.95	12.50	19.58	33.98	1.74	0.00	4.70
28/12/2012	30.83	13.42	19.44	32.78	1.61	0.00	4.70
29/12/2012	30.81	14.89	19.65	27.24	1.73	0.00	4.90
30/12/2012	31.17	13.94	19.72	24.46	1.73	0.00	5.00
31/12/2012	30.44	13.58	19.87	28.59	1.71	0.00	4.90
01/01/2013	32.25	13.48	20.11	29.97	1.66	0.00	3.10
02/01/2013	33.50	17.50	19.73	34.51	2.25	0.00	5.70
03/01/2013	33.43	19.28	19.91	36.51	2.52	0.00	3.40
04/01/2013	33.50	17.00	20.17	30.77	2.10	0.00	5.70
05/01/2013	33.40	15.71	20.45	17.70	1.67	0.00	5.30
06/01/2013	33.74	15.71	20.16	18.09	1.74	0.00	3.50
07/01/2013	30.54	14.72	20.08	19.76	1.98	0.00	5.40
08/01/2013	30.20	13.48	20.30	18.91	1.86	0.00	5.20
09/01/2013	27.26	13.12	20.46	20.98	2.07	0.00	5.20
10/01/2013	26.40	11.80	20.56	22.66	2.10	0.00	5.00
11/01/2013	27.01	11.18	20.48	31.29	1.94	0.00	4.80
12/01/2013	29.70	12.82	20.35	33.72	1.79	0.00	4.00
13/01/2013	30.77	14.00	20.41	31.88	1.88	0.00	5.10
14/01/2013	31.69	15.32	19.76	34.35	1.97	0.00	5.30
15/01/2013	33.27	16.61	20.50	39.93	1.96	0.00	5.40
16/01/2013	34.71	16.68	20.68	38.11	1.62	0.00	5.20
17/01/2013	35.55	17.03	20.73	33.24	1.47	0.00	5.20
18/01/2013	36.16	18.96	20.39	32.96	1.49	0.00	5.30
19/01/2013	37.05	18.86	20.55	28.12	1.64	0.00	5.60
20/01/2013	38.29	20.86	21.04	23.11	2.30	0.00	6.90
21/01/2013	37.87	21.29	21.11	22.97	2.37	0.00	7.00
22/01/2013	36.58	21.32	20.96	23.15	2.31	0.00	6.80
23/01/2013	36.42	20.29	20.95	29.93	2.07	0.00	6.20
24/01/2013	36.03	20.00	21.12	34.51	1.68	0.00	5.60
25/01/2013	38.48	19.10	21.28	30.23	1.34	0.00	5.40
26/01/2013	39.80	19.61	21.29	25.40	1.21	0.00	5.30
27/01/2013	41.23	20.39	21.38	19.71	1.28	0.00	5.60
28/01/2013	40.48	21.31	21.32	17.63	1.54	0.00	6.00
29/01/2013	33.10	22.43	21.52	25.32	2.27	0.00	6.40
30/01/2013	32.80	16.79	21.74	14.77	1.97	0.00	6.00
31/01/2013	28.53	16.31	21.94	15.26	2.34	0.00	6.10
01/02/2013	27.47	13.83	22.11	17.96	2.47	0.00	6.00
02/02/2013	29.86	13.83	22.27	21.09	2.11	0.00	5.80
03/02/2013	31.70	16.12	22.51	21.77	2.09	0.00	6.00
04/02/2013	35.05	16.31	22.65	25.74	1.66	0.00	5.80
05/02/2013	36.79	17.44	22.77	21.04	1.46	0.00	5.70

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
06/02/2013	37.68	18.32	22.63	22.54	1.82	0.00	6.40
07/02/2013	37.19	19.23	22.79	21.36	1.97	0.00	6.60
08/02/2013	38.89	19.76	23.12	20.29	2.03	0.00	7.00
09/02/2013	38.93	21.04	23.49	16.44	2.39	0.00	7.70
10/02/2013	37.81	19.90	23.61	16.28	2.09	0.00	7.10
11/02/2013	36.66	19.86	23.55	19.96	2.08	0.00	6.90
12/02/2013	35.49	20.04	23.79	24.39	2.08	0.00	6.70
13/02/2013	35.92	19.43	23.68	29.54	2.06	0.00	6.60
14/02/2013	37.53	19.43	23.74	24.51	1.82	0.00	6.50
15/02/2013	37.31	19.01	23.97	18.14	1.94	0.00	6.80
16/02/2013	37.57	21.15	24.03	21.86	2.22	0.00	7.30
17/02/2013	36.99	20.77	24.14	27.19	2.05	0.00	6.90
18/02/2013	38.01	20.38	24.07	25.76	1.88	0.00	6.80
19/02/2013	37.36	20.32	24.01	18.06	2.19	0.00	7.30
20/02/2013	36.80	20.60	24.32	16.95	2.20	0.00	7.30
21/02/2013	37.00	18.71	24.88	16.05	1.74	0.00	6.60
22/02/2013	37.81	17.28	25.33	12.06	1.49	0.00	6.20
23/02/2013	38.89	19.81	24.95	10.35	2.33	0.00	7.70
24/02/2013	37.37	22.00	24.74	15.49	2.62	0.00	8.10
25/02/2013	39.29	21.53	24.29	28.83	1.87	0.00	7.00
26/02/2013	42.08	22.17	24.43	28.30	1.48	0.00	6.70
27/02/2013	42.65	23.13	24.92	16.27	1.72	0.00	7.30
28/02/2013	42.02	23.80	25.24	13.79	2.06	0.00	7.90
01/03/2013	41.36	22.30	25.59	14.76	2.01	0.00	7.70
02/03/2013	40.84	22.48	25.63	17.73	1.97	0.00	7.60
03/03/2013	40.22	22.99	26.03	15.02	2.09	0.00	7.80
04/03/2013	40.25	22.37	25.94	11.92	2.02	0.00	7.70
05/03/2013	39.13	22.41	26.05	15.14	2.43	0.00	8.30
06/03/2013	38.72	21.48	26.34	17.48	2.22	0.00	7.90
07/03/2013	38.57	19.61	26.63	13.86	1.76	0.00	7.10
08/03/2013	39.93	20.33	25.92	17.14	1.62	0.00	6.90
09/03/2013	40.30	22.06	26.09	13.24	1.92	0.00	7.60
10/03/2013	38.27	21.41	27.03	9.29	2.42	0.00	8.30
11/03/2013	38.01	19.22	26.95	13.16	1.96	0.00	7.50
12/03/2013	38.44	19.23	23.49	13.89	1.59	0.00	6.60
13/03/2013	41.78	20.67	26.69	10.47	1.62	0.00	7.20
14/03/2013	44.39	22.30	26.44	10.98	1.38	0.00	6.90
15/03/2013	45.55	23.40	24.76	13.53	1.21	0.00	6.60
16/03/2013	43.48	26.04	26.48	13.78	1.98	0.00	8.20
17/03/2013	42.83	26.64	27.60	7.42	2.61	0.00	9.40
18/03/2013	39.44	22.13	27.64	12.45	2.44	0.00	8.60
19/03/2013	38.05	19.07	27.97	11.72	1.81	0.00	7.30
20/03/2013	39.43	19.14	28.07	10.83	1.72	0.00	7.30
21/03/2013	40.63	17.86	28.48	7.83	1.46	0.00	6.90

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
22/03/2013	40.50	18.47	28.15	9.62	1.61	0.00	7.20
23/03/2013	39.92	21.07	28.26	7.61	2.12	0.00	8.10
24/03/2013	39.17	20.32	28.38	10.42	1.86	0.00	7.60
25/03/2013	39.54	20.26	28.32	13.30	1.81	0.00	7.60
26/03/2013	42.04	18.81	28.52	7.61	1.48	0.00	5.60
27/03/2013	40.27	19.24	28.70	6.46	1.62	0.00	7.20
28/03/2013	39.88	19.85	28.50	9.76	1.80	0.00	7.60
29/03/2013	39.75	21.51	28.22	10.12	1.92	0.00	7.80
30/03/2013	39.93	19.00	29.24	4.64	1.69	0.00	7.30
31/03/2013	41.05	19.78	29.00	3.54	1.81	0.00	7.60
01/04/2013	41.09	21.41	28.88	5.96	2.10	0.00	8.30
02/04/2013	41.22	25.32	28.02	11.37	2.14	0.00	8.50
03/04/2013	41.98	24.95	28.59	13.16	2.01	0.00	8.40
04/04/2013	41.85	23.71	28.54	12.49	1.99	0.00	8.30
05/04/2013	40.72	23.16	29.58	6.89	2.42	0.00	8.90
06/04/2013	40.70	21.65	29.97	6.50	1.89	0.00	7.90
07/04/2013	40.83	20.87	29.57	9.34	1.77	0.00	7.70
08/04/2013	41.05	19.44	30.10	7.33	1.67	0.00	5.00
09/04/2013	41.03	19.30	30.16	5.39	1.79	0.00	7.70
10/04/2013	39.90	20.84	29.98	4.88	2.27	0.00	8.60
11/04/2013	38.66	19.17	30.10	4.61	1.93	0.00	5.50
12/04/2013	38.40	19.21	29.54	7.66	2.00	0.00	7.90
13/04/2013	38.03	20.40	29.27	9.79	2.11	0.00	8.10
14/04/2013	39.06	19.98	29.20	8.89	1.75	0.00	7.60
15/04/2013	40.54	20.85	28.73	10.29	1.77	0.00	7.80
16/04/2013	40.82	23.07	28.75	7.96	2.00	0.00	8.20
17/04/2013	41.40	22.99	28.71	7.11	2.03	0.00	8.30
18/04/2013	40.93	23.83	28.59	8.01	2.05	0.00	8.30
19/04/2013	41.51	23.34	28.48	9.50	2.26	0.00	8.80
20/04/2013	41.05	27.10	25.81	10.24	2.67	0.00	9.30
21/04/2013	40.04	28.52	22.29	8.99	2.60	0.00	8.80
22/04/2013	39.43	24.37	27.45	8.63	2.31	0.00	8.60
23/04/2013	39.80	22.19	28.99	7.77	2.28	0.00	8.70
24/04/2013	40.82	24.23	28.72	9.30	2.18	0.00	8.60
25/04/2013	42.09	24.19	29.10	10.07	1.86	0.00	6.60
26/04/2013	42.22	22.19	28.95	9.46	1.66	0.00	7.80
27/04/2013	42.14	23.46	28.64	13.42	1.71	0.00	7.90
28/04/2013	43.43	26.00	28.84	11.94	1.80	0.00	8.20
29/04/2013	42.82	25.29	28.71	10.56	2.14	0.00	8.80
30/04/2013	42.80	25.82	28.78	10.79	2.19	0.00	8.90
01/05/2013	41.94	25.37	29.06	11.92	1.82	0.00	8.10
02/05/2013	41.36	21.47	29.42	10.54	1.62	0.00	7.60
03/05/2013	42.16	21.08	29.70	7.62	1.55	0.00	7.50
04/05/2013	41.93	21.09	29.88	7.66	1.57	0.00	7.50

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
05/05/2013	42.14	21.89	30.15	6.73	1.45	0.00	7.20
06/05/2013	42.67	19.32	30.12	7.09	1.44	0.00	7.30
07/05/2013	40.84	24.30	29.18	19.29	2.01	0.00	8.40
08/05/2013	41.15	22.80	28.99	17.44	2.00	0.00	8.40
09/05/2013	43.09	21.53	29.27	9.70	1.43	0.00	7.40
10/05/2013	43.34	23.28	28.21	10.23	1.40	0.00	7.30
11/05/2013	44.52	21.23	27.74	9.77	1.20	0.00	6.90
12/05/2013	43.26	28.04	28.30	20.81	2.06	0.00	8.70
13/05/2013	44.51	28.05	28.10	24.54	1.91	0.00	8.60
14/05/2013	44.38	23.30	28.46	21.12	1.40	0.00	7.60
15/05/2013	44.17	25.80	21.08	27.15	1.31	0.00	6.50
16/05/2013	42.70	25.56	29.13	13.69	1.69	0.00	8.00
17/05/2013	42.68	23.37	29.27	8.77	1.56	0.00	7.60
18/05/2013	45.78	22.40	29.16	9.06	1.28	0.00	7.30
19/05/2013	44.32	22.38	29.35	8.75	1.33	0.00	7.20
20/05/2013	42.92	25.42	25.31	8.57	1.83	0.00	7.90
21/05/2013	43.42	27.13	27.15	18.85	1.68	0.00	7.90
22/05/2013	41.71	27.04	28.38	23.77	1.87	0.00	8.20
23/05/2013	42.64	25.07	28.36	18.68	1.69	0.00	7.90
24/05/2013	45.49	27.50	28.36	15.78	1.72	0.00	8.30
25/05/2013	45.70	28.80	27.74	25.11	1.88	0.11	8.60
26/05/2013	43.67	29.51	21.26	30.03	2.27	0.04	8.10
27/05/2013	45.51	27.87	27.97	19.99	1.86	0.00	8.60
28/05/2013	43.72	27.44	28.94	20.54	2.04	0.00	8.40
29/05/2013	45.81	21.86	29.19	10.65	1.04	0.00	6.70
30/05/2013	45.81	25.03	28.91	14.78	1.66	0.00	8.30
31/05/2013	44.77	27.77	28.37	22.83	1.85	0.00	8.50
01/06/2013	45.11	27.79	26.49	29.35	2.26	0.00	9.00
02/06/2013	42.59	26.12	28.24	31.21	2.30	0.00	8.80
03/06/2013	45.49	26.77	28.61	22.64	1.63	0.00	8.20
04/06/2013	45.70	26.22	28.88	19.96	1.79	0.00	8.60
05/06/2013	42.55	27.83	27.68	29.91	2.00	0.00	8.40
06/06/2013	44.93	28.07	27.67	29.03	1.77	0.00	8.30
07/06/2013	43.52	27.84	28.02	30.43	1.99	0.00	8.50
08/06/2013	43.99	27.65	28.15	27.45	1.90	0.00	8.50
09/06/2013	43.97	29.74	28.19	22.94	2.27	0.00	9.20
10/06/2013	41.08	29.52	27.64	28.77	2.67	0.00	9.20
11/06/2013	40.67	27.76	27.00	31.84	2.53	0.00	8.80
12/06/2013	37.25	28.52	20.17	32.10	2.69	0.00	7.70
13/06/2013	40.29	28.86	26.51	29.23	2.48	0.00	8.70
14/06/2013	42.41	26.14	28.57	32.57	2.19	0.00	8.70
15/06/2013	43.07	27.33	28.00	32.82	1.97	0.00	8.40
16/06/2013	42.10	25.87	27.81	22.63	1.69	0.00	7.80
17/06/2013	43.68	22.29	29.13	11.18	1.27	0.00	7.10

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
18/06/2013	40.74	24.74	28.40	19.65	1.66	0.00	7.70
19/06/2013	37.83	25.54	22.02	35.85	2.28	0.00	7.20
20/06/2013	33.57	27.36	9.32	46.64	2.47	0.00	4.90
21/06/2013	32.64	27.11	9.55	37.18	2.15	0.00	5.00
22/06/2013	35.35	25.58	22.01	45.23	2.86	0.80	7.20
23/06/2013	35.02	24.52	24.12	46.45	2.70	0.00	7.20
24/06/2013	40.44	25.62	18.15	54.39	2.75	0.28	6.70
25/06/2013	38.06	23.37	19.43	51.01	2.52	0.00	6.50
26/06/2013	40.83	25.00	28.06	41.88	2.06	0.00	8.00
27/06/2013	35.18	26.89	12.67	42.33	2.51	0.00	5.70
28/06/2013	37.94	27.87	18.81	30.93	2.59	0.00	7.50
29/06/2013	38.84	28.04	24.30	41.32	2.89	0.00	8.20
30/06/2013	42.99	26.80	26.93	32.98	2.07	0.38	8.40
01/07/2013	39.71	28.57	27.83	33.10	2.67	0.22	8.90
02/07/2013	39.85	25.35	23.89	35.96	2.37	0.00	7.80
03/07/2013	38.99	25.84	28.01	29.04	2.67	0.00	8.80
04/07/2013	38.50	26.66	27.38	39.56	2.91	0.00	8.60
05/07/2013	39.93	24.88	27.24	34.52	2.16	0.00	8.00
06/07/2013	39.18	25.22	25.76	39.39	2.61	0.00	8.20
07/07/2013	37.80	25.28	26.09	37.60	2.97	0.00	8.50
08/07/2013	40.29	25.17	27.80	29.12	2.33	0.00	8.50
09/07/2013	37.61	27.12	25.41	35.51	3.10	0.00	8.60
10/07/2013	38.73	27.28	26.43	38.74	2.86	0.00	8.50
11/07/2013	36.73	26.14	23.52	48.47	3.31	0.39	7.80
12/07/2013	37.53	26.15	25.27	37.56	2.66	0.00	8.00
13/07/2013	40.45	27.96	27.08	35.78	2.95	0.00	9.10
14/07/2013	38.40	24.91	26.11	41.23	3.02	0.00	8.40
15/07/2013	36.91	24.01	25.20	38.36	3.14	0.00	8.30
16/07/2013	36.77	26.73	23.01	40.64	2.95	0.00	7.80
17/07/2013	38.55	24.96	27.30	42.90	2.72	0.00	8.80
18/07/2013	36.53	25.58	22.60	46.53	3.37	0.00	7.80
19/07/2013	38.48	25.10	27.47	42.47	2.80	0.00	8.40
20/07/2013	39.52	26.36	27.51	39.02	2.65	0.00	8.50
21/07/2013	39.70	26.77	24.22	38.84	2.78	0.00	8.30
22/07/2013	35.59	25.56	15.57	45.95	2.50	2.10	6.00
23/07/2013	37.99	25.31	23.74	45.26	2.87	0.00	7.70
24/07/2013	39.59	25.03	27.51	41.71	2.37	0.17	8.10
25/07/2013	30.27	24.01	10.26	58.36	2.75	0.96	4.30
26/07/2013	34.95	22.48	26.29	63.17	3.02	0.00	6.90
27/07/2013	36.69	24.63	25.66	55.21	2.82	2.17	7.30
28/07/2013	33.63	23.42	24.54	64.69	2.83	10.65	6.30
29/07/2013	31.93	22.83	22.16	62.66	2.80	0.05	5.80
30/07/2013	34.77	23.42	25.79	54.16	2.58	0.00	6.90
31/07/2013	34.67	25.06	13.65	54.02	2.93	0.00	5.50

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
01/08/2013	29.00	24.11	13.24	62.63	2.37	3.39	4.20
02/08/2013	24.58	22.09	7.78	90.82	2.36	84.91	1.90
03/08/2013	24.78	21.96	12.50	87.97	2.41	7.70	2.70
04/08/2013	27.84	21.48	18.04	81.44	2.33	4.54	3.90
05/08/2013	27.52	21.69	17.13	76.38	1.72	1.15	3.80
06/08/2013	28.49	22.74	17.23	80.39	1.73	8.01	3.80
07/08/2013	27.95	22.73	18.66	83.95	1.91	4.74	3.90
08/08/2013	32.10	22.83	23.43	76.09	1.55	0.14	5.10
09/08/2013	34.99	22.98	25.89	67.89	1.95	1.87	6.10
10/08/2013	26.61	22.43	8.43	86.47	1.61	8.25	2.20
11/08/2013	32.88	22.50	26.30	71.78	1.90	0.00	5.80
12/08/2013	30.62	23.74	22.13	73.59	2.43	0.71	5.10
13/08/2013	28.97	21.11	21.58	83.08	2.07	22.05	4.40
14/08/2013	26.01	21.50	5.47	90.58	2.12	8.25	1.50
15/08/2013	28.83	20.74	16.18	86.64	1.63	6.31	3.40
16/08/2013	28.12	21.59	16.92	84.37	2.10	9.74	3.64
17/08/2013	27.86	21.48	16.72	85.56	2.08	9.99	3.52
18/08/2013	27.59	21.36	16.52	86.76	2.06	10.23	3.41
19/08/2013	27.32	21.24	16.33	87.95	2.05	10.47	3.29
20/08/2013	27.06	21.12	16.13	89.14	2.03	10.71	3.18
21/08/2013	26.79	21.00	15.93	90.34	2.01	10.95	3.07
22/08/2013	26.52	20.88	15.74	91.53	1.99	11.19	2.95
23/08/2013	26.25	20.76	15.54	92.72	1.98	11.44	2.84
24/08/2013	25.99	20.64	15.34	93.92	1.96	11.68	2.72
25/08/2013	25.72	20.52	15.15	95.11	1.94	11.92	2.61
26/08/2013	35.15	22.87	24.31	64.36	2.69	11.47	6.40
27/08/2013	34.32	22.48	25.59	63.70	2.28	0.53	6.30
28/08/2013	36.60	22.92	23.13	55.60	2.42	0.00	6.60
29/08/2013	36.84	24.11	23.12	54.37	2.61	0.00	6.80
30/08/2013	37.27	23.99	24.48	52.43	2.46	0.99	7.00
31/08/2013	32.79	23.36	19.06	62.44	2.35	3.37	5.30
01/09/2013	37.34	21.02	26.65	54.77	2.05	0.00	6.90
02/09/2013	34.39	23.71	24.53	53.88	3.11	0.00	7.00
03/09/2013	37.45	23.55	26.29	50.15	2.38	0.00	7.30
04/09/2013	39.39	23.56	26.31	48.83	2.09	0.00	7.30
05/09/2013	34.97	24.27	18.46	52.27	2.27	1.29	5.80
06/09/2013	36.69	25.20	22.35	55.27	2.53	1.10	6.60
07/09/2013	34.81	24.05	24.24	53.02	2.11	0.02	6.40
08/09/2013	39.80	22.80	26.12	44.30	1.48	2.49	6.80
09/09/2013	36.71	24.94	26.15	44.60	2.33	0.00	7.30
10/09/2013	36.81	24.39	25.68	47.87	2.41	0.00	7.20
11/09/2013	41.24	23.52	26.10	38.47	1.42	0.02	6.90
12/09/2013	43.11	25.17	26.02	32.86	1.53	0.40	7.30
13/09/2013	40.99	25.72	25.96	40.48	2.16	0.25	7.80

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
14/09/2013	40.31	25.83	25.74	38.73	1.90	0.90	7.40
15/09/2013	41.37	24.89	18.96	37.04	1.81	0.00	6.50
16/09/2013	37.70	26.02	25.48	40.38	2.43	2.18	7.60
17/09/2013	41.03	24.64	25.94	40.55	1.93	0.00	7.50
18/09/2013	43.34	26.19	25.26	39.80	1.64	0.73	7.30
19/09/2013	41.34	25.48	25.66	40.71	1.94	0.00	7.50
20/09/2013	42.86	25.76	25.65	37.84	1.53	0.00	7.20
21/09/2013	42.29	25.65	25.62	33.21	1.45	0.00	7.00
22/09/2013	42.75	25.23	25.63	38.74	1.67	0.00	7.30
23/09/2013	44.16	24.06	25.58	33.34	1.54	0.00	7.30
24/09/2013	42.52	25.96	25.58	38.04	1.91	0.00	7.60
25/09/2013	41.50	25.69	24.39	36.24	1.42	0.02	6.70
26/09/2013	41.07	25.55	25.36	28.08	1.68	0.01	7.20
27/09/2013	41.76	24.57	25.31	32.54	1.27	0.00	6.60
28/09/2013	41.05	23.88	21.09	28.97	1.22	0.00	5.90
29/09/2013	43.02	23.99	25.70	15.86	1.59	0.00	7.20
30/09/2013	36.32	23.47	18.48	16.75	1.60	0.08	5.90
01/10/2013	41.89	23.56	25.04	14.84	1.45	0.00	6.70
02/10/2013	36.97	22.71	22.35	31.12	1.51	0.04	6.00
03/10/2013	42.65	23.74	24.99	29.22	1.48	0.03	6.90
04/10/2013	42.63	22.82	24.54	30.54	1.32	0.00	6.50
05/10/2013	42.49	23.99	24.13	35.01	1.40	0.00	6.60
06/10/2013	41.95	26.07	24.41	29.98	1.68	0.00	7.10
07/10/2013	40.63	23.24	23.04	35.31	1.26	0.00	6.00
08/10/2013	41.80	22.69	24.60	18.97	1.43	0.00	6.60
09/10/2013	38.74	26.68	23.82	38.08	2.02	0.02	7.00
10/10/2013	40.26	23.84	23.19	37.23	1.30	0.06	6.10
11/10/2013	41.65	23.65	24.11	26.04	1.11	0.00	6.00
12/10/2013	40.80	24.65	23.60	39.39	1.44	0.00	6.40
13/10/2013	39.69	25.11	22.62	37.68	1.82	0.00	6.60
14/10/2013	36.54	25.45	17.25	48.27	1.67	0.00	5.20
15/10/2013	40.76	22.55	24.27	18.41	1.43	0.00	6.40
16/10/2013	41.20	21.94	24.06	14.23	1.57	0.00	6.60
17/10/2013	39.65	18.92	24.06	14.76	1.36	0.00	6.10
18/10/2013	41.31	18.57	23.91	15.91	1.10	0.00	5.70
19/10/2013	40.09	21.83	23.67	16.81	1.49	0.00	6.30
20/10/2013	40.45	19.23	23.63	22.59	1.18	0.00	5.80
21/10/2013	42.20	20.25	23.24	25.61	1.14	0.00	5.80
22/10/2013	42.40	20.50	23.48	18.86	1.02	0.00	4.40
23/10/2013	40.61	21.53	22.96	29.73	1.07	0.00	5.60
24/10/2013	40.85	20.46	23.22	24.27	1.05	0.00	5.50
25/10/2013	41.22	23.29	22.80	25.95	1.17	0.00	5.80
26/10/2013	41.90	23.95	22.80	25.45	1.03	0.00	5.50
27/10/2013	41.96	23.61	22.47	23.93	1.36	0.00	6.10

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective rain (mm)	ETo (mm)
28/10/2013	39.48	24.44	22.74	15.27	1.86	0.00	5.90
29/10/2013	37.39	22.53	22.78	11.61	2.34	0.00	7.40
30/10/2013	35.67	19.18	22.66	14.13	1.79	0.00	6.20
31/10/2013	35.66	19.28	22.61	14.25	1.80	0.00	6.20
01/11/2013	35.97	18.24	22.40	14.51	1.78	0.00	6.20
02/11/2013	37.91	19.64	21.99	18.20	1.68	0.00	6.20
03/11/2013	38.41	22.24	21.57	23.26	1.72	0.00	6.30
04/11/2013	38.85	22.86	21.34	28.39	1.91	0.00	6.50
05/11/2013	39.46	23.46	21.47	24.17	1.71	0.00	6.30
06/11/2013	39.39	22.88	21.40	24.18	1.73	0.00	6.30
07/11/2013	39.99	21.03	21.35	20.40	1.38	0.00	5.70
08/11/2013	39.42	20.17	21.46	21.17	1.28	0.00	5.50
09/11/2013	37.03	21.19	21.59	14.32	1.91	0.00	6.40
10/11/2013	34.30	19.14	21.30	21.60	1.97	0.00	6.10
11/11/2013	34.74	17.66	21.35	21.10	1.70	0.00	5.70
12/11/2013	34.92	17.67	21.50	18.45	1.69	0.00	5.70
13/11/2013	36.61	17.64	21.53	19.33	1.51	0.00	5.60
14/11/2013	37.68	18.35	21.23	22.75	1.50	0.00	5.60
15/11/2013	38.39	18.97	20.79	22.90	1.47	0.00	5.60
16/11/2013	37.18	19.09	20.83	23.69	1.54	0.00	5.60
17/11/2013	35.81	17.89	20.90	19.86	1.54	0.00	5.50
18/11/2013	34.20	17.52	21.16	13.63	1.70	0.00	5.60
19/11/2012	32.01	16.17	21.28	18.59	1.92	0.00	5.70
20/11/2013	31.91	14.81	21.21	19.97	1.78	0.00	5.40
21/11/2013	33.76	16.35	20.83	27.40	1.56	0.00	5.20
22/11/20013	35.95	16.59	20.54	28.49	1.42	0.00	5.20
23/11/2013	35.89	18.54	20.41	23.90	1.54	0.00	5.40
24/11/2013	37.11	18.79	20.41	22.82	1.51	0.00	5.40
25/11/2013	37.48	19.05	20.31	26.22	1.64	0.00	5.70
26/11/2013	38.54	21.45	19.95	24.57	1.73	0.00	5.90
27/11/2013	38.30	21.26	19.95	21.75	1.79	0.00	6.00
28/11/2013	38.19	20.54	20.31	20.45	1.72	0.00	5.90
29/11/2013	39.07	20.01	20.19	24.75	1.45	0.00	5.50
30/11/2013	39.33	19.88	20.01	22.00	1.23	0.00	5.10
01/12/2013	38.98	21.69	19.50	20.21	1.69	0.00	5.90
02/12/2013	38.08	20.92	19.74	19.34	1.67	0.00	5.70
03/12/2013	39.02	20.78	19.68	21.37	1.47	0.00	5.50
04/12/2013	38.88	20.07	19.66	21.94	1.36	0.00	5.20
05/12/2013	37.76	19.58	19.80	19.91	1.46	0.00	5.30
06/12/2013	36.72	18.79	19.81	19.91	1.75	0.00	5.70
07/12/2013	37.17	19.92	19.70	21.93	1.79	0.00	5.80
08/12/2013	37.15	19.02	19.69	20.37	1.59	0.00	5.50
09/12/2013	34.66	18.34	19.55	24.83	1.94	0.00	5.70
10/12/2013	32.64	19.69	19.41	36.74	2.07	0.00	5.40

Date	Temp (Max) Cº	Temp (Min) Cº	Radiation (MJ/m²)	Humidity (%)	Wind Speed (m/s)	Effective Rain (mm)	ETo (mm)
11/12/2013	31.48	17.40	19.37	32.58	1.98	0.00	5.20
12/12/2013	28.60	15.36	19.64	23.25	2.25	0.00	5.40
13/12/2013	24.20	12.08	19.14	30.12	2.48	0.00	4.90
14/12/2013	25.07	12.00	19.48	22.77	2.37	0.00	5.10
15/12/2013	25.56	12.31	19.45	26.55	2.31	0.00	5.00
16/12/2013	25.92	9.91	19.64	31.08	2.07	0.00	4.60
17/12/2013	26.18	11.06	19.70	30.18	2.00	0.00	4.60
18/12/2013	26.54	10.67	19.33	28.35	1.97	0.00	4.70
19/12/2013	28.39	12.80	19.34	22.72	2.00	0.00	5.00
20/12/2013	30.63	13.09	18.98	36.88	1.93	0.00	4.90
21/12/2013	32.44	17.49	18.91	45.88	2.07	0.00	5.00
22/12/2013	32.73	17.28	19.02	44.04	1.71	0.00	4.80
23/12/2013	32.68	16.54	19.13	42.70	1.81	0.00	4.90
24/12/2013	33.22	16.98	19.34	36.81	1.81	0.00	5.10
25/12/2013	33.59	16.05	19.45	35.11	1.57	0.00	4.90
26/12/2013	33.45	15.56	19.46	32.99	1.35	0.00	4.60
27/12/2013	35.56	16.01	19.41	33.91	1.17	0.00	4.50
28/12/2013	36.69	17.65	19.44	25.58	1.48	0.00	5.20
29/12/2013	34.55	18.86	19.33	30.23	2.04	0.00	5.70
30/12/2013	30.38	16.69	19.83	23.03	2.22	0.00	5.60
31/12/2013	28.85	11.50	20.39	18.69	1.68	0.00	4.80

Sours: - global weather data

Appendix (2) Actual effective rainfall with percentage of 50%, 75%, And 100%.

Date	Actual rainfall	50%Efficteverainfall	75%Efficteverainfall
01/07/2012	0.82	0.41	0.61
02/07/2012	2.33	1.16	1.74
03/07/2012	0.00	0.00	0.00
04/07/2012	0.00	0.00	0.00
05/07/2012	0.68	0.34	0.51
06/07/2012	0.00	0.00	0.00
07/07/2012	0.00	0.00	0.00
08/07/2012	0.21	0.10	0.15
09/07/2012	3.35	1.68	2.52
10/07/2012	0.00	0.00	0.00
11/07/2012	0.00	0.00	0.00
12/07/2012	0.00	0.00	0.00
13/07/2012	1.35	0.67	1.01
14/07/2012	0.00	0.00	0.00
15/07/2012	0.00	0.00	0.00
16/07/2012	0.00	0.00	0.00
17/07/2012	0.00	0.00	0.00
18/07/2012	0.00	0.00	0.00
19/07/2012	0.00	0.00	0.00
20/07/2012	3.50	1.75	2.62
21/07/2012	0.00	0.00	0.00
22/07/2012	0.00	0.00	0.00
23/07/2012	0.00	0.00	0.00
24/07/2012	0.00	0.00	0.00
25/07/2012	0.00	0.00	0.00
26/07/2012	0.00	0.00	0.00
27/07/2012	0.00	0.00	0.00
28/07/2012	0.01	0.00	0.01
29/07/2012	0.31	0.15	0.23
30/07/2012	3.50	1.75	2.62
31/07/2012	2.55	1.27	1.91
01/08/2012	0.02	0.01	0.02
02/08/2012	3.12	1.56	2.34
03/08/2012	2.60	1.30	1.95
04/08/2012	0.00	0.00	0.00
05/08/2012	0.01	0.01	0.01
06/08/2012	0.03	0.01	0.02
07/08/2012	0.16	0.08	0.12
08/08/2012	0.00	0.00	0.00
09/08/2012	0.18	0.09	0.13
10/08/2012	2.48	1.24	1.86
11/08/2012	8.57	4.29	6.43
12/08/2012	4.72	2.36	3.54
13/08/2012	0.09	0.05	0.07
14/08/2012	0.01	0.01	0.01
15/08/2012	0.14	0.07	0.11

Data	Actual rainfall	50%Efficteverainfall	75%Efficteverainfall
16/08/2012	0.72	0.36	0.54
17/08/2012	1.09	0.55	0.82
18/08/2012	0.00	0.00	0.00
19/08/2012	0.00	0.00	0.00
20/08/2012	0.28	0.14	0.21
21/08/2012	22.84	11.42	17.13
22/08/2012	7.90	3.95	5.93
23/08/2012	5.30	2.65	3.97
24/08/2012	0.00	0.00	0.00
25/08/2012	0.00	0.00	0.00
26/08/2012	0.00	0.00	0.00
27/08/2012	0.00	0.00	0.00
28/08/2012	0.00	0.00	0.00
29/08/2012	0.00	0.00	0.00
30/08/2012	0.04	0.02	0.03
31/08/2012	2.38	1.19	1.78
01/09/2012	1.29	0.65	0.97
02/09/2012	0.14	0.07	0.11
03/09/2012	0.01	0.01	0.01
04/09/2012	0.01	0.00	0.01
05/09/2012	0.00	0.00	0.00
06/09/2012	0.00	0.00	0.00
07/09/2012	0.00	0.00	0.00
08/09/2012	0.00	0.00	0.00
09/09/2012	0.00	0.00	0.00
10/09/2012	0.00	0.00	0.00
11/09/2012	0.00	0.00	0.00
12/09/2012	0.00	0.00	0.00
13/09/2012	0.00	0.00	0.00
14/09/2012	0.00	0.00	0.00
15/09/2012	0.18	0.09	0.13
16/09/2012	0.11	0.06	0.08
17/09/2012	0.00	0.00	0.00
18/09/2012	0.00	0.00	0.00
19/09/2012	0.00	0.00	0.00
20/09/2012	0.01	0.00	0.01
21/09/2012	0.00	0.00	0.00
22/09/2012	0.00	0.00	0.00
23/09/2012	0.00	0.00	0.00
24/09/2012	0.00	0.00	0.00
25/09/2012	0.00	0.00	0.00
26/09/2012	6.90	3.45	5.18
27/09/2012	0.00	0.00	0.00
28/09/2012	0.00	0.00	0.00
29/09/2012	0.00	0.00	0.00
30/09/2012	0.10	0.05	0.07

Date	Actual rainfall	50%Efficteverainfall	75%Efficteverainfall
01/10/2012	5.05	2.53	3.79
02/10/2012	0.04	0.02	0.03
03/10/2012	1.42	0.71	1.07
04/10/2012	0.36	0.18	0.27
05/10/2012	0.00	0.00	0.00
06/10/2012	0.00	0.00	0.00
07/10/2012	0.00	0.00	0.00
08/10/2012	0.05	0.03	0.04
09/10/2012	0.26	0.13	0.20
10/10/2012	0.75	0.38	0.56
11/10/2012	0.17	0.09	0.13
12/10/2012	0.00	0.00	0.00
13/10/2012	0.00	0.00	0.00
14/10/2012	0.00	0.00	0.00
15/10/2012	0.00	0.00	0.00
16/10/2012	0.00	0.00	0.00
17/10/2012	0.00	0.00	0.00
18/10/2012	0.00	0.00	0.00
19/10/2012	0.00	0.00	0.00
20/10/2012	0.00	0.00	0.00
21/10/2012	0.00	0.00	0.00
22/10/2012	0.03	0.02	0.03
23/10/2012	0.00	0.00	0.00
24/10/2012	0.00	0.00	0.00
25/10/2012	0.00	0.00	0.00
26/10/2012	0.00	0.00	0.00
27/10/2012	0.00	0.00	0.00
28/10/2012	0.00	0.00	0.00
29/10/2012	0.00	0.00	0.00
29/10/2012	0.00	0.00	0.00
30/10/2012	0.00	0.00	0.00

Date	Actual rainfall	50%Efficteverainfall	75%Efficteverainfall
01/06/2013	0.00	0.00	0.00
02/06/2013	0.00	0.00	0.00
03/06/2013	0.00	0.00	0.00
04/06/2013	0.00	0.00	0.00
05/06/2013	0.00	0.00	0.00
06/06/2013	0.00	0.00	0.00
07/06/2013	0.00	0.00	0.00
08/06/2013	0.00	0.00	0.00
09/06/2013	0.00	0.00	0.00
10/06/2013	0.00	0.00	0.00
11/06/2013	0.00	0.00	0.00
12/06/2013	0.00	0.00	0.00
13/06/2013	0.80	0.40	0.60
14/06/2013	0.00	0.00	0.00
15/06/2013	0.28	0.14	0.21
16/06/2013	0.00	0.00	0.00
17/06/2013	0.00	0.00	0.00
18/06/2013	0.00	0.00	0.00
19/06/2013	0.00	0.00	0.00
20/06/2013	0.00	0.00	0.00
21/06/2013	0.38	0.19	0.29
22/06/2013	0.22	0.11	0.16
23/06/2013	0.00	0.00	0.00
24/06/2013	0.00	0.00	0.00
25/06/2013	0.00	0.00	0.00
26/06/2013	0.00	0.00	0.00
27/06/2013	0.00	0.00	0.00
28/06/2013	0.00	0.00	0.00
29/06/2013	0.00	0.00	0.00
30/06/2013	0.00	0.00	0.00
01/07/2013	0.00	0.00	0.00
02/07/2013	0.39	0.19	0.29
03/07/2013	0.00	0.00	0.00
04/07/2013	0.00	0.00	0.00
05/07/2013	0.00	0.00	0.00
06/07/2013	0.00	0.00	0.00
07/07/2013	0.00	0.00	0.00
08/07/2013	0.00	0.00	0.00
09/07/2013	0.00	0.00	0.00
10/07/2013	0.00	0.00	0.00
11/07/2013	0.00	0.00	0.00
12/07/2013	0.00	0.00	0.00
13/07/2013	2.10	1.05	1.58
14/07/2013	0.00	0.00	0.00
15/07/2013	0.17	0.08	0.13
16/07/2013	0.96	0.48	0.72

Date	Actual rainfall	50%Efficteverainfall	75%Efficteverainfall
17/07/2013	0.00	0.00	0.00
18/07/2013	2.17	1.08	1.63
19/07/2013	10.65	5.32	7.98
20/07/2013	0.05	0.03	0.04
21/07/2013	0.00	0.00	0.00
22/07/2013	0.00	0.00	0.00
23/07/2013	3.39	1.69	2.54
24/07/2013	84.91	42.46	63.69
25/07/2013	7.70	3.85	5.78
26/07/2013	4.54	2.27	3.41
27/07/2013	1.15	0.58	0.86
28/07/2013	8.01	4.00	6.01
29/07/2013	4.74	2.37	3.56
30/07/2013	0.14	0.07	0.11
31/07/2013	1.87	0.94	1.40
01/08/2013	8.25	4.13	6.19
02/08/2013	0.00	0.00	0.00
03/08/2013	0.71	0.36	0.53
04/08/2013	22.05	11.03	16.54
05/08/2013	8.25	4.13	6.19
06/08/2013	6.31	3.16	4.74
07/08/2013	1.22	0.61	0.91
08/08/2013	0.01	0.01	0.01
09/08/2013	0.00	0.00	0.00
10/08/2013	0.00	0.00	0.00
11/08/2013	2.72	1.36	2.04
12/08/2013	0.00	0.00	0.00
13/08/2013	0.79	0.40	0.59
14/08/2013	0.66	0.33	0.50
15/08/2013	2.79	1.40	2.09
16/08/2013	0.04	0.02	0.03
17/08/2013	11.47	5.74	8.61
18/08/2013	0.53	0.26	0.39
19/08/2013	0.00	0.00	0.00
20/08/2013	0.00	0.00	0.00
21/08/2013	0.99	0.50	0.75
22/08/2013	3.37	1.68	2.53
23/08/2013	0.00	0.00	0.00
24/08/2013	0.00	0.00	0.00
25/08/2013	0.00	0.00	0.00
26/08/2013	0.00	0.00	0.00
27/08/2013	1.29	0.65	0.97
27/09/2013	0.00	0.00	0.00
28/09/2013	0.00	0.00	0.00
29/09/2013	0.00	0.00	0.00