SOKOINE UNIVERSITY OF AGRICULTURE

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Parched-Thirst v2.1 Help Office and Upgrading to v2.2[1]

Annex B11

PARCHED-THIRST Model Handbook

SOIL-WATER MANAGEMENT RESEARCH GROUP

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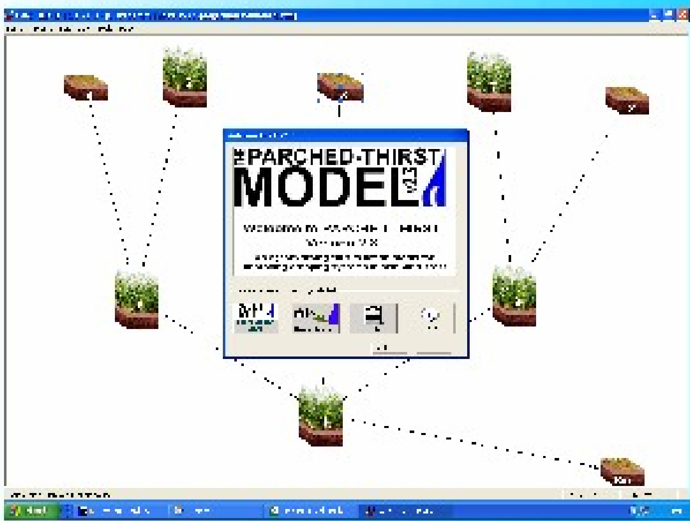
PARCHED-THIRST MODEL

for Rainwater Harvesting



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PT-MODEL HANDBOOK No. 01

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1.1 Introduction

The world's freshwater shortages result more from uneven distribution of water over time and space than from absolute scarcity. Even in some of the world's highest rainfall areas, rain falls in concentrated periods followed by prolonged dry spells, so users must capture rainwater when it is abundant to use later when it is scarce. Similarly, even in some of the driest areas, occasional intense rainfall generates runoff that can be captured and stored for subsequent use. For example, harvesting only 100 millimeters of rainfall over a one-hectare plot would yield 1 million liters of water. Ancient water-harvesting systems throughout the world took advantage of this principle to smooth intertemporal variations in water availability, making human settlement possible in a wide variety of ecosystems.

Local water harvesting declined with the development of large systems in which water is transported hundreds of miles through canals and pipes or pumped from great depths below the ground. However, growing scarcity and intersectoral competition for water, along with groundwater depletion and the problems facing major surface-water control systems, have raised interest in revitalizing water-harvesting systems that capture rainwater wherever it falls.

1.2 What is rainwater harvesting?

Water harvesting refers to the small-scale concentration, collection, storage, and use of rainwater runoff for both domestic and agricultural use. This definition implies that the catchment area from which the water is drawn is larger than the command area, where it is collected and used. The ratio of catchment to command is inversely related to the amount and intensity of rainfall, the impermeability of soil, and the slope of the land on which it falls. Rainfall intensity is particularly important, since intense storms generate the most runoff. A watershed is an area that drains to a common point (Figure 1). It may be managed for various objectives, depending on local needs, including capturing runoff, minimizing erosion, and reducing nonpoint source pollution. In management of small watersheds, capturing runoff for local use is conceptually equivalent to harvesting water. This brief encompasses all small-scale, local systems for capturing runoff from rainfall.

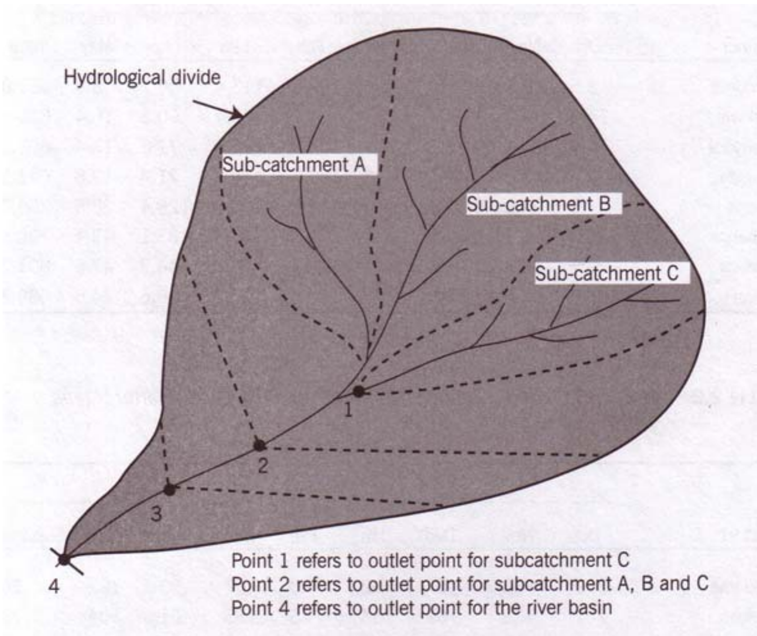


Figure 1: An example of watershed showing different sub catchments

Water-harvesting systems either concentrate water into a storage reservoir or apply water directly to the soil in the cropped area. Both types of systems can vary in scale from a few square meters benefiting a single household to a few square kilometres serving a larger group of people.

1.3 Storage systems

Systems that concentrate water into storage reservoirs can be used for a variety of purposes, including household, irrigation, or livestock consumption. Rooftop water-catchment systems provide domestic water in many places, especially dry areas with inadequate municipal supplies. A rooftop that is 50 square meters can supply an annual average of 50 liters per day with 500 millimeters annual rainfall. This supply can help to reduce competition between agricultural and household demands and can free women and children from the chore of collecting water. It can also help in reducing the spread of water borne deceases as can supplement water for sanitation.

Harvesting water into village ponds is an ancient technique in some places. The principle behind this approach is to concentrate water spatially and temporally. In arid and semi-arid areas where rainfall is low and variable, harvesting rainwater allows users to conserve it until enough water is collected to reliably support a crop. The volume of water stored at the end of the rainy season determines how much area can be cultivated. Traditional water-harvesting systems store water in ponds and reservoirs and deliver it by gravity. With the spread of motorized pumps in recent decades, water can now be captured in some places using the same techniques but allowing collected water to percolate into groundwater aquifers. The systems are small in scale, drawing from gullies and microcatchments to recharge groundwater that supplies a number of local wells.

1.4 Storing harvested water into the soils

In many traditional water-harvesting systems, runoff water is channelled directly to the cropped area during rainfall and stored in the soil. Where rainfall is unevenly distributed and soils have high water-holding capacity, this system may store water until the end of the rainy season, when a crop is grown under gradually receding moisture. Where soils are sandier and do not retain moisture for a long time, moisture may be channelled spatially to the location where crops or trees can take advantage of it. Farmers in West Africa use such systems, cultivating their dryland crops behind a variety of small earthen barriers designed to capture moisture. These systems can remain productive several months into the dry season when the surrounding land is barren.

RWH describes a wide range of techniques along a continuum from point-scale to catchment-scale (Gowing *et al*., 1999). At one end of continuum, in-situ RWH merges into several techniques (such as contour ridging, deep ploughing, terracing etc.) which prevent runoff and promote infiltration where rain falls directly on the crop area. These approaches are appropriate when rainfall amount is adequate, but soil properties limit its effective use by the crop. At the other end of continuum, RWH merges into irrigation, where runoff is tapped from a reliable source (such as seasonal rivers and permanent rivers) and transferred through a network of channels to the cropped fields. The availability of suitable sources, investment cost and difficulties of social organization are widely reported as constraints on successful development of irrigation in semi-arid Africa (Hatibu et al., 2000).

Recognizing the limitations of techniques at either end of the continuum, there has been growing interest in finding appropriate intermediate meso-scale RWH techniques. All can be represented as in Figure 2 as a combination of a runoff-producing catchment area and a runoff- receiving crop area. (Pacey and Cullis, 1986; Boers and Ben Asher, 1982). A number of classifications have been attempted (Critchley and Siegert, 1991; Prinz,1995; Barrow, 1999).

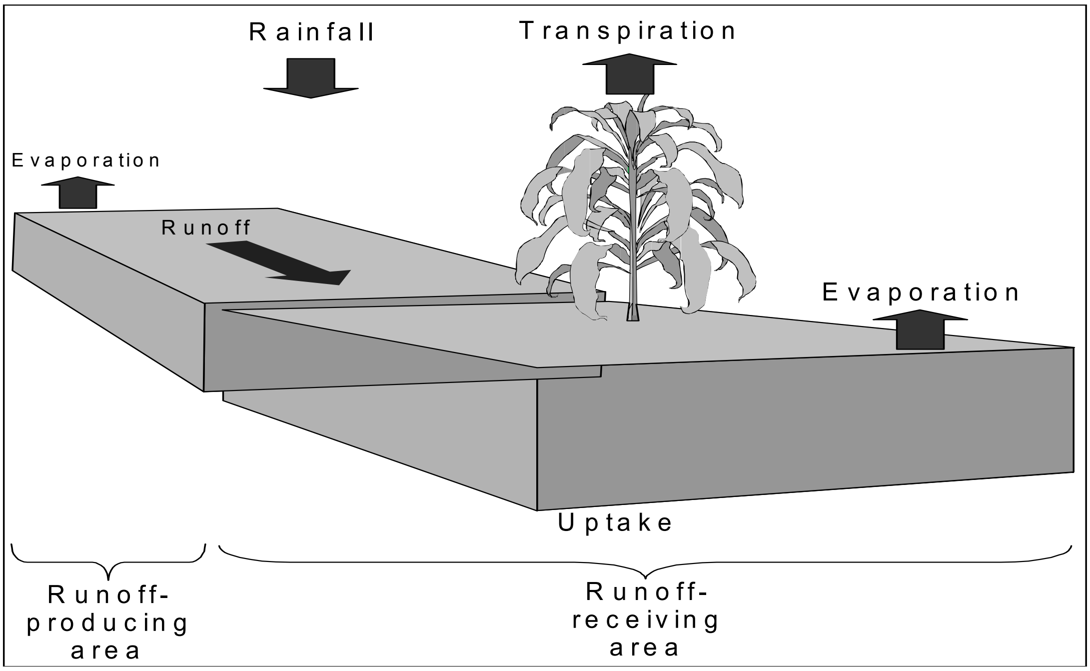


Figure 2: The hydrological components of a conceptual rainwater harvesting system.

Though several studies on experimental fieldwork to test various techniques of RWH have been carried out in different semi-arid areas (Prinz et al., 1994, Oweiss et al., 1999, Boers and Ben-Asher, 1982, Reij, 1994, Reij et al., 1988; Troung and Seattini, 1990, Rao et al., 1991), little has been done in Africa. In Africa, several research works has been done or documented, e.g. Caag system in Somalia (Reij, 1991) soil and water conservation: in Mali, Burkina Faso and Niger (Reij et al., 1996); in Kenya (Kiome and Stocking, 1993); in Zimbabwe (Thomlov and Hagmann, 1996) and RWH Research in Tanzania (Rwehumbiza et al., 1999).

1.5 Different techniques of RWH for agricultural production

Water-harvesting systems vary a great deal in the ratio of catchment to cultivated area. In dry areas with less available water, this ratio can easily reach 20:1. In such water-harvesting systems, cultivation systems must be extensive and located in sparsely populated areas so that command and catchment areas do not interfere with each other. Where rainfall is higher, the ratio declines-sometimes to the point that the entire catchment area lies within a single plot.

Various attempts have been made to classify the different techniques according to the nature of the runoff process involved (Critchley & Siegert, 1991; Prinz, 1995; Barrow, 1999). For simplicity, we will adopt a classification according to the size ratio and transfer distance between runoff producing normally called Catchment Area (CA) and the runoff receiving area, normally called Cropped Basin (CB).

1.5.1 In situ Rainwater Harvesting

In-situ, RWH, otherwise known as soil-water conservation, comprises a group of techniques for preventing runoff and promoting infiltration. The aim is to retain moisture that would otherwise be wasted as runoff from the cropped area. Rain is conserved where it falls, but no additional runoff is introduced from elsewhere.

This approach is appropriate where the main constraints are soil-related, but rainfall is adequate. Water acceptance may be hindered by low rate of infiltration caused by surfacing crusting (capping) alternatively, the problem may be attributable to low percolation rate caused by restrictive layers in the soil profile. These problems may be due to inherent soil characteristics or to previous mismanagement (e.g. formation of plough pan, compaction by trampling).

The following techniques are identified:

i) Conservation Tillage

Conservation tillage is a generic term for the use of tillage techniques to promote in-situ moisture conservation. This can be achieved by creating micro-relief to increase detention storage (e.g. tied ridges), by breaking sub-surface pans by deep cultivation (e.g. chisel ploughing), or by contour ridges.

ii) Pitting

Planting pits (Figure 3) have been documented as an indigenous practice in Mali, Burkina Faso and Niger, where they are known as zay, zai or tassia (Reij et al, 1996). In Tanzania, a notable example is the "ngoro" technique of the Matengo Highlands in Mbinga district. This system was documented during the colonial era (Pike, 1939; Stenhouse, 1944) and has received recent attention (Willcocks et al, 1996). In semi-arid Tanzania, pits are typically about 30cm diameter and 20cm deep. The system is well adapted to hand cultivation and is beneficial especially when soil surface capping is a problem.

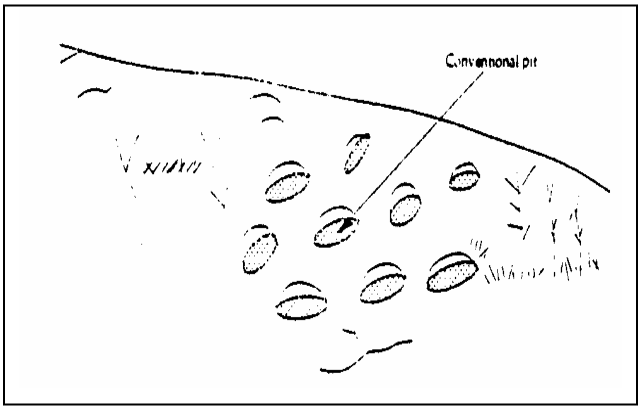


Figure 3: Layout of Pitting RWH

1.5.2 Micro-catchment RWH

Micro-catchment RWH comprises a group of techniques for collecting overland flow (sheet or rill flow) and delivering it to a cropped area in order to supplement the inadequate direct rainfall. This system involves a distinct division of CA and CB, but the two zones are adjacent. The transfer distance is typically in the range 5m to 50m. Both CA and CB are normally situated within the land-holding of an individual farmer. The system is therefore sometimes known as an "internal catchment" system.

The following techniques can identified:

i) Strip catchment tillage

This technique (also known as contour strip cropping) involves alternating strips of crops with strips of grass or cover crops. Cultivations are usually restricted to the row-planted crop strips. The uncultivated strips release runoff into adjacent crop strips (Figure 4). The system is normally used on gentle slopes (up to 2%) with the strip width being adjusted to suit the gradient. The CA:CB ratio is normally less than 2:1.

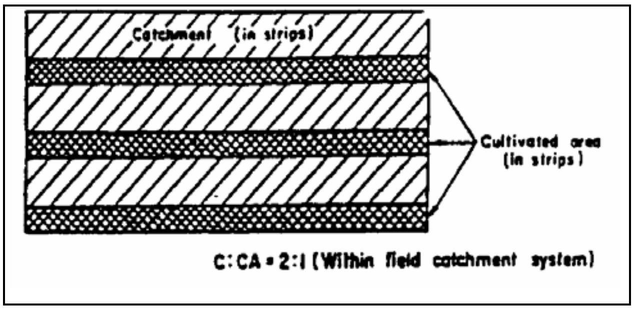


Figure 4:RWH with Strip Catchment Tillage

ii) Contour barriers

This technique involves the creation of cross-slope barriers, which may be vegetative (grass strips, trash lines) or mechanical (stone lines, earth bunds). The barrier intercepts runoff from upslope and promotes infiltration in the cropped area. In the case of earth bunds, the barrier is designed to be impermeable and water is ponded behind it. Other barriers are semi-permeable and aim to slow down and filter runoff without ponding.

Contour bunds have been advocated widely in the past as a method of soil erosion control on slopes up to 5%. They are generally constructed manually with soil either being thrown upslope (fanya juu) or downslope (fanya chini). The former system has been successfully adopted in Machakos district of Kenya, but the latter system is more common in Tanzania. Bunds are usually closely spaced (2 to 5m). There are many reported experiences of failure due to breakage or overtopping of bunds, which may lead to progressive downslope damage due to flow concentration. This problem is generally associated with poor alignment and poor maintenance of the bunds. The risk is reduced if intermittent structures rather than continuous contour bunds are created. These structures (sometimes described as demi-lunes or lunettes) are found as a traditional practice in parts of West Africa (eg. Niger).

iii) Basin systems

This practice is commonly known as the "negarim" microcatchment technique and is perhaps the best known RWH system. It is also known as the "meskat" system. In this system each micro-catchment feeds runoff to a discrete cropped basin (Figure 5). The basin size is typically in the range 10m^2 to 100m^2 and is surrounded by an earth bund approximately 30 to 40cm high. They are particularly well suited to tree crops, but other crops can be grown successfully under non-mechanised farming systems. There is a long tradition of using this system in arid regions with low-intensity winter rainfall (Evenari et al, 1971; Oweis & Taimeh, 1996). There is no experience of systematically designed micro-catchment basin systems in semi-arid Tanzania other than the research reported later in this issue, however it is apparent that some farmers recognise the natural redistribution of runoff which occurs in the farming landscape and adjust their management to reflect differences in land capability.

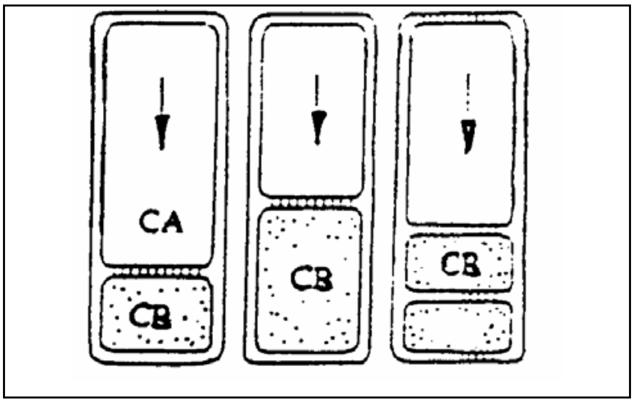


Figure 5: RWH with Meskat-type Bunding

1.5.3 Macro-catchment RWH

Macro-catchment RWH comprises a group of techniques for harvesting runoff from a catchment area (CA) and delivering it to a cropped area (CB), where CA and CB may have markedly different characteristics (i.e. slope, soil etc) and the transfer distance may be in the range 100 metres to several kilometres. The catchment generally lies outside the land holding of the farmer(s) using the runoff, so the system is sometimes known as an “external catchment” system. This distinct separation can be particularly beneficial if runoff events can be harvested at times when there is no direct rainfall in the cropped area.

The runoff efficiency is normally less than for a micro-catchment system, but the large catchment area ensures that the runoff volume and flow rate are high. This gives rise to problems in managing potentially damaging peak flows, which may lead to serious erosion and/or sediment deposition. Substantial channels and runoff control structures may be required and this usually involves collective effort amongst a group of farmers for construction and maintenance. This sometimes gives rise to problems over management of water distribution.

We can identify the following techniques:

i) Hillside systems

These systems exploit hillslope runoff processes by which runoff from stoney outcrops and grazing lands in upland areas tends to flow naturally downslope. Some farmers grow their crops in wetter lowland areas which receive runoff in this way without any active manipulation or management. Farms in these areas are called "mashamba ya mbugani" and are found throughout semi-arid Tanzania to grow maize, rice, sugar cane vegetables and bananas. They are attractive not only for their improved moisture regime, but also because of higher fertility levels due to enrichment. In some villages there is high demand for such land and favoured areas which also have good access and low risk of flooding tend to be fully exploited.

One technique for improving the capture of hillslope runoff involves the construction of cross-slope barriers and basins using earth bunds to intercept and store runoff. In principle, these systems are similar to contour barriers and basin-type micro-catchment systems, but they involve larger external catchments (Figure 6). In Tanzania the "majaluba" system of Sukumaland is the best known example. It is used primarily for production of rainfed lowland rice (Meertens et al, 1999). It is arguably not a traditional practice (Shaka et al., 1996), but its introduction can be traced to the colonial era (Thornton and Allnut, 1949) and its rapid adoption and spread indicates the potential of RWH in semi-arid areas.

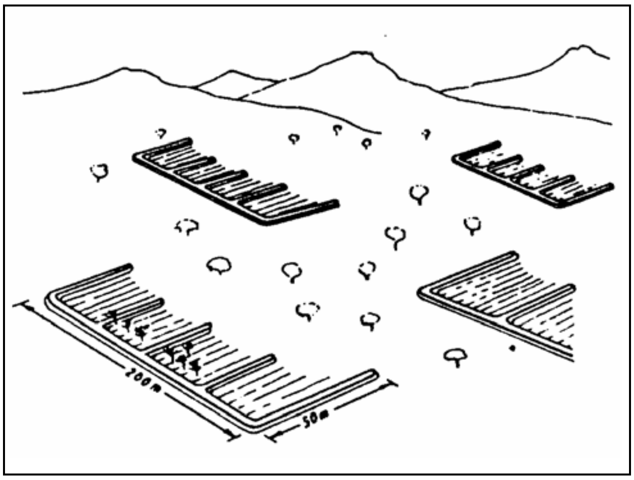


Figure 6: Examples of hill sheet flow RWH

ii) Stream-bed systems

These systems use barriers, such as permeable stone dams or earth banks, to intercept water flowing in an ephemeral stream (wadi) and spread it across adjacent valley terraces to enhance infiltration (Figures 7). This technique is sometimes known as the "liman" system and is difficult to distinguish from spate irrigation. In north India (especially Rajasthan) the "khadin" system has received considerable attention (Hudson, 1992). In east Sudan a similar system, known locally as "teras" has also been studied extensively (van Dijk and Ahmed, 1993). The size of these structures varies a great deal, but some systems run for several kilometres with one structure spilling excess flow to another downslope and so on (Kolakar et al, 1983). Normally, planting occurs at the end of the wet season using stored soil moisture.

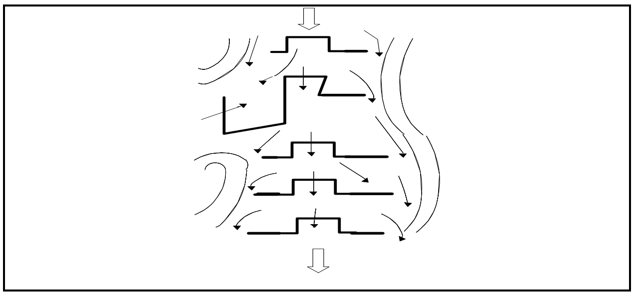


Figure 7:Flood water harvesting with the stream bed

iii) Ephemeral stream diversion

These systems are also difficult to distinguish from spate irrigation, since they involve diverting water from an ephemeral stream and conveying it to a cropped area. There are two distinct ways of distributing the water in the cropped area. The first uses a cascade of open trapezoidal or semi-circular bunds (Figure 8). The water fills the top basin and spills around the end of the bund into the next basin (sometimes known as the “caag” system). In the second system, the field is divided into closed basins and water is distributed either through a channel or in a basin-to-basin cascade using small spillways (as in the “majaluba” system).

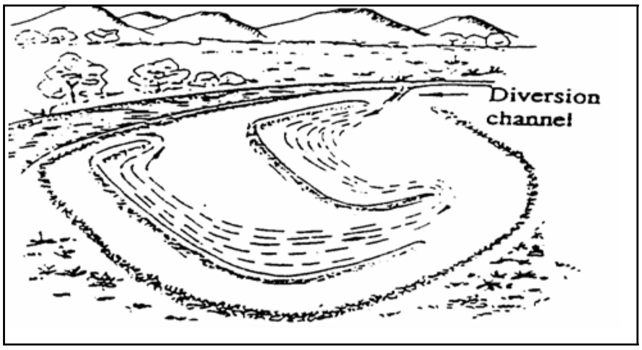


Figure 8:Ephemeral stream diversion

iv) Storage systems

Macro-catchment RWH systems often yield high volumes of runoff and it may be advantageous to store it in a reservoir or use it to recharge groundwater. Simple reservoir systems have been used widely for livestock watering. They are sometimes known as "charco dams” or “haffirs”. Siltation is often a problem and the labour requirement for sediment removal can be a considerable burden. Evaporation and seepage losses may also be high, but in some cases they are avoided by using sand dams as a method of small-scale groundwater recharge.

2 PARCHED-THIRST Model

2.1 *Introduction*

In arid and semi-arid climates the major factor limiting the growth of crops in most years is the imbalance between the demand for water by the atmosphere and the supply from the soil. There is little that can be done to decrease the atmospheric demand but water conservation can increase the amount of water stored in the soil by reducing the proportion of rainfall that runs off the surface. Alternatively, water can be harvested from adjacent areas thus increasing the amount of water available to the plant (rainwater harvesting). In order to assess whether this type of intervention by farmers is worthwhile, the benefits in terms of crop yield need to be determined over a number of years with different seasonal rainfall patterns. However, to carry put this exercise of testing different scenarios will require experimental research, of which it is resource consuming and will require long time to capture spatially and temporal variability.

Due to constraints in resources to carry out experimental work for every rainwater harvesting technology inverted, efforts have been directed in the development of simulation models. Several crop, hydrological and agrohydrological models have been developed, established and published describing various aspects of agricultural production systems (Mathews *et al*., 2000). Agrohydrological models do not only concerned with simulating hydrological responses over given input, but also are used to predict crop production. Among several agrohydrological models existing, Parched-Thirst is one of them.

PARCHED-THIRST stands for **P**redicting **A**rable **R**esource **C**apture in **H**ostile **E**nvironments **D**uring the **H**arvesting of **I**ncident **R**ainfall in the **S**emi-arid **T**ropics. It is a user-friendly, process-based model which combines the simulation of hydrology with growth and yield of a crop on any number of distinct or indistinct RPAs and RRAs. It is a distributed model which simulates the rainfall-runoff process, soil moisture movement and the growth of sorghum, rice, maize and millet in response to daily climate data. The landscape is divided into units which are assumed to represent homogeneous portions of the landscape. The only transfer of mass between profiles is surface runoff. The first version of P-T simulated only maize under microcatchment RWH. Version 2 includes the simulation of rice and macrocatchment systems up to the hillside or small catchment scale. It comprises a number of components (fig.9):

- a user-friendly interface which allows users to input, output and analyse data, set options and run the model (Young et al., 2001)
- data pre-processing to minimise data input requirements;
- soil moisture simulation;
- a runoff prediction component and;
- crop growth simulation.

2.2 Components of the PT Model

2.2.1 *Data pre-processors*

P-T has been designed to minimise input data requirements. Because it is physically-based, it uses parameters which are measurable and (with the exception of crop cultivars) do not require long series of historical data for calibration. However, where data are difficult to obtain, three data pre-processors have been included. These are the climate generator, the rainfall disaggregator and pedotransfer functions (PTFs).

2.2.2 *Climate generator*

To drive P-T, daily climate data are required. Although there are long records for a number of sites in sub-Saharan Africa, in many areas climate data have only been collected for a few years or contain large numbers of missing data. This may be due to instruments breaking down, running out of consumables or even destruction of paper records by vermin (Kihupi, 1990). P-T therefore includes a climate generator, which can:

- extract the statistical properties of short-term climatic data to generate longer series of data with the same statistical properties. Long series of data are required for a thorough assessment of the sustainability of RWH, especially in highly variable semi-arid climates.
- 'fill in' missing data using the statistical properties of other data at the same site or from other climatically similar sites. Because the wet or dry status of a day is often the most significant determinant of the other climatic variables, missing data are generated conditional upon this.

Rainfall is generated using a two-state Markov chain (Gabriel and Neumann, 1962; Richardson, 1981) which determines the wet or dry status of a day. Rainfall amount on wet days is sampled from a gamma distribution (Buishand, 1978; Hutchinson and Unganai, 1991). Generation of other weather variables is based upon the approach of Richardson (1981) which has also been used in the EPIC model (Sharpley and Williams, 1990) and, with the exception of wind speed, is conditional upon the wet or dry status of the day.

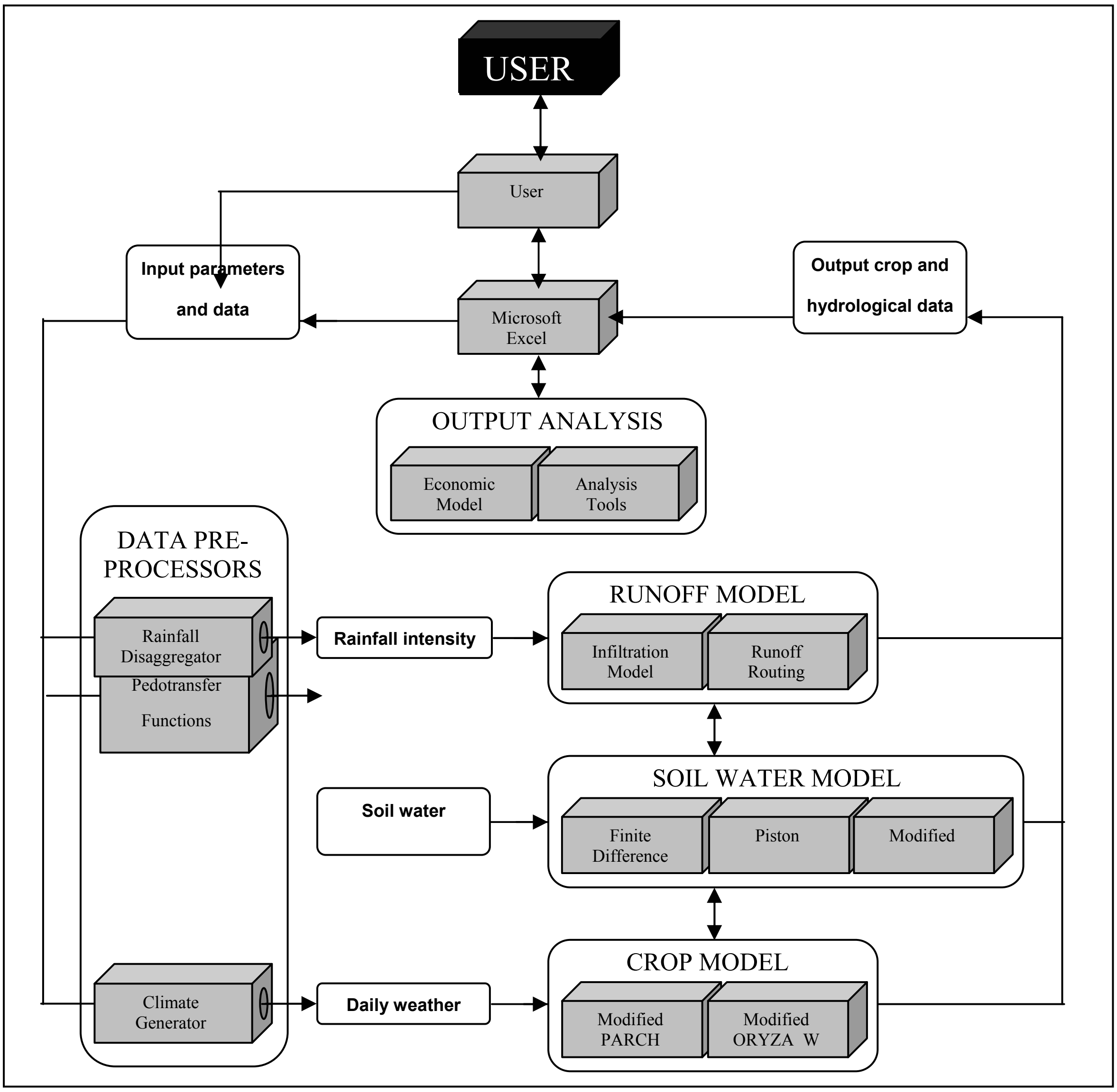


Figure 9: Interaction between the components making up the PARCHED-THIRST model. The user interface incorporates Microsoft Excel functionality as an ActiveX component.

2.2.3 *Rainfall disaggregator*

The runoff component requires rainfall intensity data at intervals of less than 1 day – typically 5 minutes. Where rainfall intensity data are available, they can be input to the model directly. More commonly, intensity data are either not available or are summarised into the maximum 30-minute intensity (I_{30}), rainfall duration and total rainfall amount.

P-T provides a rainfall disaggregator which generates 5 minute rainfall intensity data from an assumed rainfall intensity distribution) similar to that proposed by Oron et al (1989). This distribution is fitted to rainfall amount, duration and I_{30} using a Newton-Raphson iterative technique on a daily basis. Where observed durations and I_{30}s are not available, regression equations (which can be developed from data at climatically similar stations) are used to estimate them.

2.2.4 *Pedotransfer functions*

The process-based soil moisture and runoff components, in common with most other cropping systems models, require a number of time-consuming and difficult-to-measure soil hydraulic parameters including the K(θ) and h(θ) relationships for each soil type in each layer of each area simulated. Where these are not already available, P-T provides a choice of the Rawls and Brakensiek (1989), Vereecken et al. (1989) or Campbell (1985) pedotransfer function components. These can be used to estimate all the necessary soil hydraulic properties from data such as soil texture and bulk density which are often available from standard soil surveys.

2.2.5 *Soil moisture models*

Accurate soil moisture accounting is vital for both runoff and crop growth simulation. P-T provides a choice of three one-dimensional soil moisture simulation components.

One-dimensional finite-difference

Based upon the PARCH model's (Bradley and Crout, 1994) soil water balance, it uses a finite-difference solution to Richards equation as described by Hillel (1977). It also includes a simple, two-parameter macropore flow model based on Jarvis et al. (1991) which allows for bypass flow of infiltrated water from the top layer of the soil under saturated conditions. Potential evaporation is calculated from measured Class A pan evaporation modified by the fractional light interception of the crop (estimating soil cover) in an approach similar to Monteith et al. (1989). At low water potentials, isothermal vapour flow is modelled using an approach derived from Campbell (1985).

Piston Flow

In wet, coarse textured soils, the finite-difference method can underestimate the observed speed of water through the soil profile (van der Meer, 2000). P-T includes a modified version of the finite-difference approach which includes piston flow (van der Meer, 2000). Instead of moving water from layer to adjacent layer each time-step, this allows water to move from one layer, through any intervening layers whose water content is greater than or equal to field capacity (or any other user defined matric potential), into the next closest layer with a water content lower than field capacity layer. This enables a better match to the speed of movement of water in wet, coarse textured soils.

Lowbal

P-T has been designed to model a number of RWH systems including those growing rainfed, lowland rice as found in the Lake Zone of Tanzania. For these systems, where rice in grown in puddled soils above an impenetrable layer and groundwater is deep, the LOWBAL model included with ORYZA_W (Wopereis et al., 1996) is suitable. This is a simple one-layer soil water model which simulates the shrinkage and cracking of the puddled layer and is used by default on profiles where rice is simulated.

2.2.6 *Runoff model*

Runoff and infiltration on both the RPA and RRA are calculated using the Green and Ampt (1911) infiltration equation. Runoff amount is infiltration excess which is modified by depression storage and surface sealing. Runoff routing is simple, based upon the SCS unit hydrograph (USDA, 1972).

Depression storage

Depression storage can be either permanent for structures such as bunds around rice fields or temporary for tillage-induced relief. Temporary depression storage is calculated from random roughness using an approach described by Mwendera and Feyen (1992). Random roughness tends to decrease after tillage due to the effects of rainfall, wind, etc. In P-T this reduction with time is modelled as a function of cumulative rainfall (Zobeck and Onstad, 1987).

Surface Sealing

The development of a soil crust or surface seal can dramatically reduce infiltration (and thus increase infiltration excess). Rawls and Brakensiek (1989) present a relatively simple crust factor which is used to modify the hydraulic conductivity of the surface of the soil. As crusts reach a stable state very quickly (usually after circa 0.5cm of rain), the development of a crust with time is ignored.

Runoff routing

Estimation of runoff rates is important for erosion risk assessment. On larger catchments, runoff lag times can be significant. Runoff routing is accomplished using the USDA-SCS synthetic unit hydrograph with the time of concentration of the drainage basin calculated according to Kirpich (1940). One unit hydrograph is calculated for each interval determined by the input intensity data (normally 5 minutes) and these are added together to calculate actual runoff rate at any given time.

2.2.7 *Crop models*

P-T incorporates two crop models – PARCH (Bradley and Crout, 1994) for the simulation of sorghum, millet and maize and ORYZA_W (Wopereis et al., 1996) for the simulation of rainfed, lowland rice.

PARCH Model

The PARCH model simulates the growth of sorghum, millet and maize in response to the capture of light, water and nutrients on a daily basis. Partitioning of resources between crop organs depends upon empirical equations which account for growth stages and stress. Resources allocated to leaves and roots increase leaf area and root length which feed back into increased light interception and water and nutrient uptake. PARCH was developed specifically for semi-arid areas. Growth is light, water or nutrient limited. If the crop is stressed by limited resources, responses such as leaf rolling and increased partitioning to roots are simulated.

PARCH does not simulate crop emergence, rather 100% emergence is assumed. In many cases, the second sowings and gap filling practiced by farmers make this assumption valid.

ORYZA_W Model

ORYZA_W is a model developed to simulate water-limited growth and development of rice. It is based upon the ORYZA 1 model (Kropff et al., 1994) but modified to enable linkage to LOWBAL and to include the effects of drought on plant growth and development such as leaf rolling and senescence and plant death. Like PARCH, ORYZA_W uses a daily time step and partitions dry matter according to development stage and stress. The growth of rice in nurseries (a common practice in Tanzania) and shock due to transplanting are also modelled. Nutrient supply is considered non-limiting and weeds are not simulated.

2.3 Modelling approach

P-T has been developed in Microsoft Visual Basic v5.0 using an approach which has been:

- User oriented and iterative – both the usability and functionality of the model have been iteratively tailored to user needs through seminars and workshops in the UK and Tanzania (Young et al., 2001). For example, although P-T v1 was well-received as a user friendly model for simulating microcatchment RWH, farmers were keen on macrocatchment RWH and rice and users wanted more analysis features. This functionality has been provided in P-T v2.
- Modular/component-based – P-T comprises a number of components which, combined, produce the required functionality. This modular approach has a number of advantages:
  - Individual components can be easily updated with only minimal alterations to the code extending the lifespan of the software
  - New components (e.g. other crop models) can be slotted in according to need.
- Object oriented – although the modular design means that crop and soil water balance components are largely unchanged from PARCH and ORYZA_W, the user interface and linkages between the models are all object-oriented. This forms the basis for the rationale behind the model front end . Each simulation scenario is known as a system. A system has a number of properties which include start date, sowing dates, etc. It is also made up of a number of profiles. These are one dimensional 'blocks' of soil/plant/atmosphere which are assumed to represent an area with homogeneous soils, topography, vegetation, etc. Each profile is composed of crop, soil and weed objects which define the behaviour of the profile. A soil object is itself composed of a number of soil layer objects each with defined physical properties. As well as being conceptually easy for users to understand, object-orientation increases the robustness of the model and eases debugging, maintenance and further development.

3 Application of the PARCHED THIRST Model

The PARCHED-THIRST model is a planning, research and teaching tool.

As a Planning tool

- Testing various RWH and rainfed system scenarios depending on the available resources in implementation of new investment and on improving the existing project.
- Using climatic generator component of the model to predict what will happen in ten years or more to come in agricultural planning.

As a research tool

- Testing out a proposed field experiment in order to predict the likely range of response to the inputs proposed.
- Extrapolating the results of one or two years field experiments to different weather conditions and considering the long time variability of the yields.
- Extrapolating the results of the field experiments to different soil conditions, different planting density and different soil-water management practices.

As a teaching or educational tool

- Studies of rainfall runoff relationship.
- Allowing student to carry out 'field experiments' in the classroom and consider a wide range of treatments and treatments interactions such as:- weeding treatments (Days after emergence), planting density experiments, planting date experiments (Treatments), Soil variability experiments (Texture, Structure, Drainage, nutrients)

The following subsections give detail of model applications on the field of crop Management, soil management, land and water management, climatology and planning and designing of rainwater harvesting system.

3.1 Crop Management

The Parched Thirst Model can be used in simulating various agronomical aspects, which can be used in

- Assessment of the effect of planting date on crop yield
- Assessment of the effect of planting density on crop yield
- Assessment of the effect of weeding on crop yield

3.2 Soil Management

The Parched Thirst Model can be used in simulating the effect of soil variability on crop yield and moisture status of the soil.

- Assessment of the effect of soil type on surface runoff and crop yield.
- Assessment of the effect of soil management practice on surface runoff and crop yield

3.3 Land and Water Management

- The model can estimate the amount of runoff water that can be collected from catchments and hence: -
  - ➢ Used as a basis for soil and water conservation strategies.
  - ➢ Used as a basis for selection of land use option.
  - ➢ Used to estimate strategic location for water storage structures like Charcoal dams.
- The model can estimate long-term rainfall, evaporation, and drainage data, which are important information in designing size and location of water storage structures like Charcoal dams.

3.4 Climatology

In many sites in the sub Saharan Africa, there is no consistent of the climatic data records. Data may exist for short periods and contains large number of the missing data. In many stations if data exist will be for only few parameters common being rainfalls, other climate variable are not commonly collected. Other problems leading to poor records of climate data are such as instruments breakdown, running out of consumable or even destruction of the paper records by vermin (Kihupi, 1990). The PT model has an inbuilt climate generator capable of generating missing data within the existing data series of the same site using the statistical properties of the other data at the same site or from other climatically similar site.

- The model can be used in assessment of the effect of weather variability on crop yield.
- The model can be used in filling gaps of missing data and generating long term series of climatic data.

3.5 Planning and Design of RWH

PARCHED THIRST models RWH systems in which runoff is collected and delivered to a crop without storage other than in the soil within the cropped area. Different RWH systems can be recognised across a range of spatial scales. A distinction can be made between:

Micro-catchment or within-field methods, which involve transfer of water over a short distance (0-50m) usually by sheet flow;
Macro-catchment or external catchment methods, which involve collection of water from a catchment area at a considerable distance from the receiving area and its transfer by channel flow.

The model is designed to assist agricultural planners and advisers whose aim is to improve cropping systems in dry-land environments, where the major factor limiting crop performance is the imbalance between water supply and demand (Gowing et al, 2001). In seeking improvements, they face difficulties in finding answers to questions such as:

- For a given field, which of the many RWH techniques is going to best match the livelihood strategy of the farmer.
- What is the optimum configuration of RWH technique?
- Given a successful technique in one area, how to identify other areas where the technique might also be successful?
- The model is therefore a tool that helps to identify best-bet RWH system options at any particular

4 Tutorials

4.1 Tutorial 1:

Getting Started with Parched-Thirst Model

In arid and semi-arid climates the major factor limiting the growth of crops in most years is the imbalance between the demand for water by the atmosphere and the supply from the soil. There is little that can be done to decrease the atmospheric demand but water conservation can increase the amount of water stored in the soil by reducing the proportion of rainfall that runs off the surface. Alternatively, water can be harvested from adjacent areas thus increasing the amount of water available to the plant (rainwater harvesting). In order to assess whether this type of intervention by farmers is worthwhile, the benefits in terms of crop yield need to be determined over a number of years with different seasonal rainfall patterns. While PTv2.3 can be used to simulate rainfed crop growth, the simulation of rainwater harvesting is an integral part of its functionality. The following section takes you through the steps necessary to use PTv2.3 to evaluate options for RWH interventions.

Creating a RWH system

A complete RWH system must have both a Catchment Area and a Cropped area. In PTv2.3 these areas are represented by Profiles. A profile is assumed to represent an homogeneous area of the landscape. A profile has properties which define the soil characteristics, the soil surface, the crop to be grown and any weeds. Each profile is joined to another with a link which specifies the direction of movement of any runoff. Every profile must be linked to at least one other, and at least one profile must be linked to the sink, which represents an undefined destination for runoff lost from the RWH system. Runoff from one profile can only be directed to one other profile, but a profile may receive runoff from any number of profiles.

In PTv2.3, a simulation scenario is called a *System*. A system, which can be thought of as a landscape, is a collection of profiles (each of which has its own properties) with information on the geographical location (including weather data to be used), simulation start dates and crop planting dates. The system can have as many profiles as desired, but the current setting of the model allows only up to 20 profiles. In this tutorial we will create a system with two profiles where profile 2 will be our runoff producing (catchment) area and profile 1 will be our runoff receiving (cropped) area. Profile 2 will be linked to profile 1, which means that runoff collected from profile 2 will flow towards profile 1, which will then be connected to a sink.

Starting the Model

Double-click on the PTv2.3 model icon, or from the Start task bar go to *Programs* and from the program list click PTv2.3 The PTv2.3 main window and Welcome screen will appear. On the Welcome screen click on the icon *Use the Model* to be taken straight to the main system window of PTv2.3.

1. On the main windowpane select *System* menu and click on *New*. A warning message will appear which will ask you if you want to create a new system – any changes to the current system will be lost, and will ask you to Continue, select YES to continue.
2. A new system will appear which has only one profile connected to a sink. We need to have two profiles. Therefore, click on right mouse button so that a pop-up menu will appear and select *new profile.* Alternatively, click on the profile menu in the Main Window and select *New*. This will create a new profile, which is numbered 2, that means profile 2. Click on the profile 2 while holding down the left mouse button and you will be able to drag profile 2 to any position on the screen. Move it to the right of profile 1 and release the mouse button.

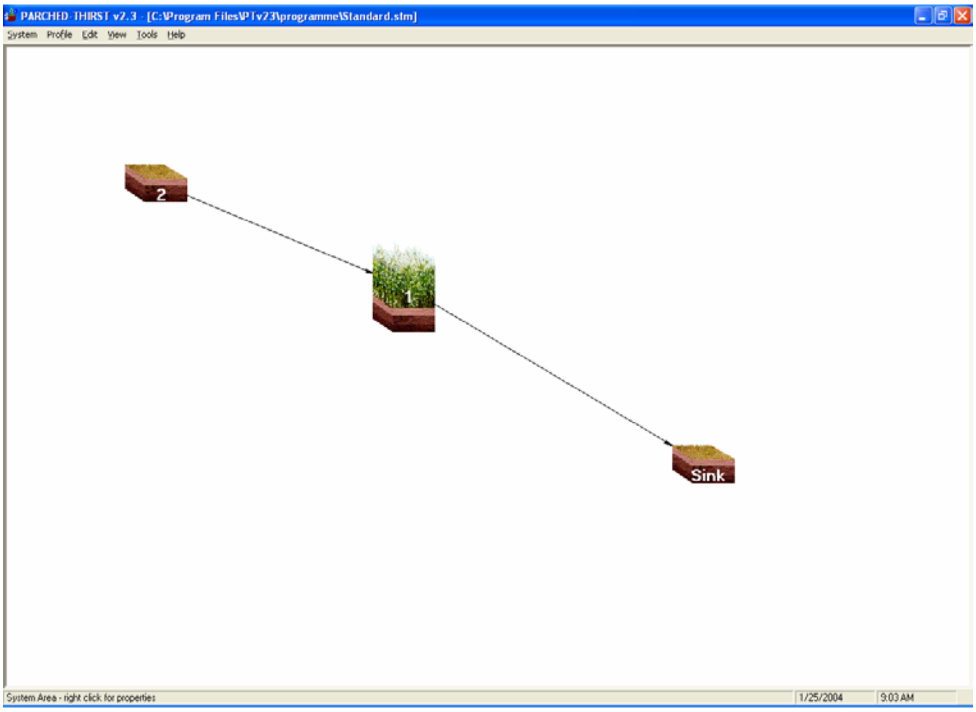


Figure 10: A simple RWH system in which runoff is harvested from Profile 2 (the catchment area) and directed to Profile 1 (the cropped area).

3. The next step is to link the profiles, note that profile 1 is already linked to the sink; therefore we need to link profile two to profile one. Linkage between profiles can be achieved by a click and drag operation from the centre of source profile to the centre of receiving profile Dragging should be done while holding down the left mouse button. Therefore, click on profile 2 and drag the link from the centre of profile 2 to the centre of profile 1. You now have a complete RWH system with two profiles where profile 2 is linked to profile 1, as shown in Figure 2.
4. You now need to specify the properties of each profile in the system. To do this, right click on profile 2 and the pop-up menu will appear, then select *Properties of Profile 2*. A window will appear (as in Figure 3) where you can set crop, weeds, soil properties and soil surface. For this exercise set properties as follows:
   - Crop (select "No Crop"),
   - Weed (leave "Allow Weeds" box empty)
   - Soil properties (leave at current settings)
   - Soil surface (set area as 2ha and slope as 8%; Otherwise leave at current setting)

   Then set properties for profile 1 following the same procedure as follows:
   - Crop (select maize with 44,000 plants density)
   - Weed (leave "Allow Weeds" box empty)
   - Soil Properties (leave at current settings)
   - Soil Surface (tick "Area is bunded" and set height of 20 cm; Set area as 1ha and slope as 3%)

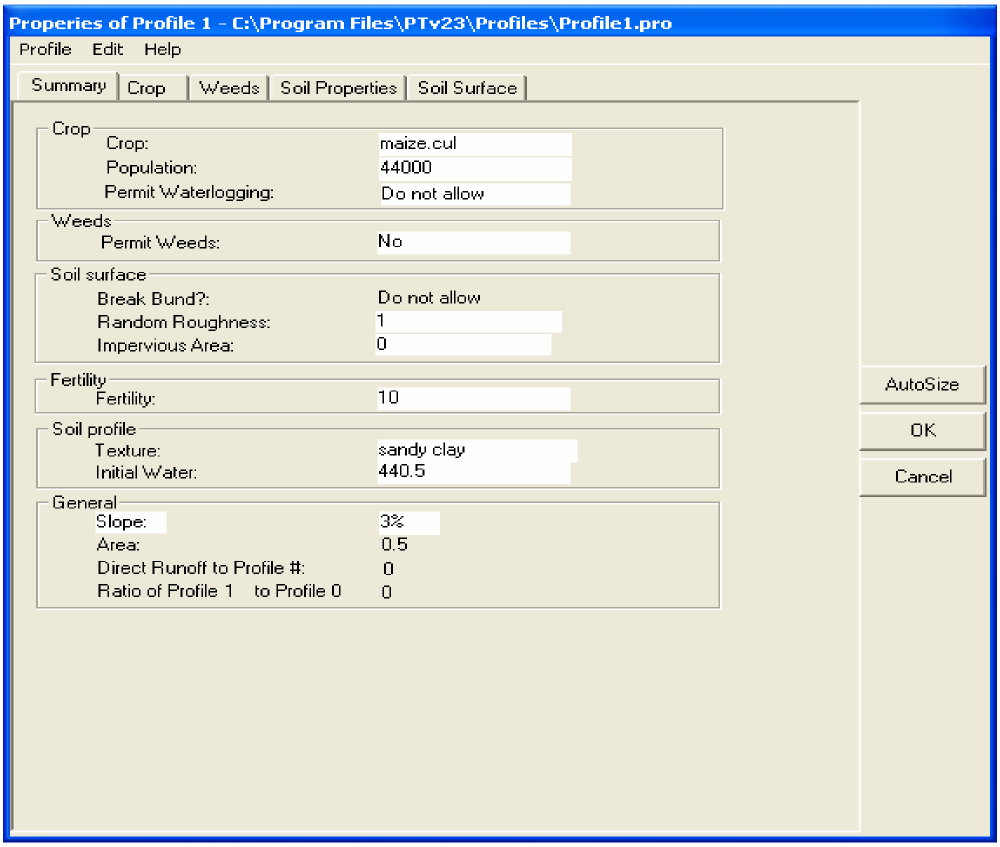


Figure 11: Profile properties window

5. After setting the profile properties, you have to set the system properties. From the System menu click *Properties* and the System Properties window will appear as in Figure 4.

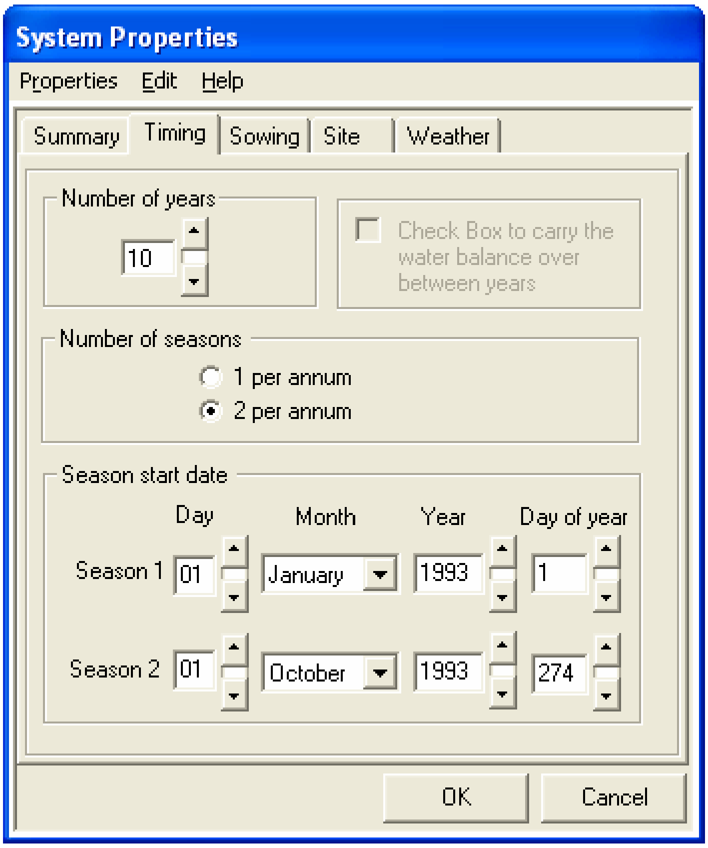


Figure 12: System Properties Window

Set the following properties:

- Timing (Number of years you want to simulate and your start date for seasons) Number of Years (5 Years), Start date Season 1: 1 Feb 1980, and Second Season 1 October 1980.
- Sowing (Select your sowing criteria, this can be defined or predicted) Check predicted button to select predicted criteria where the model will sow after meeting sowing criteria.
- Site Characteristics (Specify site location and latitude): Location is Same and Latitude is -4 Degrees (-/+ means South/North of Equator)
- Weather (specify the weather input data location and type of the data). Location of the data is at C:\….\Weather\Generated*.Wea. Click on Same80.Wea. The model will use the data from 1980 for Same Station to run the simulation. Type of data select Standard (i.e. CSV files).

6. Systems can be saved and then opened again later using the System menu. From the system menu click *save as*.., and enter SAME.stm. By default, a system is saved with a ".stm" extension in the "\PTv2\systems\" directory. When a system is saved, all the profiles which make up the system are also saved at \...\PTv2\Profiles\.*.pro. So you will be asked to save the profile, give the name to the profile, as you prompted (give a name which you will remember). Note that the system file does not contain the properties of each profile, rather it contains a pointer to the location of the profile file. Thus, if a profile file is changed, so too will any system which uses that profile file.

Running a rainwater harvesting simulation

1. You can now run the simulation of this system by a click on the *Run* button in the System menu. The first thing you will be asked is where to save your simulation results. Give the file name, which you will remember and have a look on the path where your output is going to be saved, then Click OK. You will be asked whether you want to see Simulation Runtime Graphics. Click Yes and select the speed of simulation as Medium. Then Click OK. The simulation run time graphics will be as shown in Figure 5.

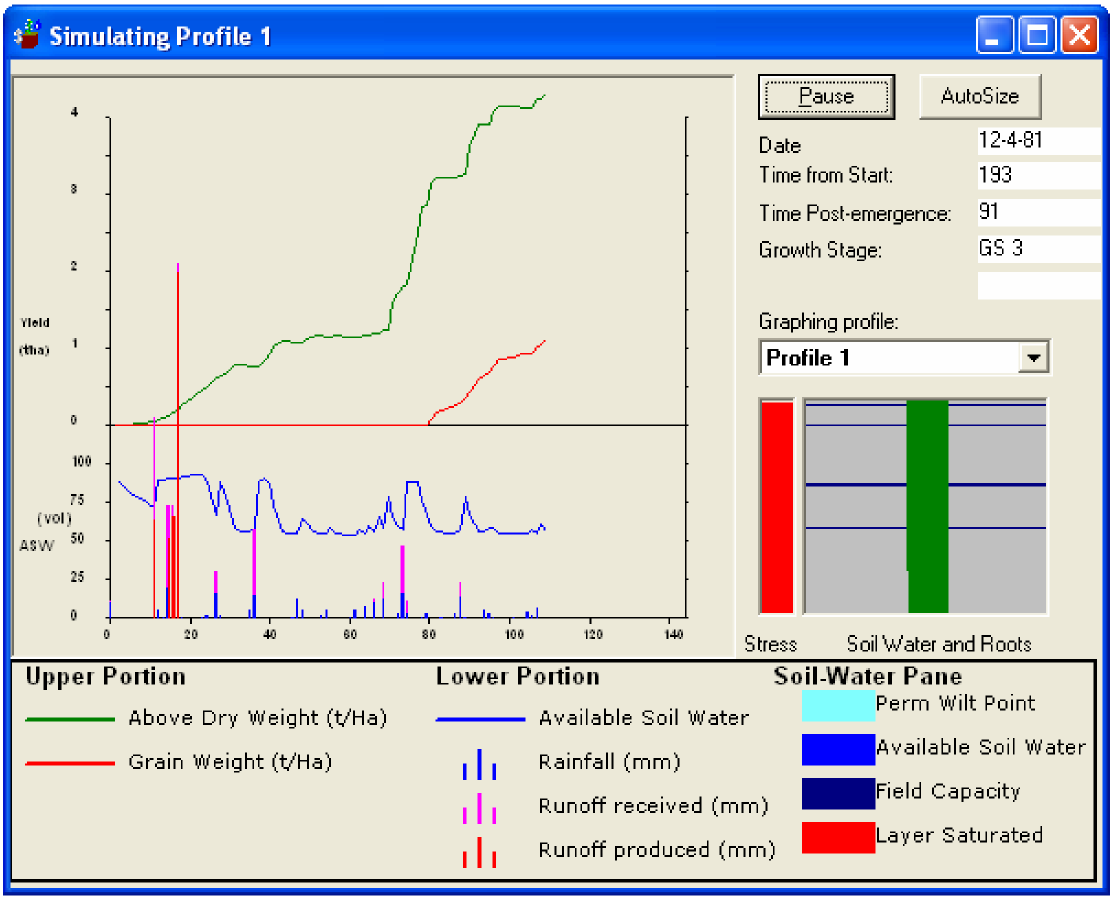


Figure 13: Simulation Run-time Graphics Window

2. You will be told that you have simulated results for the number of years you have specified. The summary simulation of the output is as shown in Figure 6. This can be viewed through Tools menu.

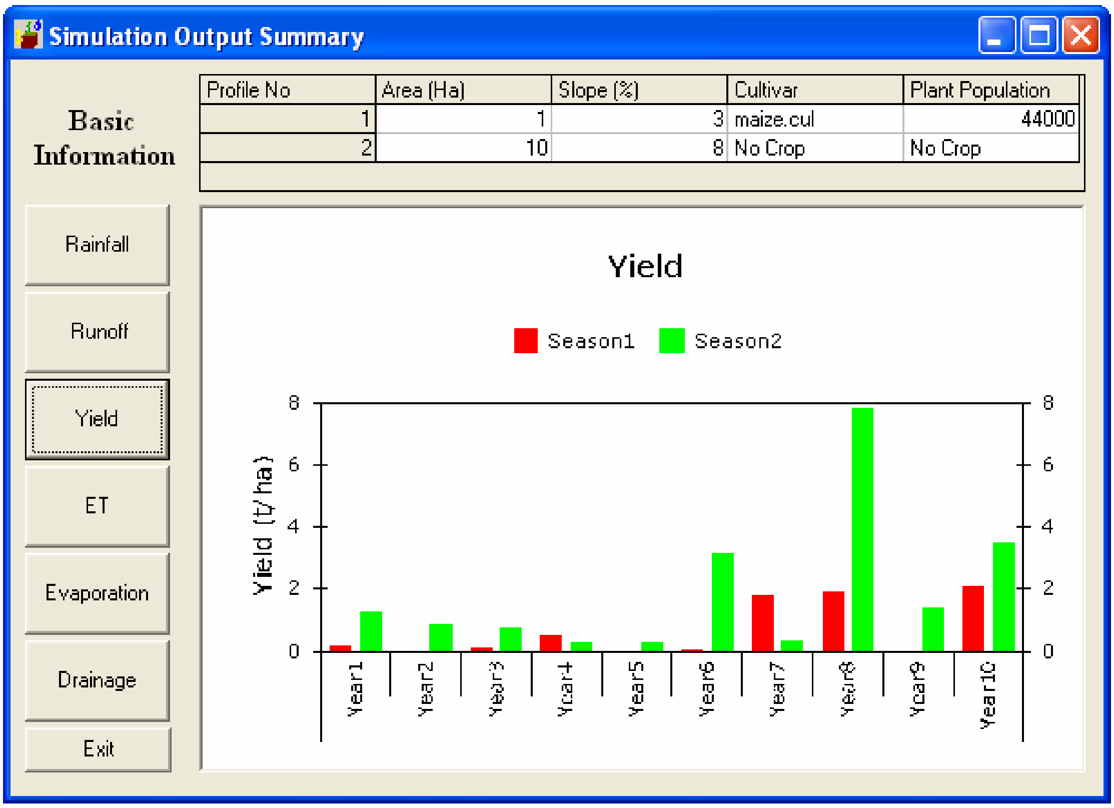


Figure 14: Example of Graphical Output from Simulation

4.2 Tutorial 2:

Using the climatic generator

4.2.1 Starting the Model to access the climatic generator

i. Double-click on the PTv2.3 model icon or from the Start task bar go to *Programs* and from the program list click PTv2.3. The PTv2.3 main window and Welcome screen will appear.

ii. On the Welcome screen click on the icon *experienced user* to be taken straight to the main system window of PTv2.3.

iii. Click on the word *Tools* on the menu bar. From the menu choose *Climate Generator* and the Climate Generator window will appear as in Figure 1.

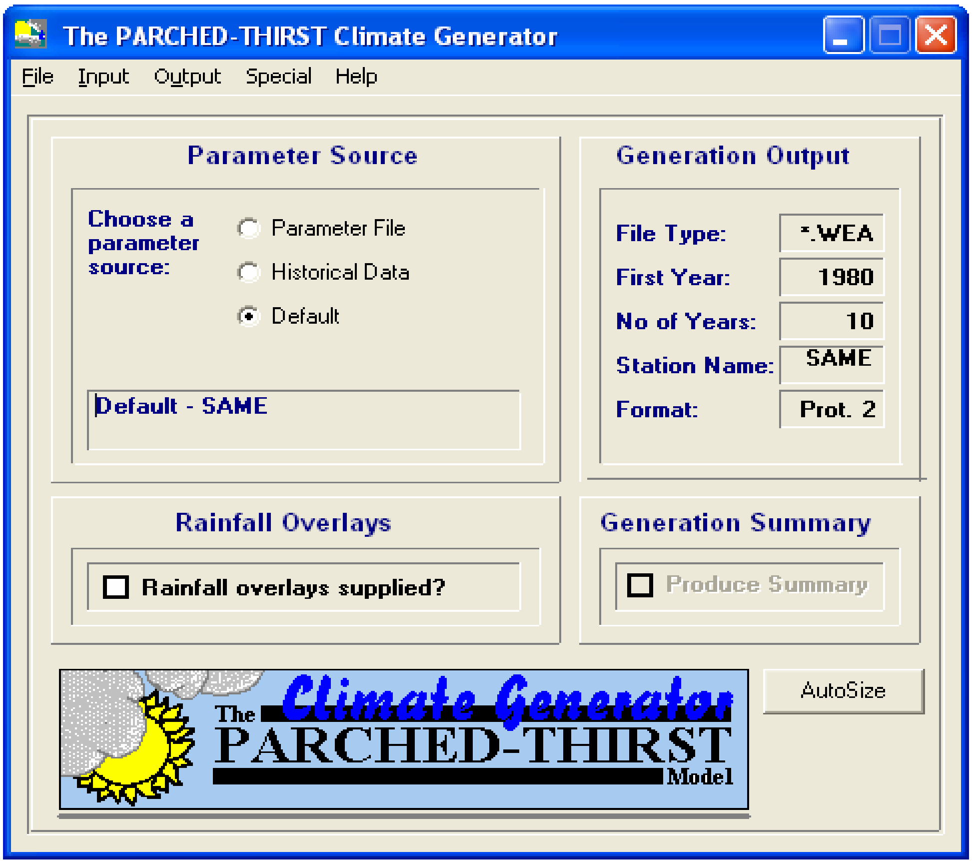


Figure 15: Climate Generator Main Window

4.2.2 Generating climatic data (using .GEP files)

i. On the Climate Generator menu, click on the word *Input* and a drop-down menu will appear.

ii. Click the *Parameter File* item on the drop down menu to indicate that the parameter source will be our Parameter Files. The Parameter File Window will then appear as shown in Figure 16.

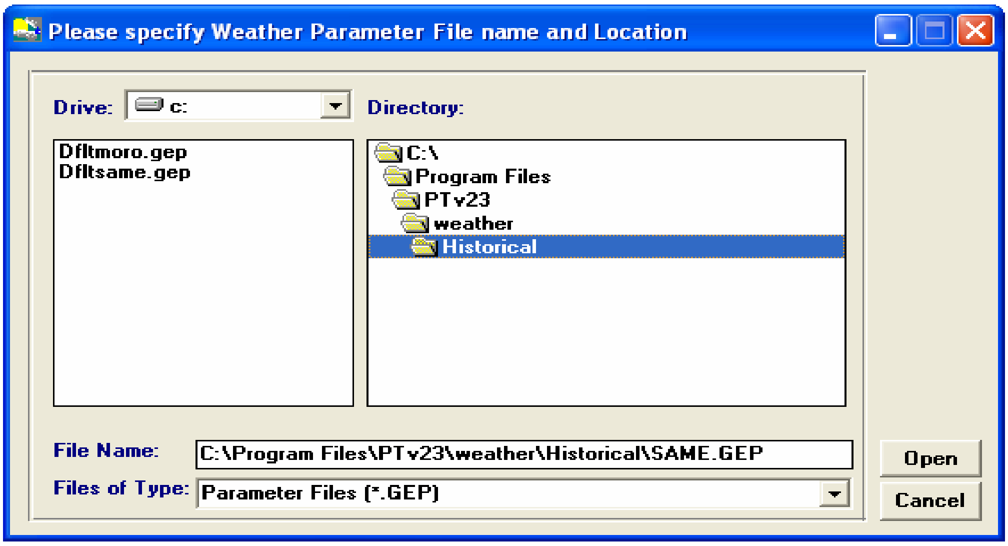


Figure 16: Parameter file window

iii. From the Parameter File window browse to the Weather folder and Historical sub- folder and select the file dfltsame.GEP. This means we will use the Same parameter file to generate the 30 years of data from Same station.

iv. Click *Open* and return to the Climate Generator window. We have indicated the source of the data. Now we need to tell the programme how much data to generate and what filenames to store it in.

v. On the Climate Generator menu, select *Output* and in the drop-down menu click on *Files..*,.

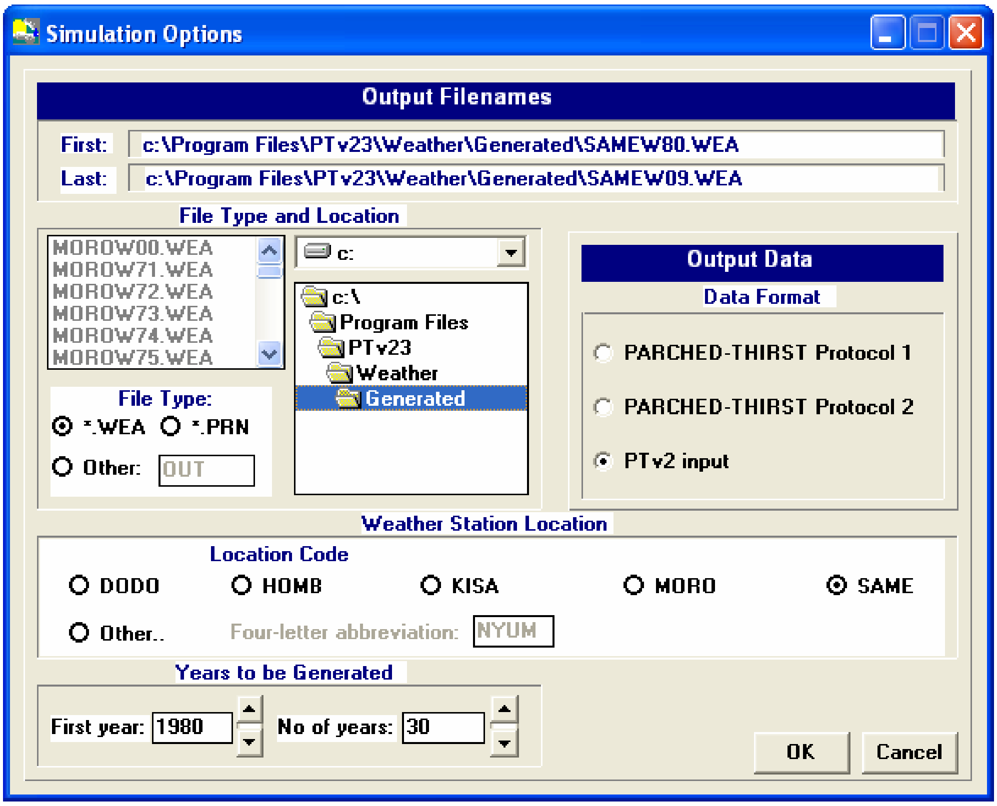


Figure 17: Climate Generator output window

vi. Select output file type with extension .WEA and save it in \Weather\Generated\.

vii. For output format select PTv2.3 input, and check the Same button.

viii. Under *Years to be Generated*, change First Year to 1980 and the No of Years to 30. The simulation output window will appear as in Figure 17.

ix. Click OK to return to the Climate Generator window. Now we can run the Climate Generator to produce the data.

x. Click on the word *File* on the Menu bar and select RUN from the drop-down menu.

A status box indicates progress, first with extracting the statistical properties of the Parameter Files and then, with generating the new climatic data. At the end of the generation, you will be asked whether you wish to generate more data. Answer No and you will be returned to the Main Window.

We have now generated 30 years data for Same Station, which we can use later. For Morogoro station, follow the steps as in Same above, except at step iii, instead of SAME.GEP select MORO .GEP, and at Step vii, check Morogoro Station. Following that we will have generated 30 years of Morogoro data.

4.2.3 Generating Climate Data (using .DAT Files)

i. On the Climate Generator menu, click on the word *Input* and a menu will appear.

ii. Click the *Historical* item to indicate that the parameter source will be our historical data. The Historical Data window will appear as in Figure 18.

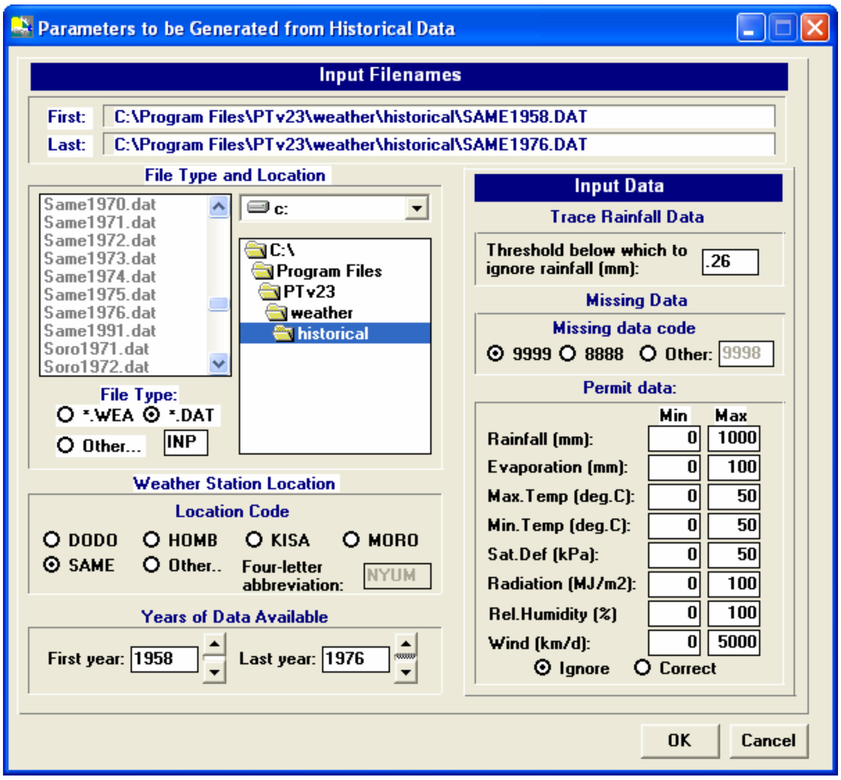


Figure 18:Climatic Generator input window: Using Historical *.DAT Files

iii. Under *File Type*, choose the option button labelled *.DAT to indicate that our file names end in .DAT. A list of files of this type will appear in the left hand box.

iv. Under *Weather Station Location*, choose the option button labelled MORO to indicate that our data are from Morogoro meteorological station.

v. Under *Years of Data Available*, click on the arrows to change the First year to 1972 and the Last year to 1982. The names of the first and last files should now be shown in blue in the two boxes at the top of the window.

vi. Click OK to return to the Climate Generator window.

We have indicated the source of the data. Now we need to tell the programme how much data to generate and what filenames to store it in.

vii. On the Climate Generator window menu select the word *Output*

viii. On the output sub menu click on *Files..,* Simulation Options window will appear

ix. Select output file type with extension .WEA and saved it in \Weather\Generated\.

x. For output format select *PTv2 Input*, and check the Moro button.

xi. Under *Years to be generated,* change First Year to 1983 and the No of Years to 30. This means we will generate 30 years of data starting from 1980. The climatic generator window will look as shown in figure 5

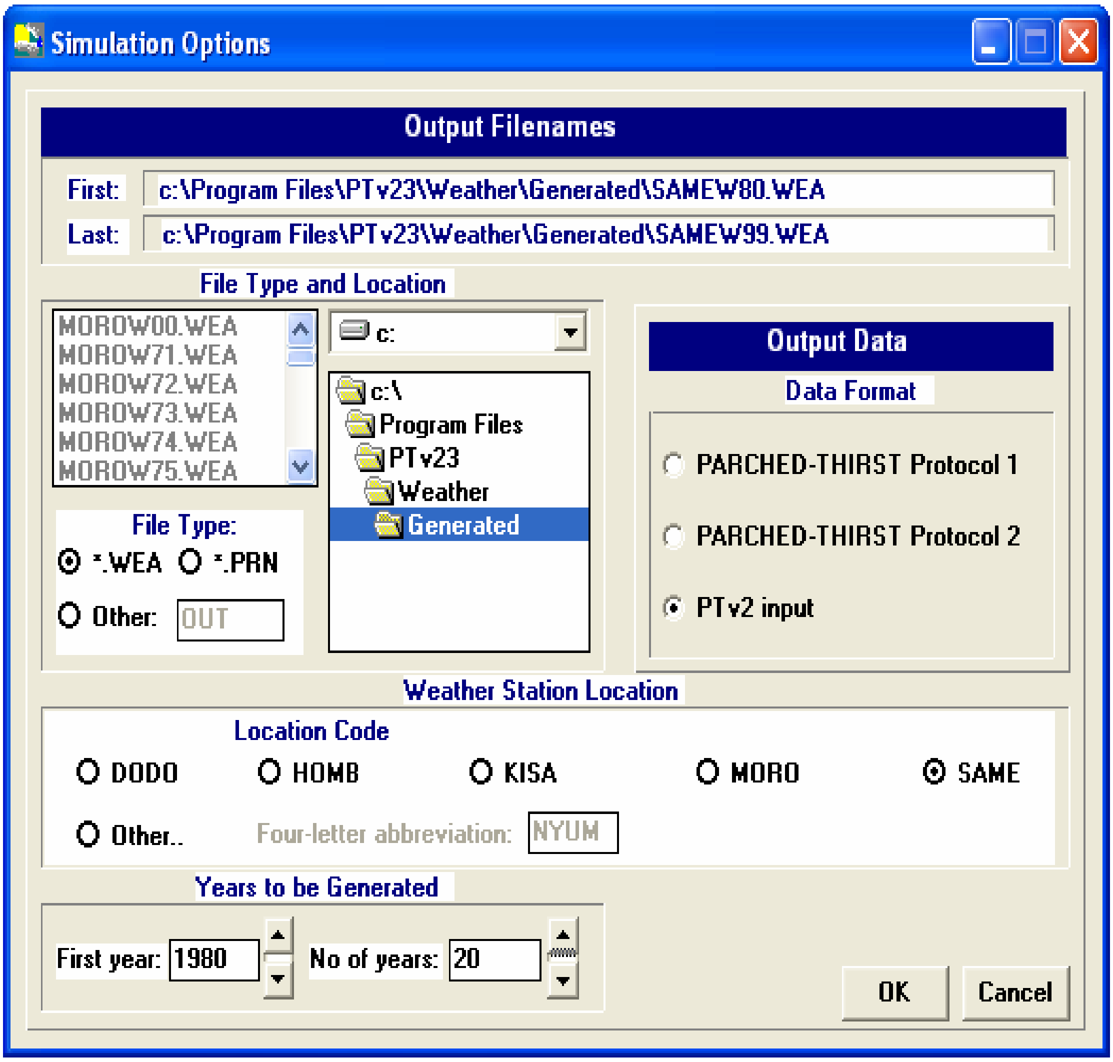


Figure 19:Climatic Generator output window using Historical *.DAT Files

xii. Click OK to return to the Climate Generator window.

xiii. Enter the latitude and longitudes of Same stations as follows

-Select output and then click evaporation

-The evaporation data window will appear

-Enter the latitude and elevation for Morogoro (Lat –6 and elevation 600) .

-Click ok

Now we can run the Climate Generator to produce the data. However, it would be nice to see a comparison between the data we have input and the data the model is going to generate.

xiv. Under the words GENERATION SUMMARY, click on the check box to Produce Summary.

xv. Finally, go to the File drop-down menu and select RUN.

A status box indicates progress, first with extracting the statistical properties of
the historical data and then, with generating the new climatic data. At the end of the simulation, you will be asked whether you wish to see a comparison of observed and generated data. Answer Yes and the Generation Summary Window will appear. By clicking on the buttons to the right, and the option buttons at the bottom of the window, you can see a comparison of various aspects of the historical and simulated data. When you have finished press Exit. You will then be asked whether you wish to generate more data. Answer No and you will be returned to the Main Window.

We have now generated 30 years data for Same Station, we can then use these generated data in all the subsequent simulation. Note that the generated data are all stored in the directory…\Weather\Generated*.Wea.

For Other stations, follow the identical procedure, except that at step iv, select location such as ELDO, SAME or SORO (instead of MORO) if the station is not in default select others and type its four letter name and at step vi, specify First Year and Last Year depending on the available data.

4.2.4 *Generating agro-meteorological data around supplied, historical rainfall data overlays*

Rainfall Overlays

The **Rainfall overlays supplied? *check box*** allows the user to toggle on and off the facility to generate appropriate agro meteorological data around supplied, historical rainfall data overlays. If the box is checked, the Climate Generator will search the \weather\historical subdirectory of the main programme directory (default ..\PTv2\weather\historical) for a rainfall overlay file for each year to be generated (specified in the Output Weather Window). These files must be named with the same stem as the weather files to be generated but with the file extension ".RAI". Each file should contain 365 or 366 (depending upon whether the year is a leap year or not) rows of data in ASCII text format with no gaps within the data. Missing data is not allowed in rainfall overlay files and therefore should be replaced either with a 0 or with rainfall 'borrowed' from the same period of another year at that site.

Example:

A user wishes to generate 30 years of **PARCHED-THIRST Model** input weather data for Soroti, starting from 1971. The user has 10 years of full agro meteorological data (SORO1991.DAT to SORO2000.DAT) and 20 years of rainfall only data (SORO1971.DAT to SORO1990.DAT).

First of all the weather data and rainfall overlay files should be placed in the \weather\historical subdirectory of the main programme directory. The user should then start the **Climate Generator** to specify the years of data to be parameterized.

The next step is to rename the 20 years of rainfall only data to SORO1971.RAI, SORO1972.RAI... SORO1990.RAI.

Making.RAI files

To generate other weather parameters using rainfall overlays we need to make .RAI files from the available .DAT files using the following procedure.

Open the .DAT files in excel. The screen should be as shown in figure 20

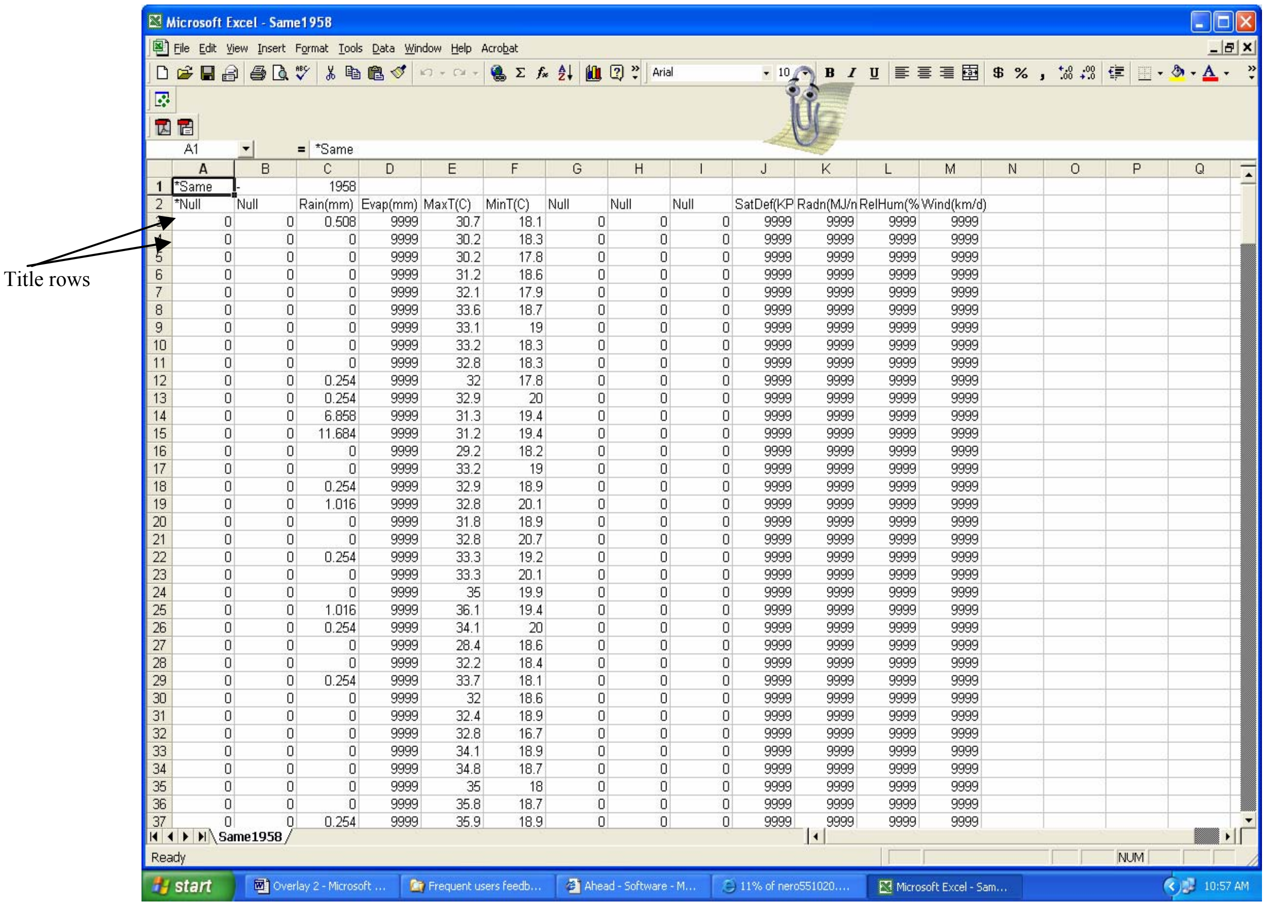


Figure 20: DAT data opened in excel worksheet

i. Delete all weather parameter columns except rainfall.

ii. Delete the title rows. This will make the file to be as shown in figure 21

iii. Save the file as a text file. Note the folder where the file is saved.

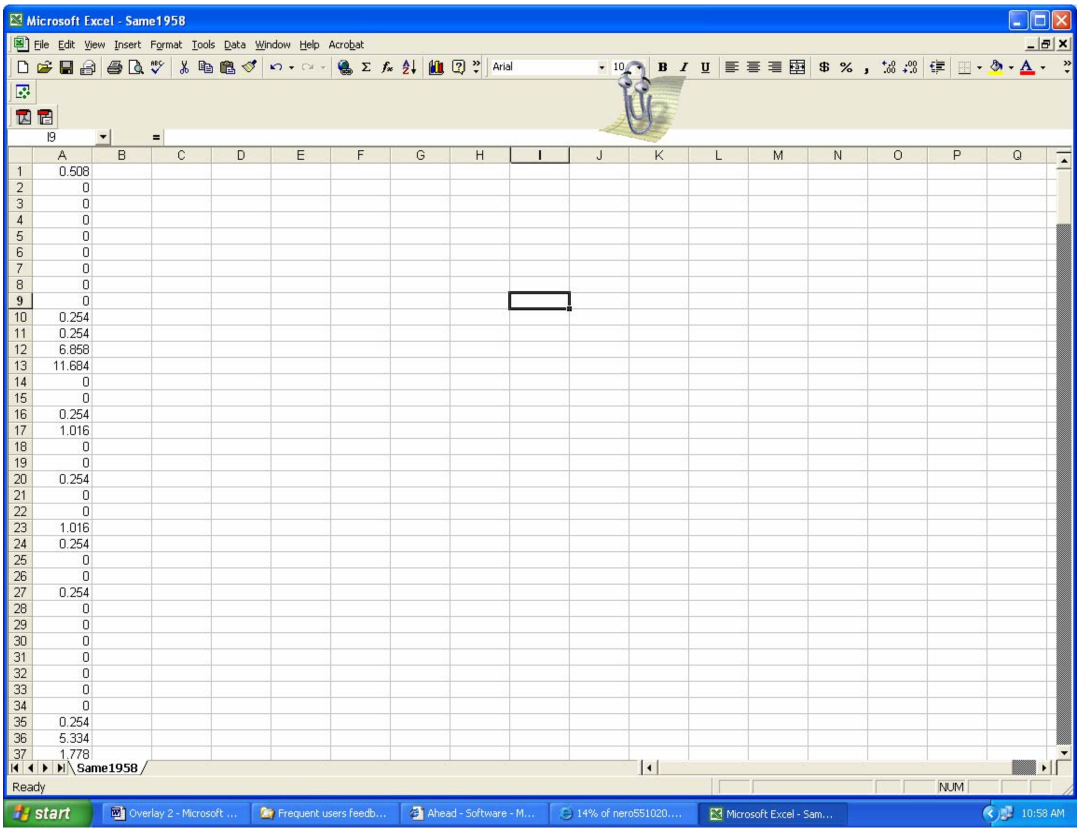


Figure 21: Excel data sheet for .RAI transformation

Open the file with notepad.

Then save the file as .RAI by selecting all files in the file type and typing SORO1971.RAI in the file name and then click save. See Figure 22.

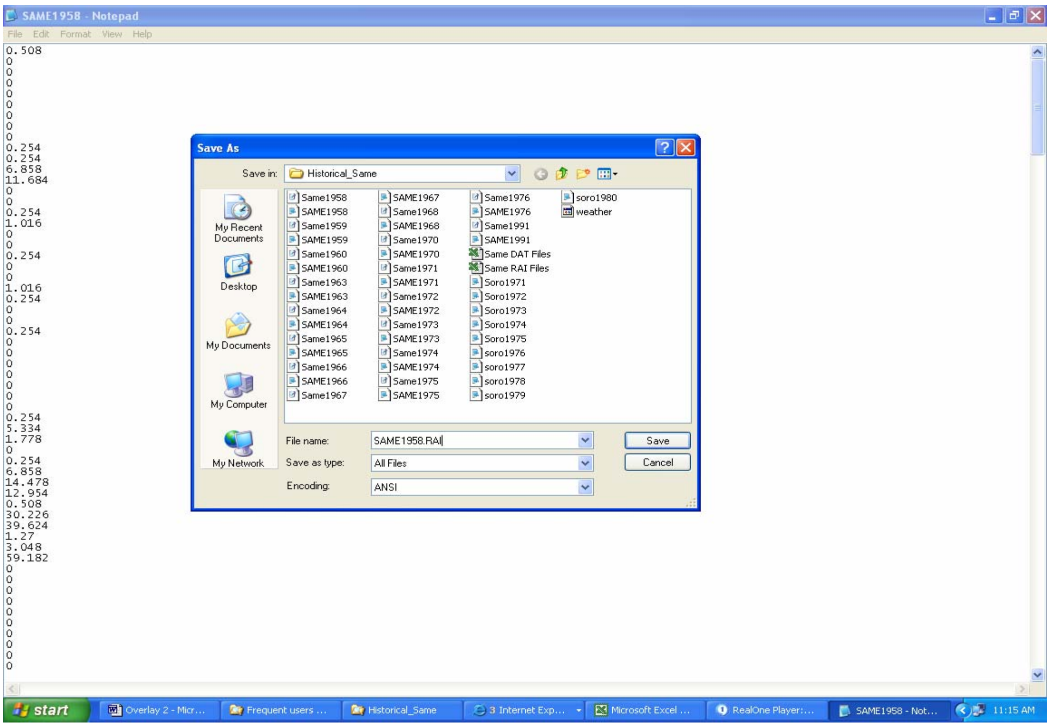


Figure 22: Notepad window view when converting files to .RAI

Repeat the procedure for the remaining files and make sure they are in the folder…PTv2\weather\historical.

To add the other agro meteorological data to the 20 years of rainfall-only data, the user then runs the model with ..PTv2\weather\historical\SOROWEA.GEP as the weather parameter file, the **Rainfall overlays supplied? *check box*** checked (Figure 23) and, in the Output Weather Window, the output files set to SORO1971.WEA to SORO2000.WEA The porcedure below should be followed

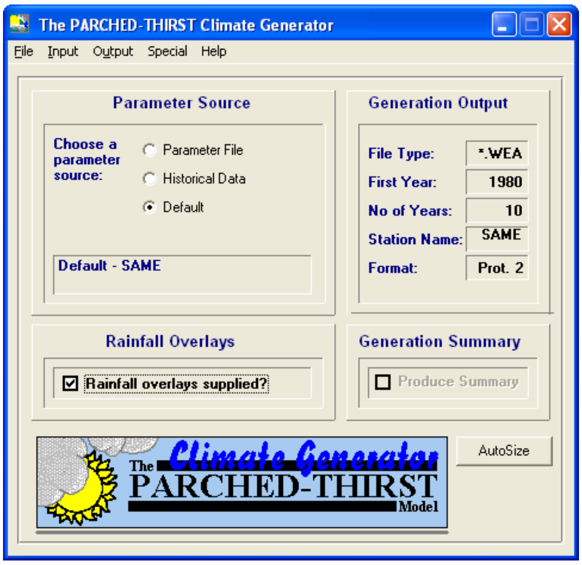


Figure 23: Climatic generator with Rainfall overlays supplied? *check box* checked

Procedure for genarating WEA Files from rainfall overlays

i. Put the .RAI and .DAT data files for SORO 1971 to 2000 in the C\Programe files\ PTv2.3\weather\historical
ii. Open the PTv2.3 programme
iii. Click the tool option in the main window.
iv. Click the climatic generator option

-The Climatic Generator main window will appear Figure 9.

v. Click output on the menu bar.
vi. Click create parameter files.

The weather parameter files window will appear.

vii. On the weather parameter file name select C\Programe files\ PTv2.3\weather\Generated\ …. And at the file name type SORO.GEP. The file will then read C\Programe files\PTv2.3\weather\Generated\SORO.GEP (Figure 24)

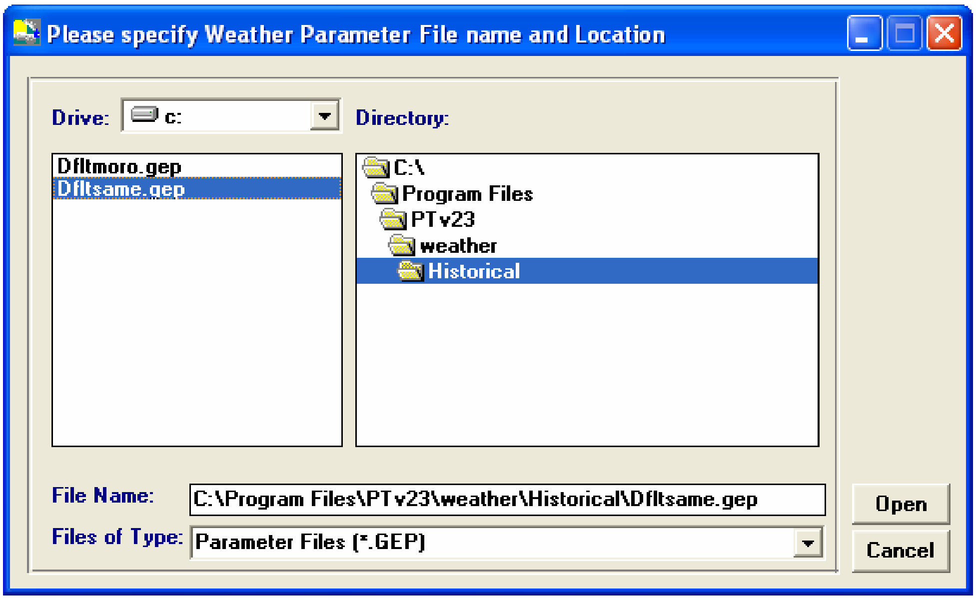


Figure 24: Weather parameter file window

viii. Click ok

-The input files name window will appear.

-Select ..weather\Historical on the file location

-Select .DAT on the file type

-Select others on the weather station location and type SORO

-On years of data available select 1992 for the first year and 2000 for the last year

The window will look as shown in Figure 12

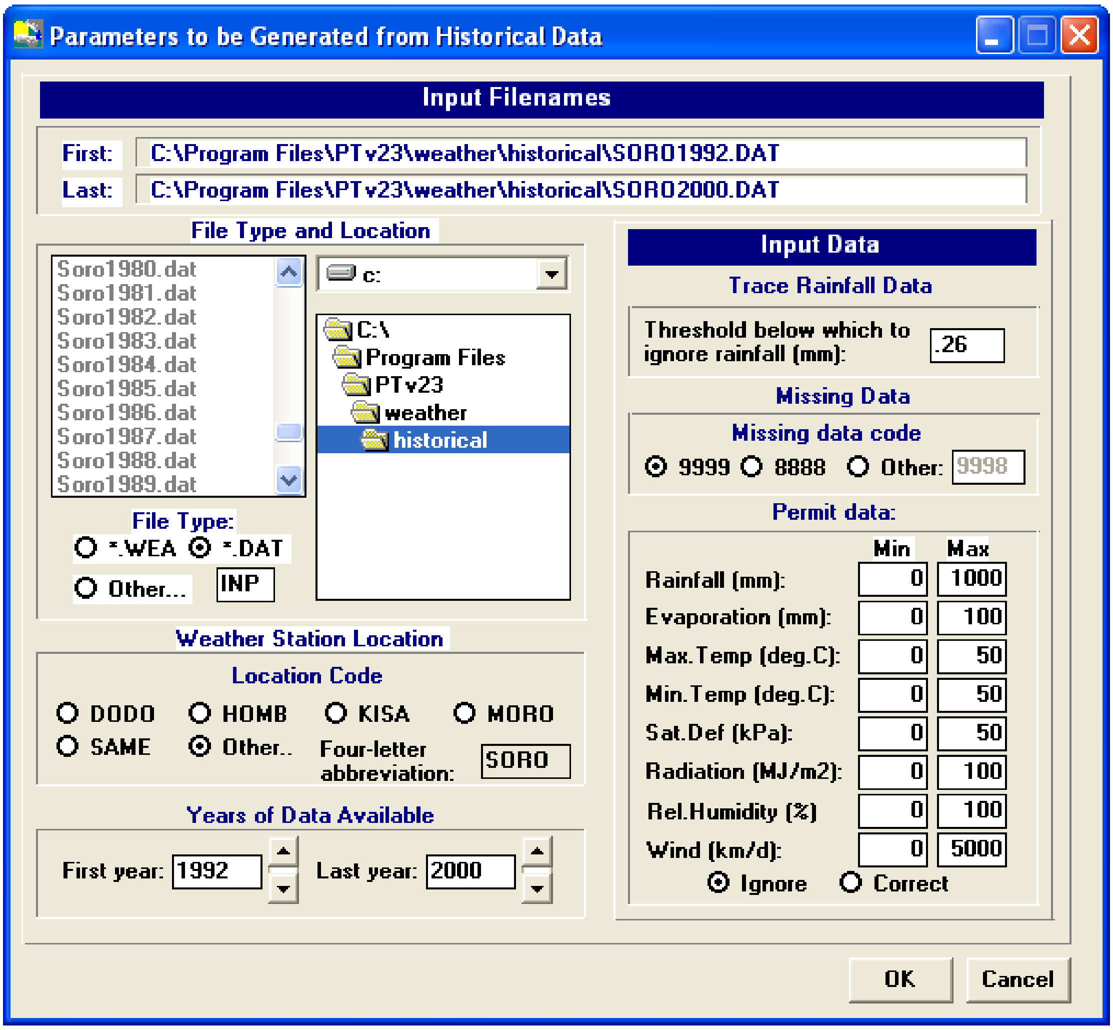


Figure 25: Input window

ix. Click ok

-The model will run and the parameter file will be saved as C\Programe files\PTv2.3\Weather\Soro.GEP. This will be indicated in the model status (Fig …)

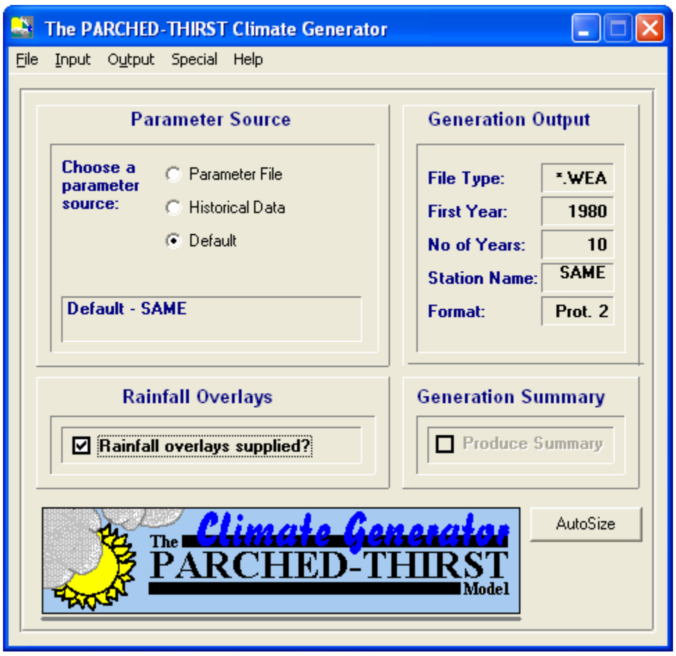


Figure 26: Parameter files summary information

x. Click ok

- This will take you back to climatic generator window

xi. Click the output option

-The output file options window will appear.

-On the location code select others and type SORO

-On years to be generated, type 1971 at the first year and 30 at the number of years.

-On file type select .WEA.

-On file location select .C\Programme Files\PTv2.3\weather\generated

-On output data format select PTv2.

The window will look as shown in Figure 27

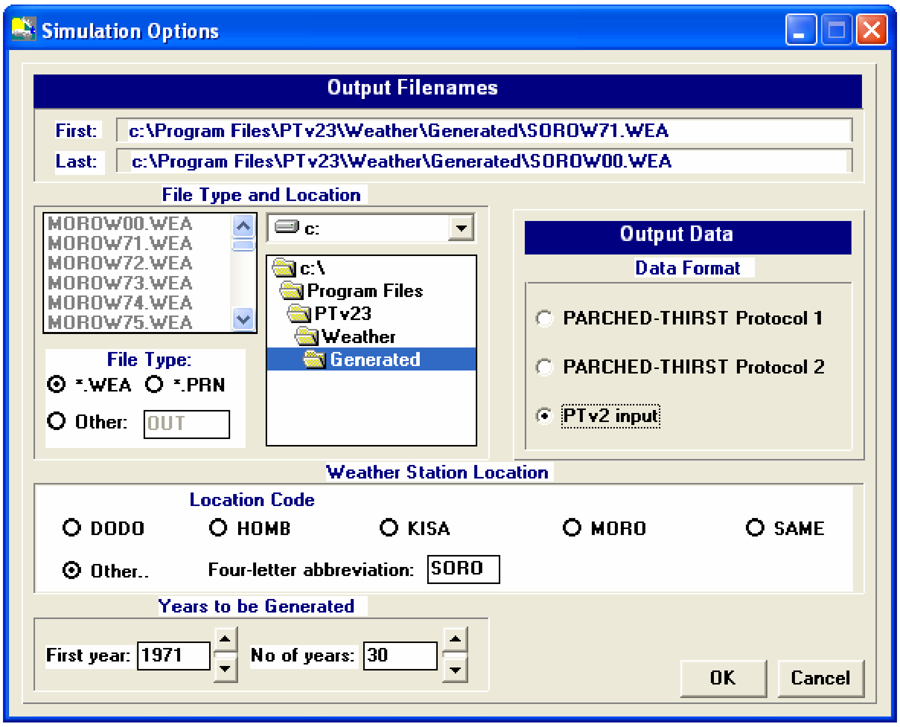


Figure 27:Output File window

xii. Click ok

This will take you back to climatic generator window

xiii. Check the Rainfall Overlays Supplied Check Box

xiv. Click file

xv. Click Run

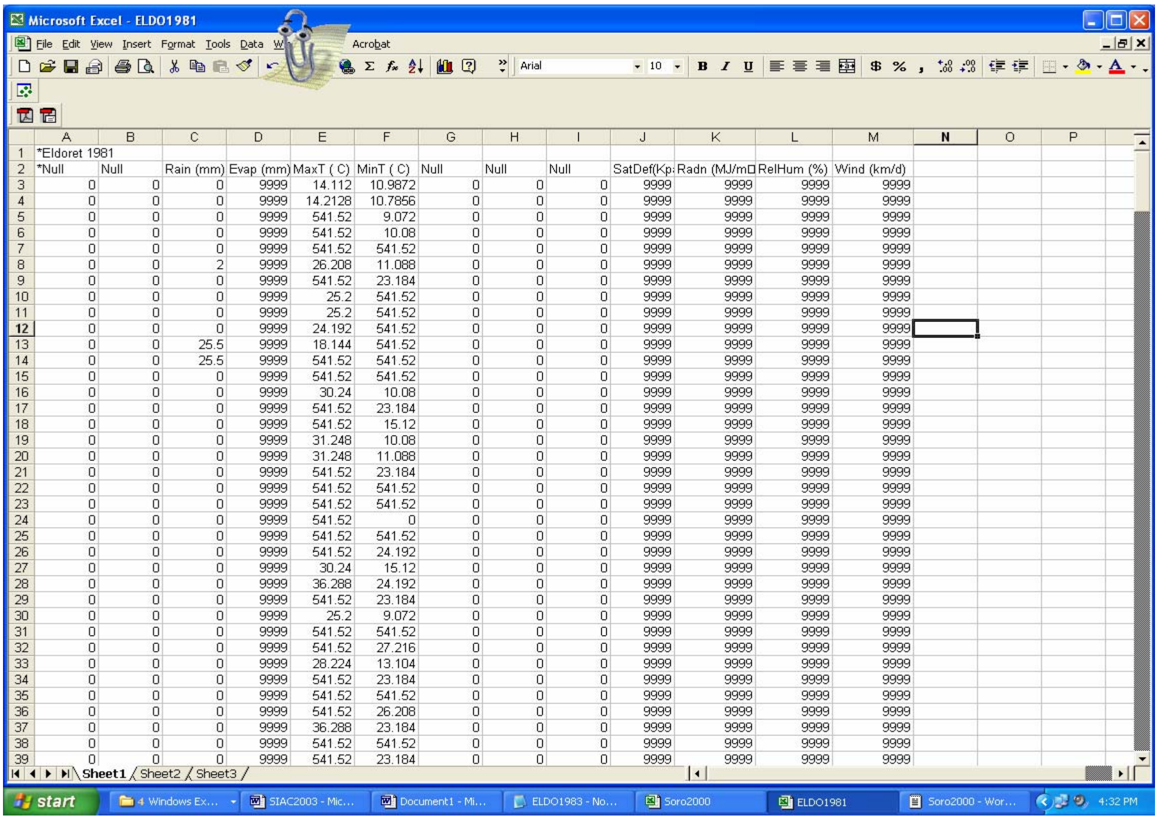
The model will run and the number of generated years will be shown.

4.2.5 *Managing raw data from other countries/stations*

A user wants to use 15 years raw data from Eldoret weather station Kenya to generate long-term weather data for the station. The user wants the data to be in compatible format to PT v2.3. To achieve the user have to follow the following procedures.

i. Arrange the respective data in excel to be in the PT workable format

The data will be as shown in figure 28



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	*Eldoret 1981												
2	*Null	Null	Rain (mm)	Evap (mm)	MaxT (C)	MinT (C)	Null	Null	Null	SatDef(Kp	Radn (MJ/m	RelHum (%)	Wind (km/d)
3	0	0	0	9999	14.112	10.9872	0	0	0	9999	9999	9999	9999
4	0	0	0	9999	14.2128	10.7856	0	0	0	9999	9999	9999	9999
5	0	0	0	9999	541.52	9.072	0	0	0	9999	9999	9999	9999
6	0	0	0	9999	541.52	10.08	0	0	0	9999	9999	9999	9999
7	0	0	0	9999	541.52	541.52	0	0	0	9999	9999	9999	9999
8	0	0	2	9999	26.208	11.088	0	0	0	9999	9999	9999	9999
9	0	0	0	9999	541.52	23.184	0	0	0	9999	9999	9999	9999
10	0	0	0	9999	25.2	541.52	0	0	0	9999	9999	9999	9999
11	0	0	0	9999	25.2	541.52	0	0	0	9999	9999	9999	9999
12	0	0	0	9999	24.192	541.52	0	0	0	9999	9999	9999	9999
13	0	0	25.5	9999	18.144	541.52	0	0	0	9999	9999	9999	9999
14	0	0	25.5	9999	541.52	541.52	0	0	0	9999	9999	9999	9999
15	0	0	0	9999	541.52	541.52	0	0	0	9999	9999	9999	9999
16	0	0	0	9999	30.24	10.08	0	0	0	9999	9999	9999	9999
17	0	0	0	9999	541.52	23.184	0	0	0	9999	9999	9999	9999
18	0	0	0	9999	541.52	15.12	0	0	0	9999	9999	9999	9999
19	0	0	0	9999	31.248	10.08	0	0	0	9999	9999	9999	9999
20	0	0	0	9999	31.248	11.088	0	0	0	9999	9999	9999	9999
21	0	0	0	9999	541.52	23.184	0	0	0	9999	9999	9999	9999
22	0	0	0	9999	541.52	541.52	0	0	0	9999	9999	9999	9999
23	0	0	0	9999	541.52	541.52	0	0	0	9999	9999	9999	9999
24	0	0	0	9999	541.52	0	0	0	0	9999	9999	9999	9999
25	0	0	0	9999	541.52	541.52	0	0	0	9999	9999	9999	9999
26	0	0	0	9999	541.52	24.192	0	0	0	9999	9999	9999	9999
27	0	0	0	9999	30.24	15.12	0	0	0	9999	9999	9999	9999
28	0	0	0	9999	36.288	24.192	0	0	0	9999	9999	9999	9999
29	0	0	0	9999	541.52	23.184	0	0	0	9999	9999	9999	9999
30	0	0	0	9999	25.2	9.072	0	0	0	9999	9999	9999	9999
31	0	0	0	9999	541.52	541.52	0	0	0	9999	9999	9999	9999
32	0	0	0	9999	541.52	27.216	0	0	0	9999	9999	9999	9999
33	0	0	0	9999	28.224	13.104	0	0	0	9999	9999	9999	9999
34	0	0	0	9999	541.52	23.184	0	0	0	9999	9999	9999	9999
35	0	0	0	9999	541.52	541.52	0	0	0	9999	9999	9999	9999
36	0	0	0	9999	541.52	26.208	0	0	0	9999	9999	9999	9999
37	0	0	0	9999	36.288	23.184	0	0	0	9999	9999	9999	9999
38	0	0	0	9999	541.52	541.52	0	0	0	9999	9999	9999	9999
39	0	0	0	9999	541.52	23.184	0	0	0	9999	9999	9999	9999

Figure 28: File data arrangement in xls format

ii. Change the xls data format to DAT data format

To achieve this, first change the xls format to text format as follows

-Click the file option and select save as

-On the save as type select Text

-On the file name leave the ELDO1981

The window will be as shown in figure 30

-Click ok

-Accept all options and do not accept changes to. text.

iii. Open the ELDO1981.text with notepad

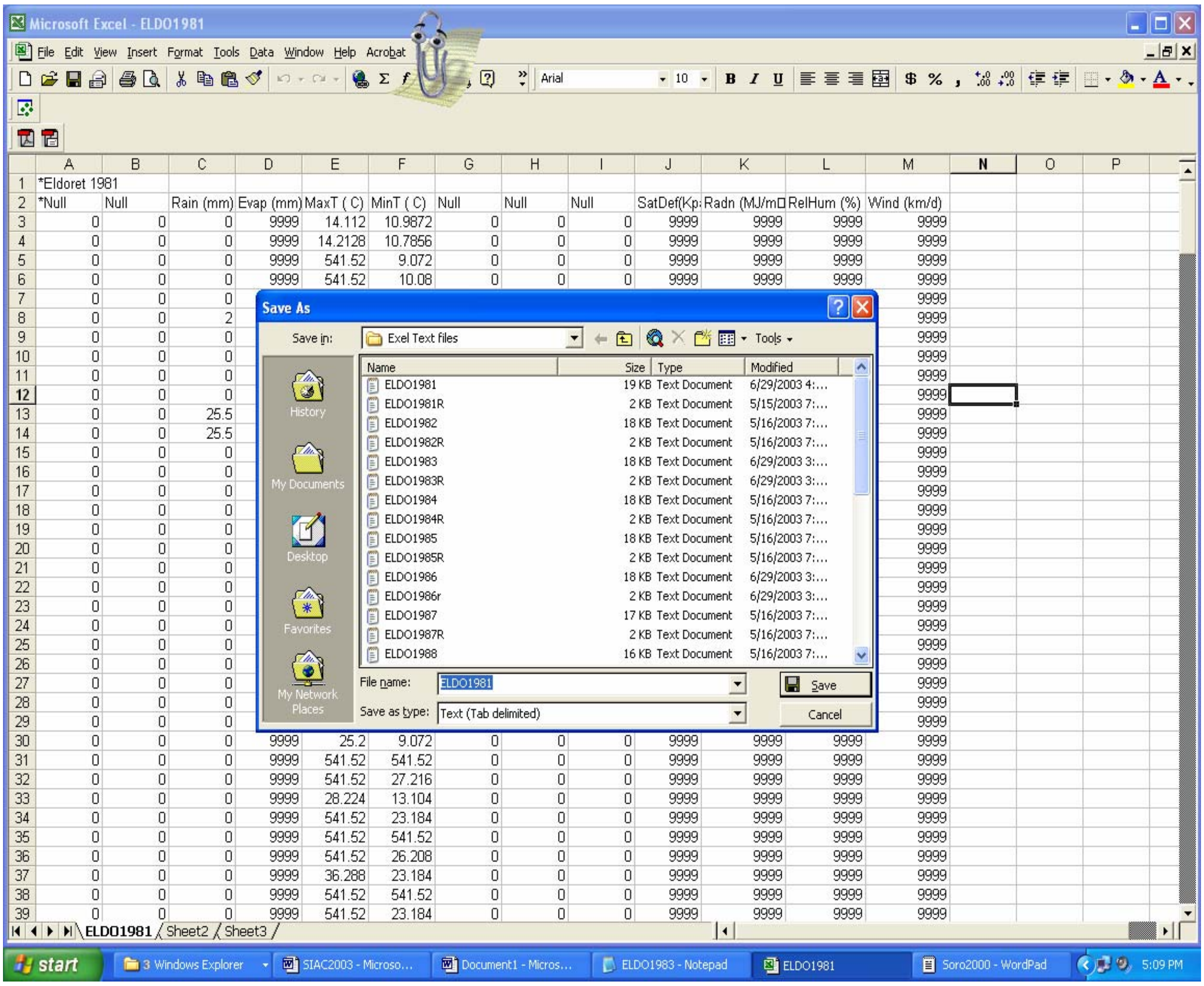


Figure 29: Saving data in Text Format

iv. On the file menu select save as

v. On the file name ELDO1981.DAT

vi. On the save as type select all files (the window will look as in Figure 31)

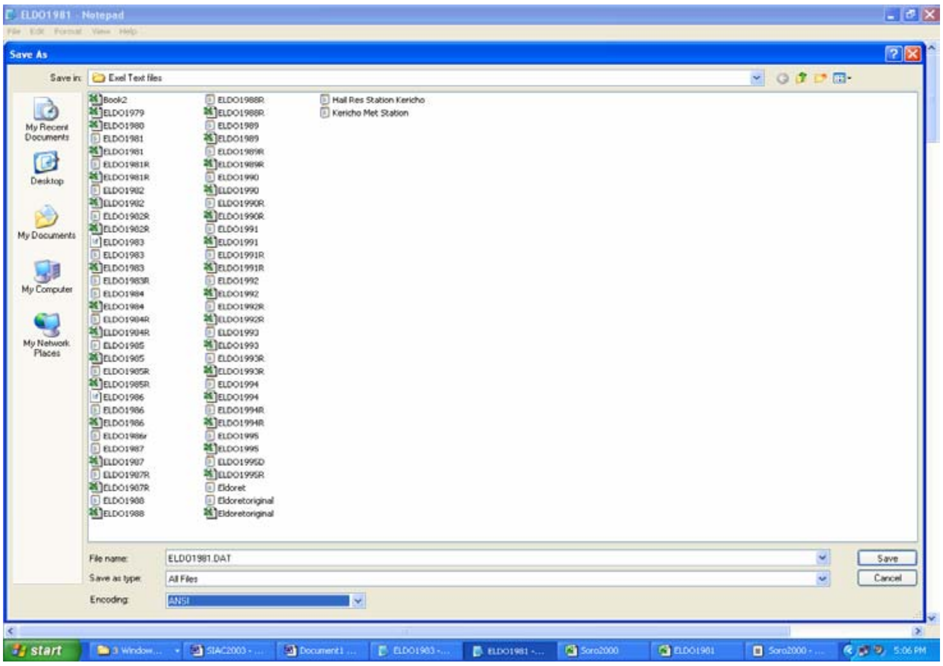


Figure 30: Saving data in .DAT format

vii. Click save and the file will now be saved in .DAT format.

viii. Follow the same step to make DAT files for ELDO1982 to ELDO 1995

ix. Save/copy the files to C\Programme files\PTv2.3\weather\Historical

The data are now ready to be used as Historical data input in PT v2.3 during generation of weather data.

4.3 PT Application in Investigating the Influence of Crop management

4.3.1 *Assessment* of: - Effect of planting date

Semi-arid areas are characterised by low and erratic rainfall with variable start date and duration for the growing season. Every season farmers need to decide on when to plant depending on the real time situation. A farmer's decision to plant is based upon a large number of factors which include the availability of labour, seeds, the perceived moisture status of the soil, the perceived likelihood of continued rains, knowledge of historical climate pattern, etc. As well as allowing the user to specify a planting date, The PT-model attempts to simulate the farmers planting decision in four ways:

1. The amount of available water in the soil,
2. The number of preceding rainy days (semi-arid rainfall tends to occur in 'clumps' and therefore the wet days is always followed by another wet day),
3. A date before which planting will not occur (corresponding to the knowledge of when the rainy season normally starts),
4. The maximum number of days of which farmer is prepared to wait before planting at any risk (corresponding to concern about latest acceptable harvest date).

Traditionally, determining the optimum planting criteria required many years of experiments at site with a wide range of climates. PT-Model can help you to test different planting strategies for long runs of climate data to investigate the probability of achieving a required yield.

A reasonably long series of weather data is important for this exercise, as the response of the planting strategy should be tested over a wide range of conditions as possible. The Climatic Generator can be used to generate the required amount of data.

Example

Since we have exercised on how to create a system, in this tutorial, create a system with the settings as shown in (fig 32) and set profile settings as Shown in fig (33)

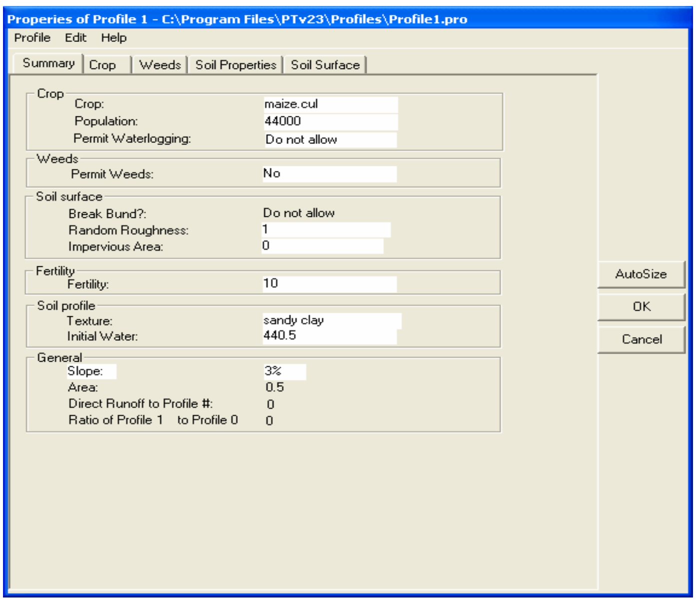


Figure 31: Pt model profile property window

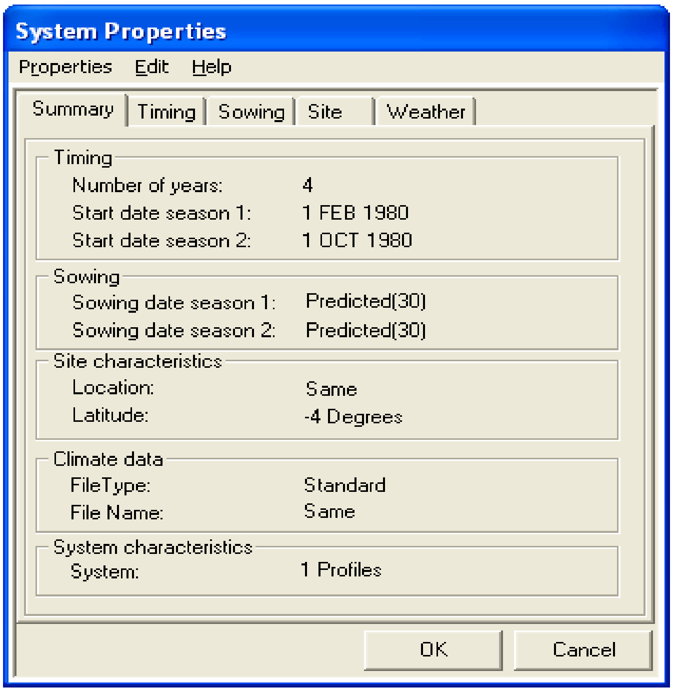


Figure 32: Pt model system property window

Save the system as SAMEPREDICTED. stm this is a rain fed system where in both rainy season the planting date will be predicted by the model The rainy seasons are considered to start on the same day each year – 1st October (Vuli season) and 1st February (Masika season).

Then, follow the steps below to run different planting dates simulation.

1. Run the simulation where planting dates are predicted by the model. You will be asked to save your simulation output before running of simulation, save as SAMEPREDICTED.cvs and then save the simulation daily output as SAMEPREDICTEDDAILY.cvs.
2. Follow all instructions as they appear on the screen and select to see simulation run time garphics.
3. Open again the system SAMEPREDICTED. Stm and change the system properties; in this exercise we will change the **sowing date**.
4. Click on the system properties and the system properties window will appear,
5. Click on the Sowing Tab, the Sowing window will appear, on the Sowing Decision click on the Defined button, the Defining Sowing decision option will be activated.
6. Change the sowing date for both season and save the system as follows, for different simulations:

No.	Season 1	Season 2	Save system as	Save output as	Save output as
1	5 February	5 October	Samedefined1.stm	Samedefined1.csv	Samedefined1.csv
2	20 February	20 October	Samedefined2.stm	Samedefined2.csv	Samedefined2.csv
3	30 February	30 October	Samedefined3.stm	Samedefined3.csv	Samedefined3.csv
4	5 March	5 November	Samedefined4.stm	Samedefined4.csv	Samedefined4.csv
5	20 March	20 November	Samedefined5.stm	Samedefined5.csv	Samedefined5.csv

7. Now repeat the exercise for the other planting strategies as shown above and save the output as indicated in the table above.
8. After that you can compare the results of yield obtained with different planting dates.

Note the planting date determined automatically above was considering that planting will be done on the first day when the available soil water exceeds 20mm. You can change this criterion to indicate that planting should be done on the first day when the available soil water exceeds 30 mm, and only if 3 out of previous ten days have had rainfall. If these conditions are not met after 75 days, the crop will be planted anyway in the hope that it will rain soon after planting.

9. Start the Excel Programme and open all the output files. On the Summary sheet look at the yield simulated for both season 1 and season 2. Copy the results in new spreadsheet differently i.e. Vuli and Masika for the different planting date, draw the graph of yield vs. season in different planting date and compare the results, or you can do any comparison analysis for different yield obtained in different planting dates.

The result will look like this

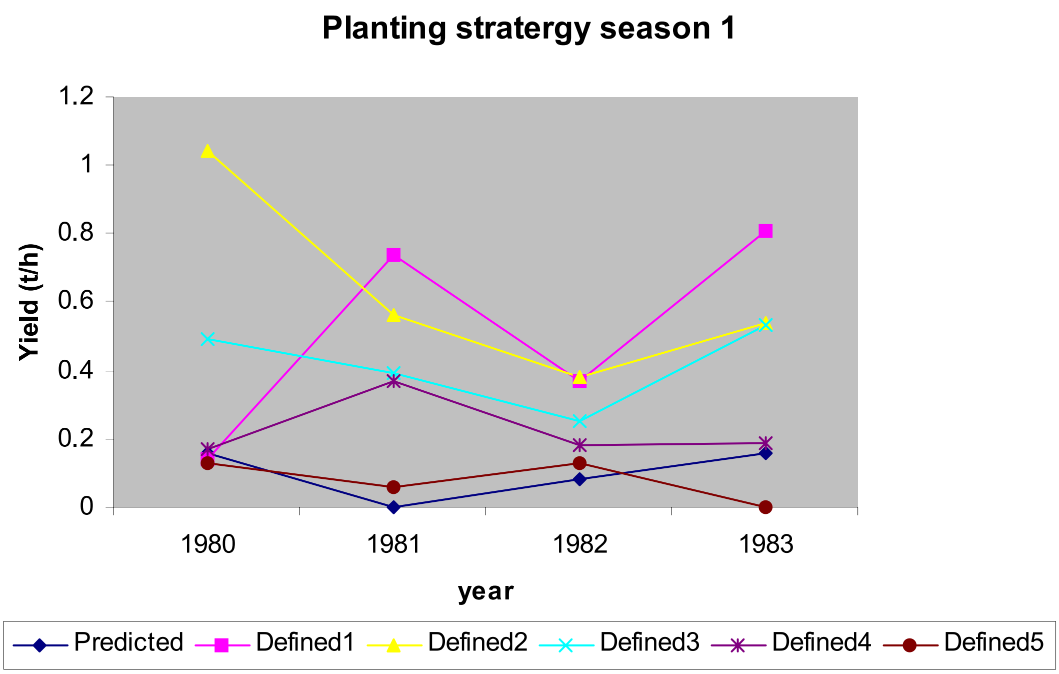


Figure 33: Comparison between the different planting strategies in season one.

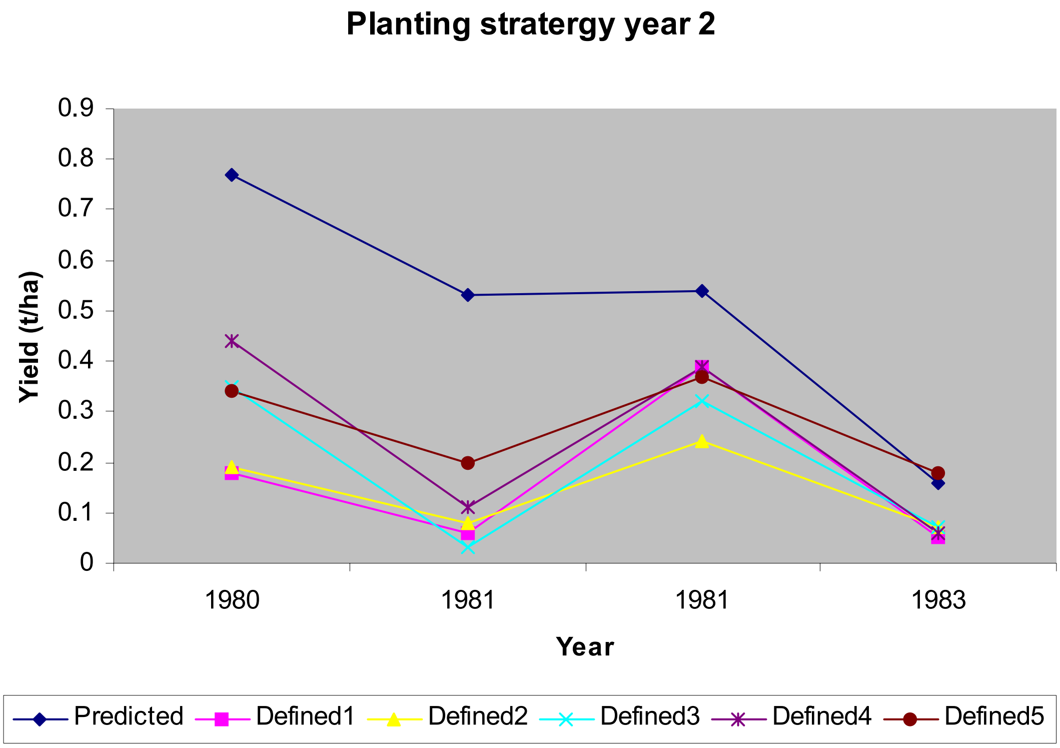


Figure 34: Comparison between the different planting strategies in season two.

Interpretation

Print the graph you have produced and use it to help answer the following questions:

1. Which is the best planting strategy?
2. Does the best strategy vary with season?

4.3.2 *Assessment* of the Effect of weeding in crop yield Consider time of weeding

In many semi-arid areas farmers try to guarantee their yield by reducing the potential competition for water and nutrients, thereby ensuring that there is at least some yield. Weeds can have a profound effect on crop yield due to competition on water, nutrients and light. PT-Model considers water competition, where weed growth is modelled in two stages, pre-planting stage, and the re-establishment stage after destruction of the pre-planting weeds.
A reasonably long series of weather data is important for this exercise, as the response to weed competition should be tested over as wide a range of conditions as possible.

Example

Let us compare the case where we don't allow weeds and when we allow weeds. Then we can compare the effect of weed managements during crop growth. which will be controlled by schedule of weeding.

1. SeT up a simple rainfed system with two profiles as they appear in the main window profile one (cropped field), and connected to the sink. Set out profile properties.
2. Choose Soil Surface tab, allow surface storage, keep the slope at 3% and set the area to be 1 ha.
3. Set soil properties from the Soil Properties tab, The current setting is OK; just

   Change the soil type to be Sandy Clay Loam.
4. Select maize crop on the crop tab, and set the plant population to 44,000 plants per hectare.

5. On the Weed tab, here is where we need to vary different weeding options. First case will be to run simulation without allowing weeds, that is the allow weed check box is left unchecked. Then we will allow weed, here we can run the simulation with no weeding that is the number of days from weeding be 0 that is first weeding 0 days, second weeding 0 days and third weeding 0 days, after emergence;

6. Set up the System Properties.

    a. Click properties, system properties window will appear From the system main window select system menu and. System properties window can also be activated by clicking mouse right button, and on the popup menu select click system properties.

7. Choose Timing from the menu bar and in the window which appears, use the arrows to change the Start Date year to 1980, set the No of Years to 10, set number of season to 2 per annum, and change the season start date, Season 1 to March 15, 1980 and season 2 to 15 October, 1980.

8. Choose Sowing Tab and set the sowing decision to Predicted: you can also see the criteria used to determine the predicted sowing date, doesn't change, and leave it to the current settings.

9. Now choose the Site tab from the System Properties Window. Choose the option button labelled "Location" and select Same among the listed location. And on ten specify Same Latitude by scrolling up or down on the latitude scroll bar.

10. Now choose the Weather Tab from the System Window Properties, to select the weather file to be used in the simulation. Click the Tab specify location this will allow to browse to the generated Same file, select file SAME80.WEA, the file stem will change to SAME, The generated files are text file (CSV), therefore the file type should beset to standard.

11. Now choose the Summary Tab from the System Window Properties to see the summary of the system properties set. If all system properties are set properly then click OK. This returns you to Main Window. From the system menu or by popup menu select Save the system as.. to save the current system. Save the system as SAMEWEED

12. From the system menu or by popup menu click Run to simulate 10 years of rainfed Maize grown at Same, without any weed competition.

13. Now run PT. The model will request you to specify the simulation output file, save your simulation as SAMENOWEED.csv Then click save. The follow all the simulation step, as they will appear on the screen to complete a full simulation where there is no weed allowed in the cropped area. The output window will look like this

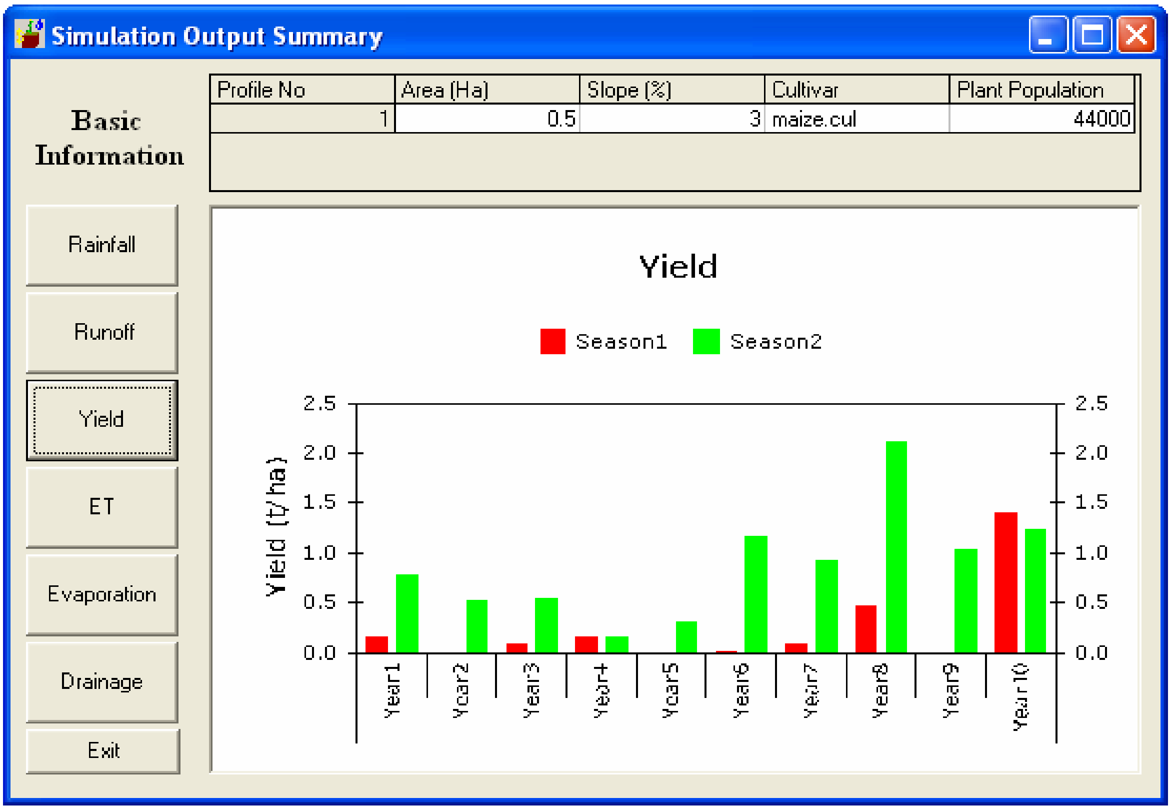


Figure 35: Simulation Output summary window showing yield of a weeded maize crop.

14. Now repeat the exercise for the allowed weed scenario. I n the profile property window check the allow weed check box, the weeding operation options will be activated.

15. In the numbers of days from emerging put zero for first weeding, second and third weeding. The window should look as shown in figure 36 below.

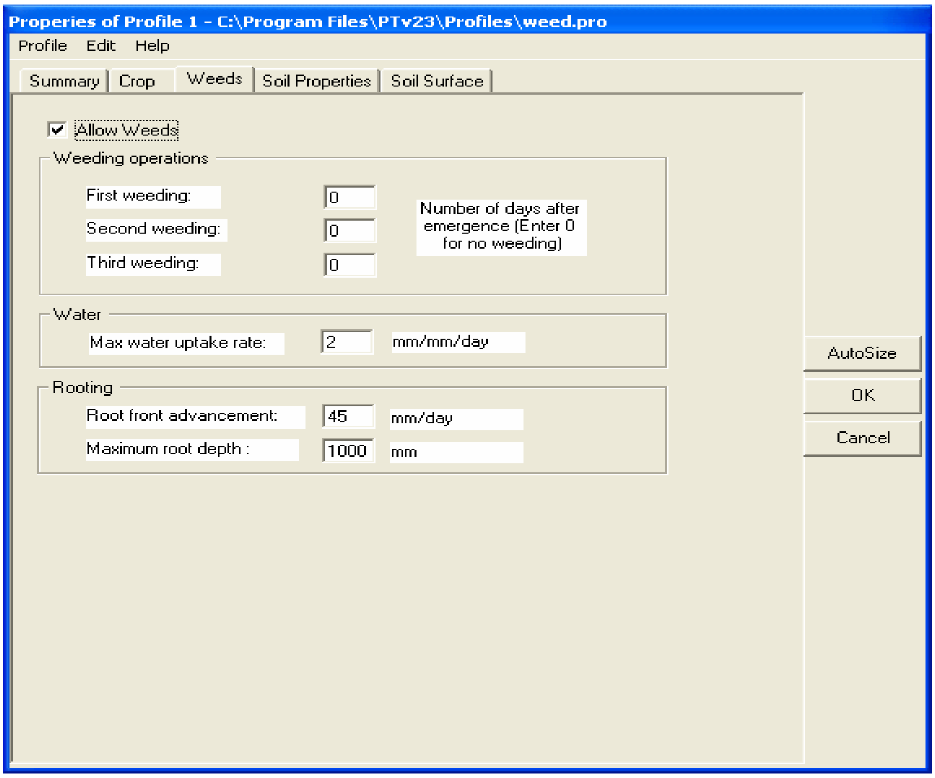


Figure 36: Profile property window with allow weed check box checked

16. (a) Save your system as SAMEWEED, and then run, other system properties should remain unchanged.

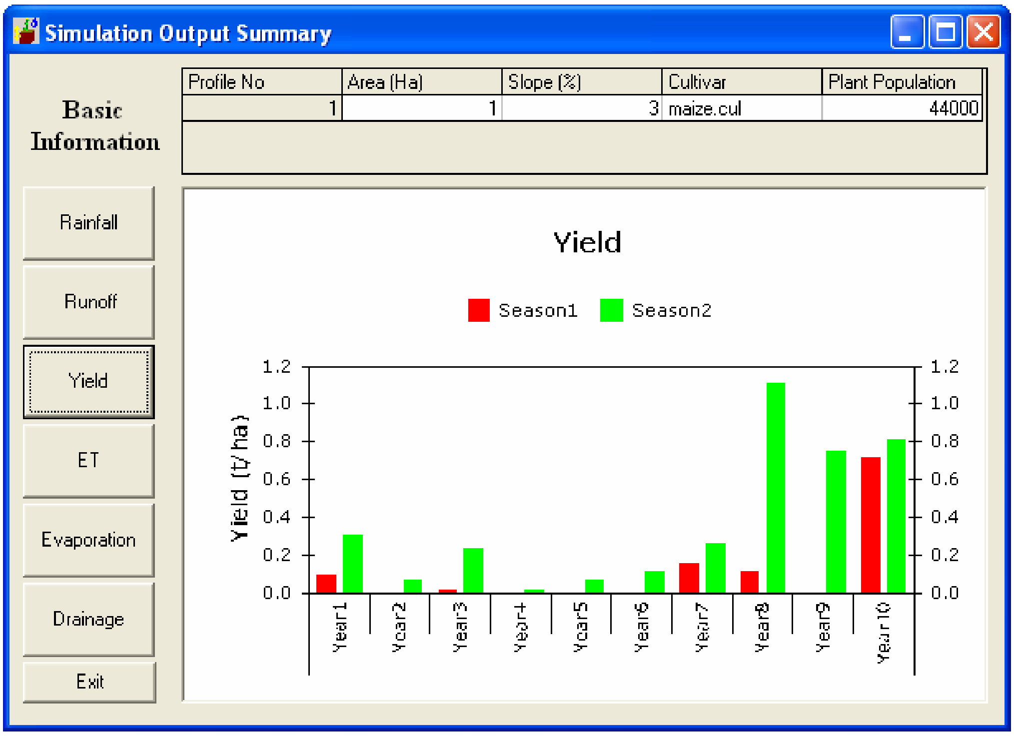


Figure 37: Simulation Output summary window showing yield of a non weeded maize crop.

17. (b) At the end of all simulation, open all output files with Excel. Copy these results to a new spreadsheet. Draw the graph of grain yield obtains for year versus weed options and you can compare the grain yield from weeds and no weed Scenarios.

The graphs will look like this

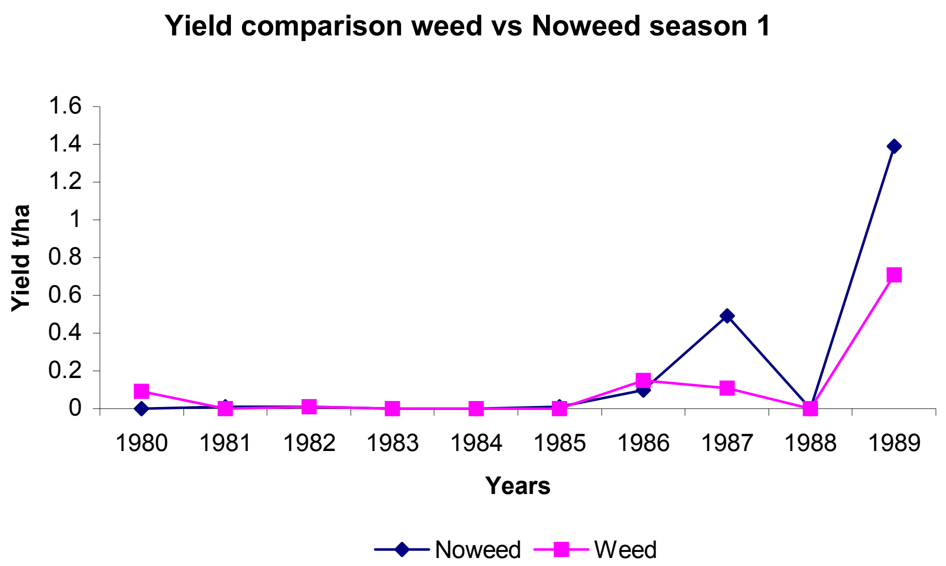


Figure 38: Yield comparison for a weeded and non weeded maize crop in season 1

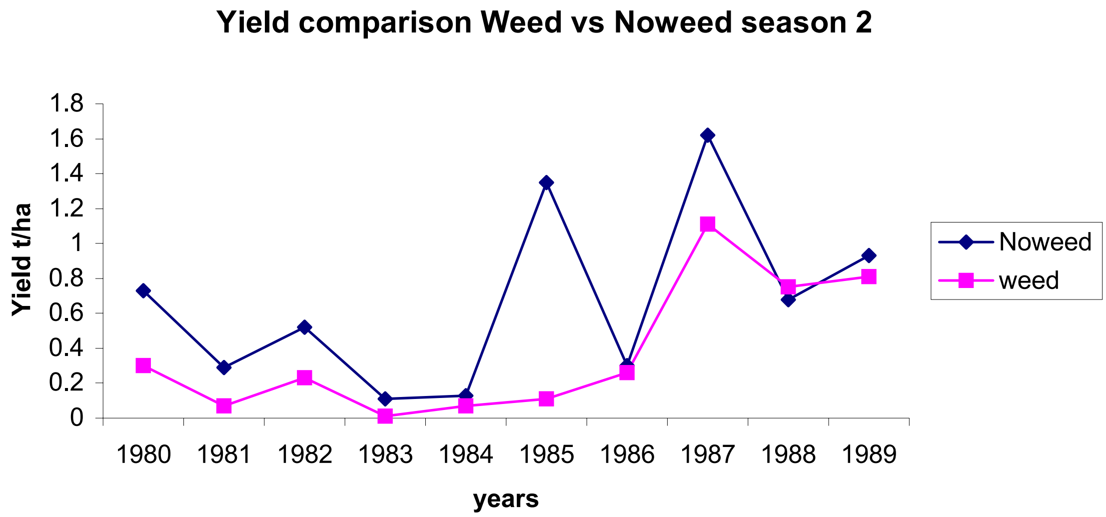


Figure 39: Yield comparison for a weeded and non weeded maize crop in season 1

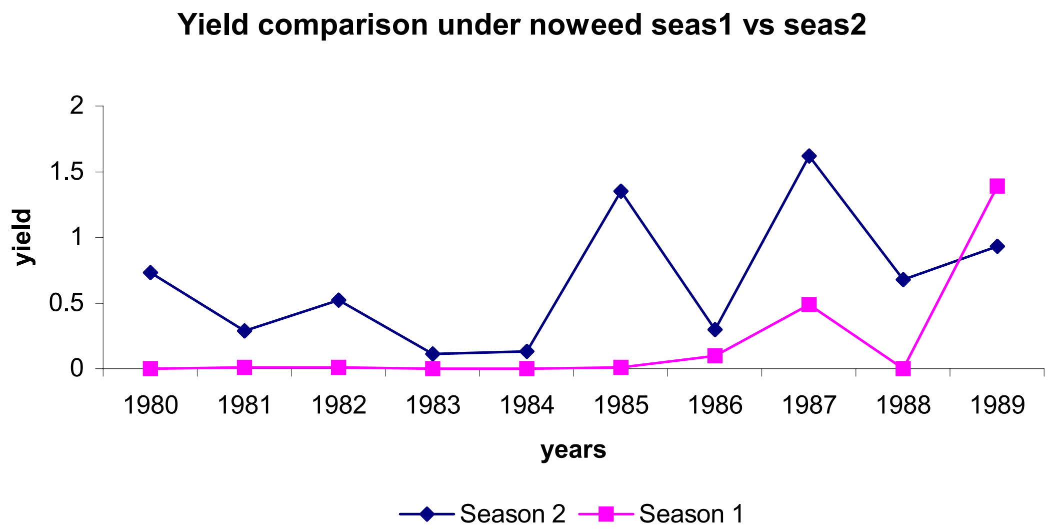


Figure 40: Yield comparison between season 1 and 2 under no weed condition

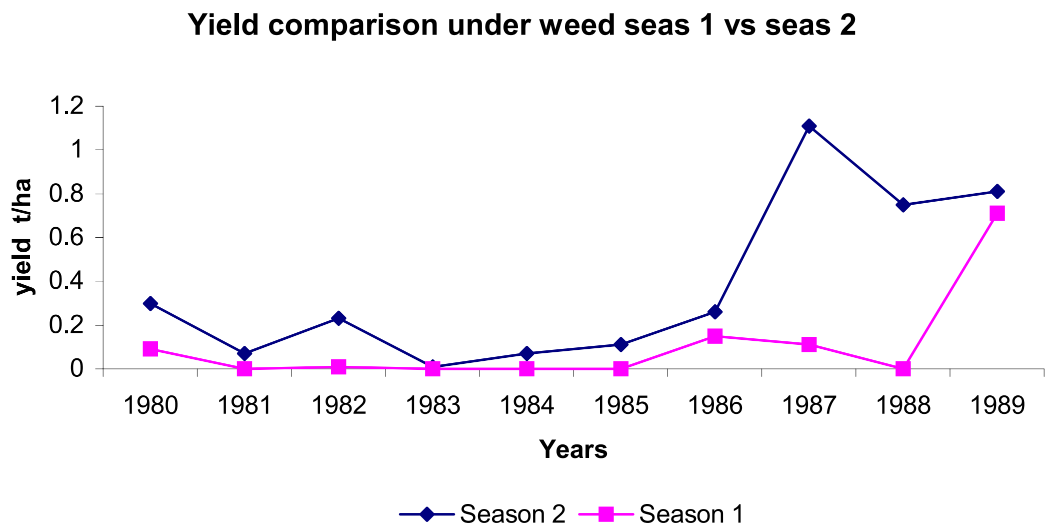


Figure 41: Yield comparison between season 1 and 2 under weed condition

18. **Note:** While PT-model is running look carefully at the differences in crop development shown on Run-Time Window. Note how the crop grows differently with different weed options.

Interpretation

Looking at the graph you have produced, use it to help answer the following questions:

1. What is the crop yield if no weeds are allowed at all?
2. Is it necessary to do weeding?
3. Is there any difference between the two seasons?

Example.

4.3.3 Effect of plant population on crop yield

In many semi-arid areas, growing maize is a fairly risky enterprise, since the rains are unreliable and maize is a drought-sensitive crop. Farmers try to guarantee their yield by modifying the plant population to reduce the potential interplant competition for water and nutrients, thereby ensuring that there is at least some yield. Traditionally, determining the optimum spacing required many years of experiments at sites with a wide range of climates. PARCHED-THIRST can help you to test different plant densities for long runs of years to investigate the probability of achieving the required yield. This tutorial shows you how to determine the effects of plant population on yield using PARCHED-THIRST.

Example

Procedure

A reasonably long series of weather data is important for this exercise, as the response to planting density should be tested over as wide a range of conditions as possible.

Using PT Model

Now to use the data we have generated to assess the effects of planting density on yields of maize. (Note: We will only be using ten years of the data we generated, to save simulation time). Comparison of the yield on the different planting density can be by using Microsoft Excel graphs.

1. Set up a simple system with two profiles as they appear in the main window profile one (cropped field), and connected to the sink.
2. Choose Soil Surface Tab, allow surface storage, keep the slope at 3% and set the area to be 1 ha.
3. Set soil properties from the Soil Properties Tab, The current setting is OK; just change the soil type to be Sandy Clay Loam. Allow no weeds on the Weed tab.
4. On the Crop Tab, here is where we need to vary the plant population density while other settings remain the same. Therefore, select maize crop, and population density to 44,000. Save the profile as Same44. Pro. For the purpose of testing different plant population density we can run three different population density scenarios, which are 44,000, 30,000 and 22,000 (or any depending on your choice). Therefore, in the second and the third case you will only change plant population density to 30,000 and 22,0000 and save the profile as Same30.Pro and Same22.Pro, respectively.
5. After setting profile properties and properly linking the profiles, the next step is to set up the System Properties. From the system main window select system menu and click properties, system properties window will appear. System properties window can also be activated by clicking mouse right button, and on the pop-up menu select system properties.

6. Choose Timing from the menu bar and in the window which appears, use the arrows to change the Start Date year to 1970, set the No of Years to 10, set number of season to 2 per annum, and change the season start date, Season 1 to march 15, 1970 and season 2 to 15 October, 1970.
7. Choose Sowing tab and set the sowing decision to Predicted: you can also see the criteria used to determine the predicted sowing date, don't change, and leave it to the current settings.
8. Now choose the Site tab from the System Properties window. Choose the option button labelled "Location" and select Same among the listed locations. Specify Same latitude by scrolling up or down on the latitude scroll bar.
9. Now choose the Weather tab from the System Window Properties, to select the weather file to be used in the simulation. Click the tab Specify Location, which will allow us to browse to the generated Same file. Select file SAME70.WEA, the file stem will change to SAME. The generated files are text file (CSV), therefore the file type should beset to standard.
10. Now choose the Summary tab from the System Window Properties to see the summary of the system properties set. If all system properties are set properly then click OK. This returns you to Main Window. From the system menu or by pop-up menu select *Save the system as*.. to save the current system. Save the system as SAMEPP.stm
11. From the system menu or by pop-up menu click Run to simulate 10 years of rainfed Maize grown at Same at a density of 44000 plants per ha.
12. Now run PTv2.1. The model will request you to specify the simulation output file, save your simulation as SAME44000.xls Then click save. Then follow all the simulation steps as they will appear on the screen to complete a full simulation where population density is 44,000 plants per hectare.
13. Repeat the exercise for a number of different plant densities (for example 30000 and 22000). Save your simulation as SAME??000.xls and then run, other system properties should remain unchanged. At the end of all simulation, open all output files i.e. SAME??000.XLS within Excel. From each open workbook, you will find a summary worksheet, this contains the simulated yields for the given population density. You can copy these results to a new spreadsheet (Copying is best done by highlighting the required block of values and then pressing Ctrl and C. Then move to the indicated location (bold text) and press Ctrl and V to paste the copied data. Continue this process for the Season 1 yields and then again for the Season 2 spreadsheets). Draw the graph of grain yield versus plant population and you can compare the grain yield from different population density for different season..
14. While PTV2.1 is running look carefully at the differences in crop development shown on Run-Time Window. Note how the crop grows differently with different planting densities.

Interpretation

Looking at the graph you have produced, use it to help answer the following questions:

1. What is the plant density above which yields do not increase?
2. Do yields decline at the greatest plant populations?
3. Does the optimum planting density vary with season?
4. What differences in growth did you notice on the Run-Time Window?

4.3.4 *Investigating* the Influence of Weather Variability

Rainfall in many semi arid areas is characterised by very low amount and high spatial and temporal variability. Rainfall is the least dependable of all the weather variables and yields are strongly related to the seasonal rainfall amounts. It is therefore important to be able to predict the yield for the whole range of likely weather conditions.

One of the strengths of PTv2 is the ability to run the model for a series of years and quickly generate summary results relating yield to weather conditions at a site. This tutorial aims to show you how to compare the variability in yields between years and sites.

In this tutorial we will compare Maize grain yield and above ground biomass for a series of years in Same and Morogoro in Tanzania. Since this exercise requires long rainfall records, we can use climatic data generated in Tutorial 2.

Procedure

1. Double-click on the PTv2 model icon or from the Start task bar go to *Programs* and from the program list click PTv2. The PTv2 main window and Welcome screen will appear. On the Welcome screen click on the icon experienced user *Model* to be taken straight to the main system window of PTv2.
2. In the Main window, open the system SAMEWEATHER. stm, this is a RWH system where the catchment area is 5 ha and the cropped area is 2 ha, both with slope of 3%. The crop is maize, which is grown in two rainy seasons per year. In both rainy seasons the planting date will be predicted by the model.The rainy season is considered to start on the same day each year – 1st October (Vuli) and 1st February (Masika) for all 15 years set for simulation. While running the simulation, save simulation output as SAMEWEATHER.su (note that you have to specify the extension).
3. Repeat step 2 above for Morogoro, in this case you open MOROGOROWEATHER.stm, and you can save your output as MOROGOROWEATHER. su.
4. The output file contains seasonal runoff, run-on, yield etc. of your simulation. The output workbook will have different sheets, but the sheet which is important in this exercise is the sheet-containing summary. It contains a summary of grain yield and biomass yield for all years of simulation for both seasons.
5. Start Excel and open all the output files (SAMEWEATHER.su and MOROGOROWEATHER. su). On the Summary sheet, copy the four column-containing year, season, grain yield and biomass yield and paste them into a new workbook. From the new workbook rearrange the yield and output such that you have yield and biomass for season 1 and 2 separately (i.e. Vuli and Masika). Repeat that for Morogoro. By using graph compare the result of season 1 for Morogoro and Same, and repeat for season 2.

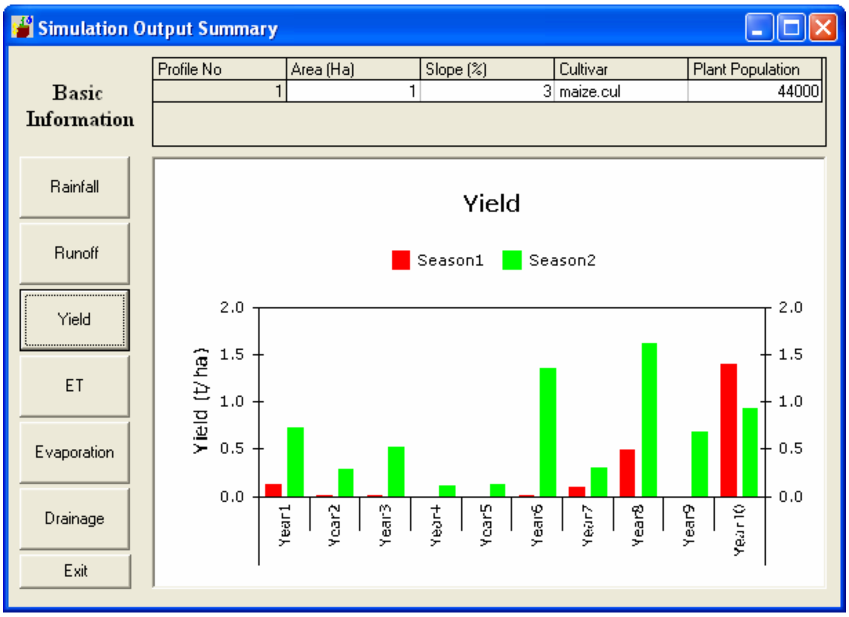


Figure 42: Simulation summary showing yield for Rainfed system in Same.

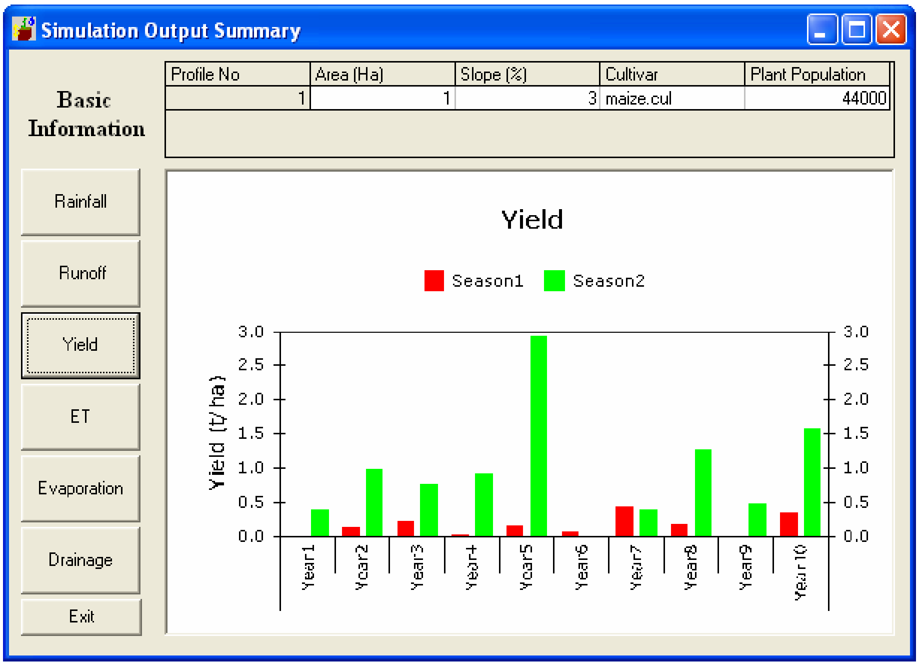


Figure 43: Simulation summary showing yield for Rainfed system in Morogoro

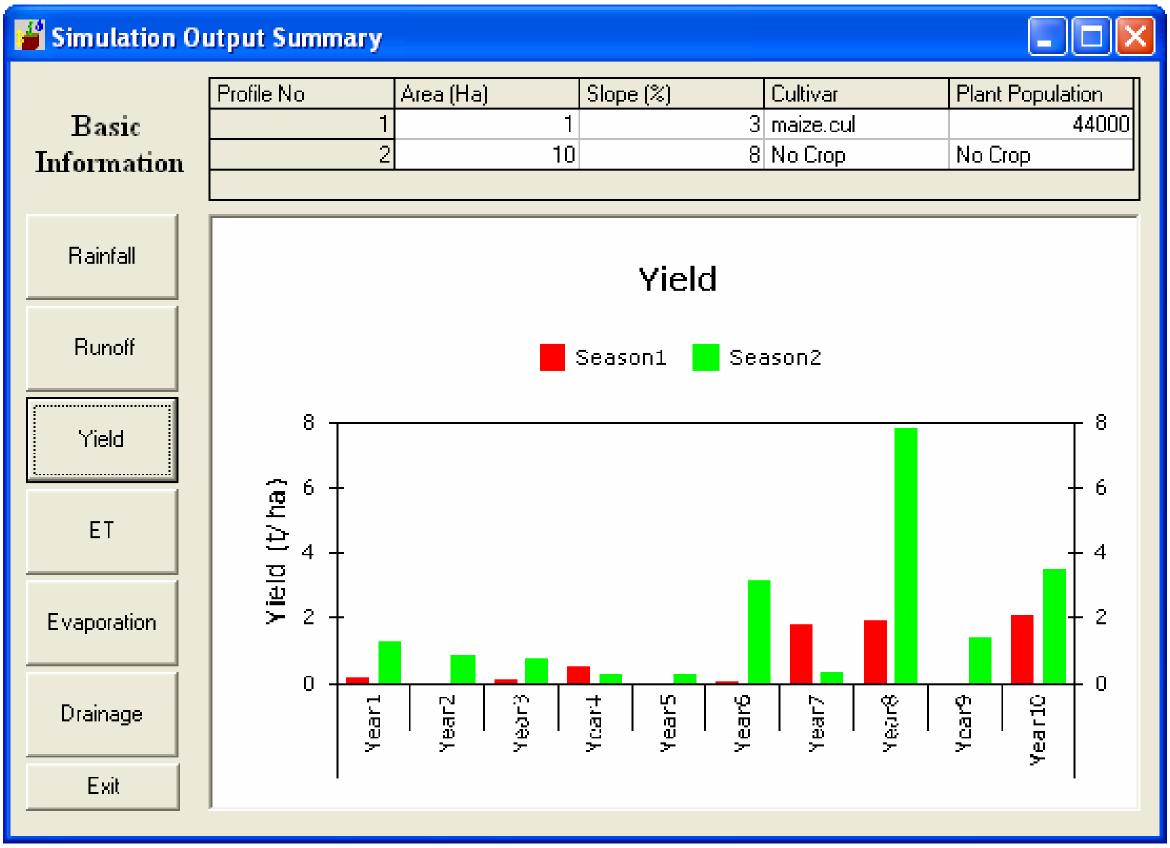


Figure 44: Simulation summary showing yield for **RWH 10:1** system in Same

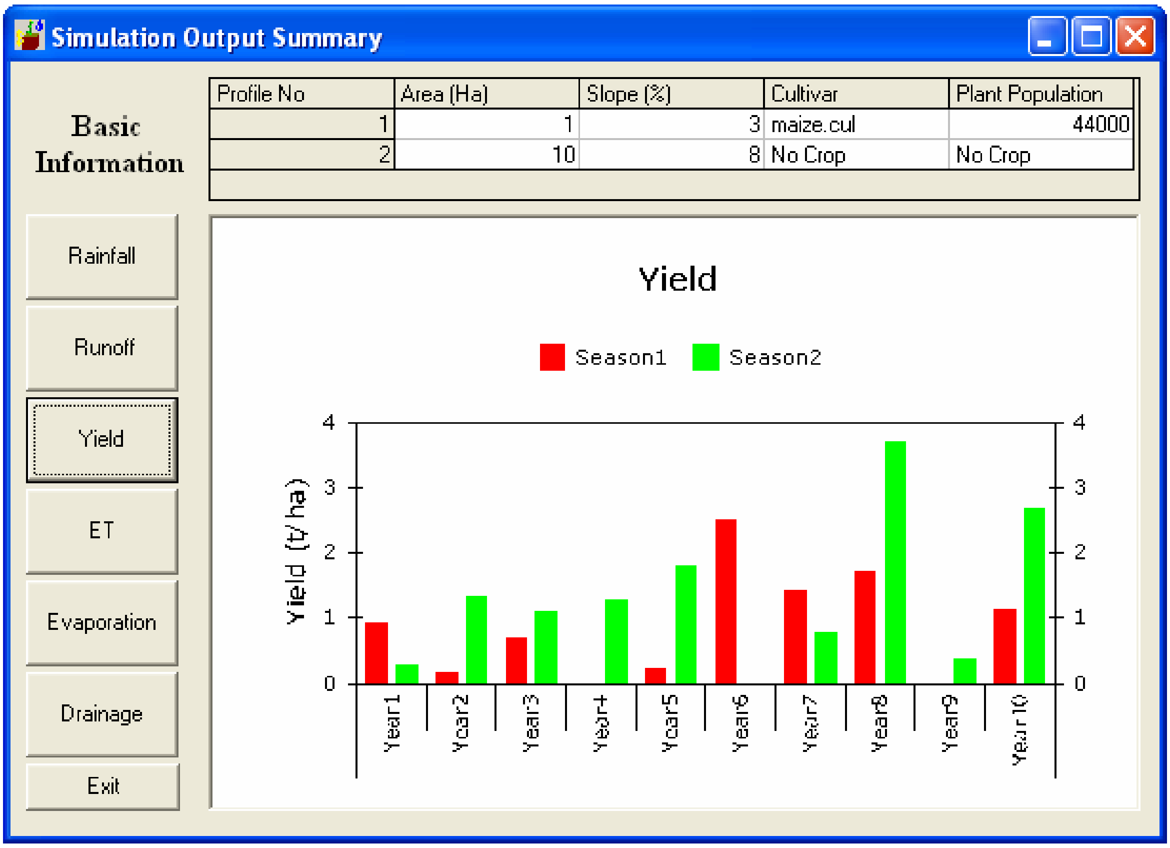


Figure 45: Simulation summary showing yield for **RWH 10:1** system in Morogoro

4.3.5 *Investigating* the effect of Water Management

Effect of moisture (supplementary water (RWH/irrigation on crop yield)

In Tutorial 1 we have seen how to create a simple RWH system and run a simulation. In this tutorial we will try to simulate different RWH systems for maize and rice crops. We will use data we have generated for Morogoro station to test different system designs and compare them with the rainfed system. Therefore we will run our tutorial for three cases (a) rainfed system (allowing bunds for moisture conservation), (b) 4:1 micro-catchment RWH system and (c) 10:1 macro-catchment RWH system.

Procedure for Maize Crop

1. Start PTv2 and open the NEWSYSTEM.stm, which was created in Tutorial 1.
2. We need to create three systems: rainfed, 4:1, and 10:1. Therefore, we will change properties of profile 2 by varying the catchment area to 0 ha, 4 ha and 10 ha, for rainfed, 4:1 and 10:1 RWH system respectively. We will also need to set the system properties, as follows:
    1. Timing: 10 years, Two seasons per annum, Season start date: Season 1: 1 February 1980, Season 2: 1 October 1980
    2. Sowing Decision: Predicted
    3. Site Morogoro, latitude – 6.
    4. Weather file details: Stem Morogoro. Specify location of the weather files: ..\Weather\Generated\MOROW80.wea
3. Save the system as MaizeMoroRain.stm. Run the simulation and save simulation output as MaizeMoroRain.xls.

4. Repeat this for 4:1 and 10:1 RWH systems. For 4:1 and 10: 1 RWH System, simply open MaizeMoroRain.stm, change the catchment area in profile 2 to 4 ha (or 10 ha) and save the system as MaizeMoro4RWH.stm and MaizeMoro10RWH.stm, respectively. Save your simulation outputs as MaizeMoro4RWH.xls and MaizeMoro10RWH.xls for 4:1 and 10:1 RWH system, respectively.

5. After running the three systems you will have your out put results in Excel and you can use the output to compare between three different systems.

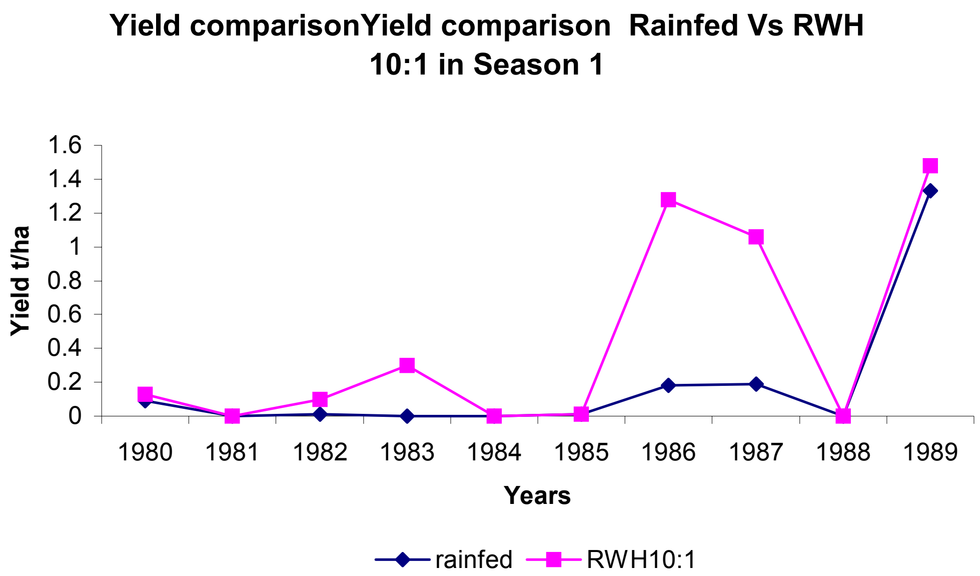


Figure 46:Yield comparison RWH Vs Rainfed system for Same in season 1

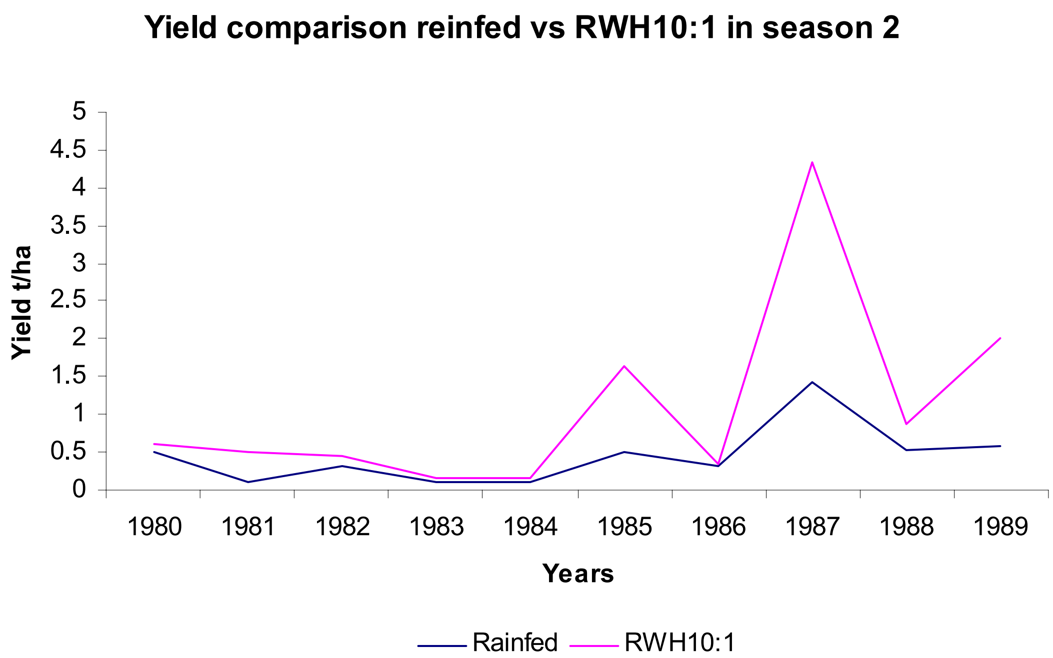


Figure 47:Yield comparison RWH 10:1 Vs Rainfed system for Same in season 1

Interpretation

While looking at the graphs you have produced, ask yourself the following questions:

1. Is there difference in yield between seasons for the same type of rainwater harvesting?
2. How much difference in yield is there between rainfed growth and rainwater harvesting, and between one type of rainwater harvesting and another.
3. Is it worth using rainwater harvesting? If so, which is the best catchment: cropped area ratio to use and in which seasons should it be used?

4.3.6 Investigating the Influence of Soil Variability

Variations in soil texture and structure can have large effects on the performance of the RWH system. Soil properties affect the amount of runoff produced by rainwater harvesting systems and the amount of water, which can be stored in the soil profile of the cropped area. PT-model uses the soil information you provide to calculate the amount of water available and the ease with which it can be extracted by the crop. If you do not know the soil water release characteristics for your soil then PT-model will estimate values from information about the soil texture and dry bulk density using pedotransfer functions. These soil properties can be selected by using the texture triangle shown in Figure ….. The minimum information that you require is therefore the depth and texture of the soil profile you wish to use. The profile can have up to six different soil types defined.

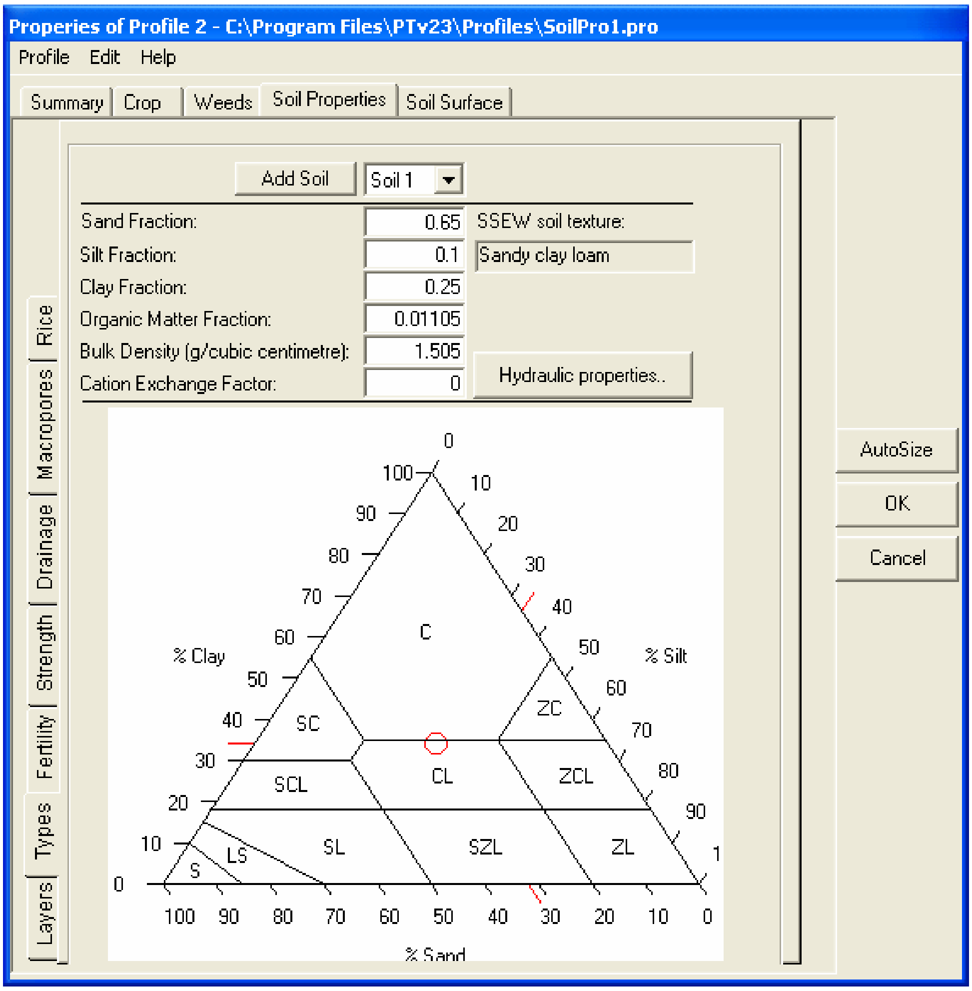


Figure 48: Soil Texture Triangle in Soil Type Window

This section shows you how to change the soil parameters to investigate the effects of soil properties on the reliability of rainwater harvesting systems. (Note: we will only be using ten years of the data we generated). Any soil profile in PT-Model is represented by layers, because most natural soils display distinct horizons and this has an influence on soil water movement. Each soil layer can represent a different soil type. In the *Soil Properties* window, different layers can be accessed through the *Layers* tab, where depth, soil type and initial water can be specified for each layer. The *Soil Type* tab is where we can specify soil texture parameters for each soil and these can be used to estimate the soil hydraulic properties required by the PTv2 by using the Pedotransfer Functions.

Other important soil properties which can be accessed through Soil Properties tab on the Profile Properties window are:

- *Macropores*, which explains infiltration of water from the surface of the soil. The flow of water via micropores in the PTv2 is simulated using two parameters – the crack distribution parameter and the macropores flow rate.
- *Soil Strength*, which simulates soil mechanical resistance to root penetration. It is represented by two parameters – soil strength parameter a and soil strength parameter b.
- *Soil Fertility*, which can also be limiting factor in crop production, however, in semi-arid areas water and temperature limitations are often more severe. PTv2 incorporates a comprehensive nutrient simulation, where fertility of profile can be controlled and allow for practices such as addition of manure in the cropped area.

In this tutorial we will vary soil texture in each soil and all other soil properties will remain fixed.

1. Set up a simple system with two profiles as in Tutorial 1. Set the catchment area (profile 2) size as 10 ha at 8% slope and the crop area (profile 1) as 1 ha at 3% slope. That will give us a RWH system with a Catchment Area: Cropped Area Ratio of 10: 1.
2. Right click profile 2 and on the pop-up menu select item *Properties of Profile 2*.. , Profile Properties window will appear. Click on *Crop* tab and on the cultivar option select *No Crop*; Click on the *Weed* Tab, don't allow weeds in catchments to have ideally bare catchment; Choose *Soil Surface* tab, don't allow surface storage, keep the slope at 8% and set the area to be 10 ha.
3. On the S*oil Properties* tab, we will make changes to soil type and drainage properties. To make changes on the soil type, click on the *Types* tab, and on the soil triangle click anywhere on the clay. Click on the *Drainage* tab and on the drainage rate box enter 0.5. Click on the *Summary* to check that all the changes you have made are properly done. If there is anything, which is not correctly set, click on it and correct it. If everything is correct, then click OK. You will be asked to save changes you have made, click YES, save as SoilPro2 and click OK.
4. Now we will set properties for Profile 1 (Cropped area). Right click profile 1 and on the pop-up menu select item *Properties of Profile 1*.. The Profile Properties window will appear. Click on *Crop* tab and on the cultivar option select Maize; Click on the *Weed* tab, don't allow weeds in the cropped area; Choose *Soil Surface* tab, allow surface storage at the bund height of 10 cm, keep the slope at 3% and set the area to be 1 ha.

On the *Soil Properties* tab, we will allow three different soil types, where soil A will have four layers (layers 1,2,3 and 4), soil B will have two layers (layer 5 and 6) and soil C will have two layers (layer 7 and 8). Depth of layer 1, 2, 3, and 4 will be 10, 20, 30 and 40mm respectively, where layer 5 to 8 will have depth of 100mm. Initial water for each layer will be 15 %. The window should look like in fig Figure:49:

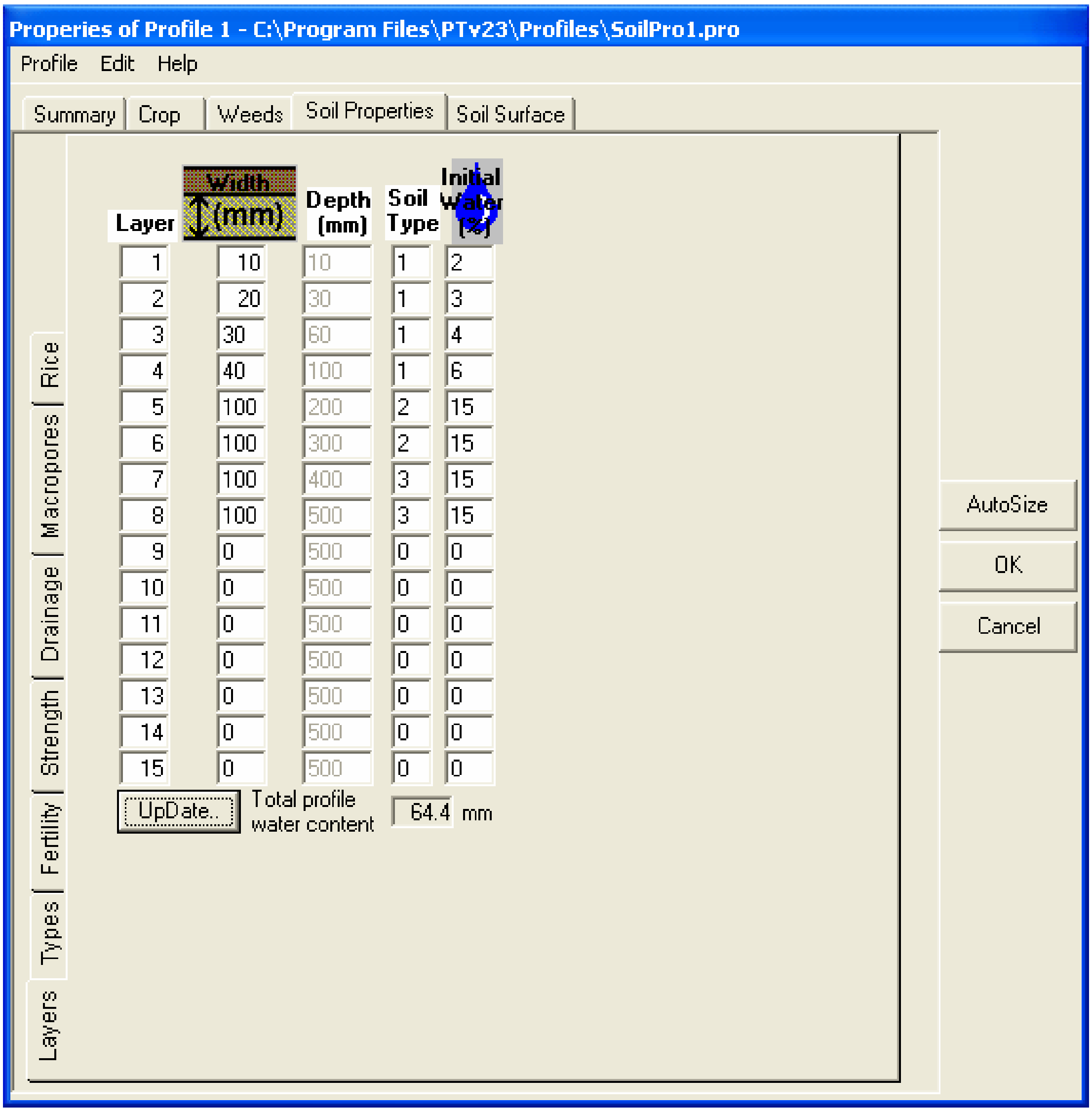


Figure 49: Profile Property window showing the different soil layers

5. Click on the *Types* tab, to set soil properties for each soil, On the *Add Soil* box, it will read Soil 1, then on the soil triangle click on Sandy Clay Loam (SCL), make sure that the box under SSWE soil texture reads Sandy Clay Loam, then click on the *Hydraulic properties* to reflect the new soil textures you have entered. If you get a message telling you that the texture of Soil x is not physically possible, you will have to go back to the soil triangle and click on an appropriate soil texture. Now click OK to return to the *Type* window, click on *Add Soil* and in a similar process as for Soil 1, then change Soil 2 and Soil 3 to Sand Clay and Clay Loam respectively. Other properties should remain at default settings. Click on the *Summary* tab to check that all the changes you have made are properly done If there is anything which is not correctly set, click on it and correct it. If everything is correct, then click OK. You will be asked to save changes you have made. Click YES, and save as SoilPro1, and click OK.

6. Link profile 2 to profile 1, and save the system as SOIL1.stm.

7. Now run PT-Model. You will be asked to enter the output file name, enter SOILSCL.XLS (for soil clay loam) and save. At the end of the simulation, you will be offered the chance to view a summary of the results. You will then be invited to run another simulation, say YES. Change the soil type of soil 1 to sand loam, then run the simulation, save output as SOILSL.XLS, Repeat these for third soil type, Go to Excel, choose File and then Open from the menu bar. Open files SOILSCL.XLS, SOILSC.XLS and SOILS.XLS. On each workbook, go to the summary worksheet, you will have the summary of crop yield from the RWH system with Catchment Area: Cropped Area Ration 10:1 in different soil types.

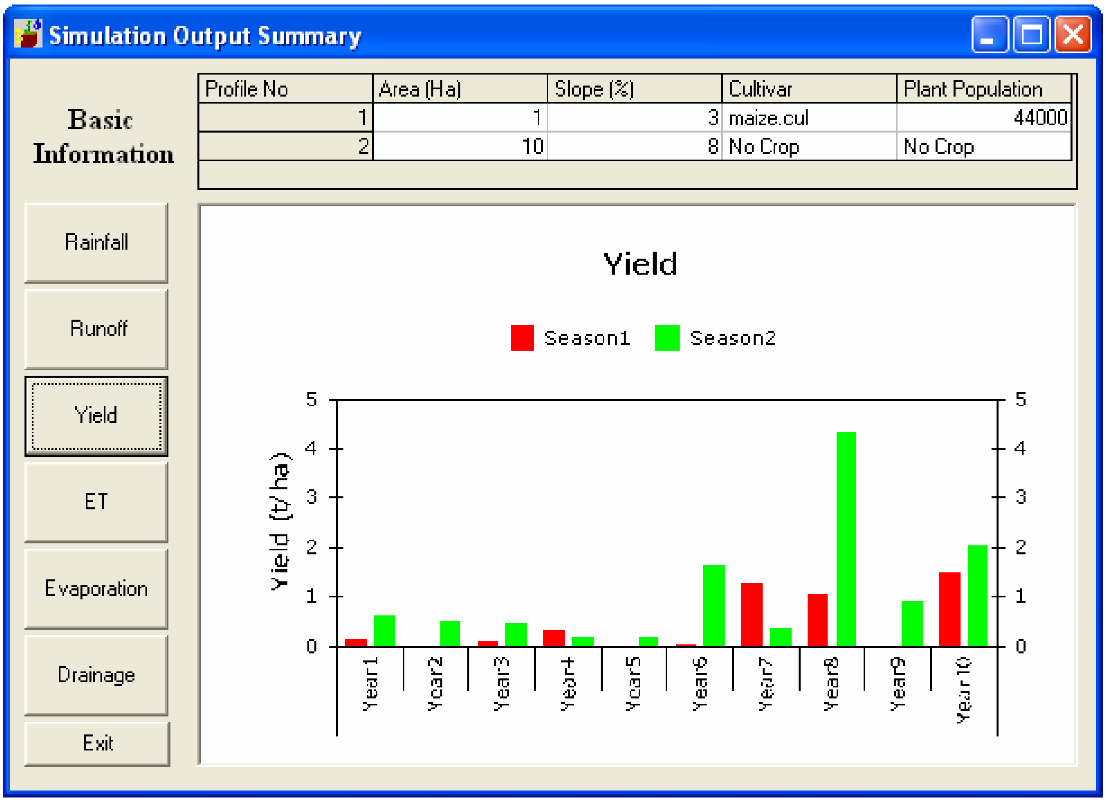


Figure 50: Yield for a Sand clay Loam

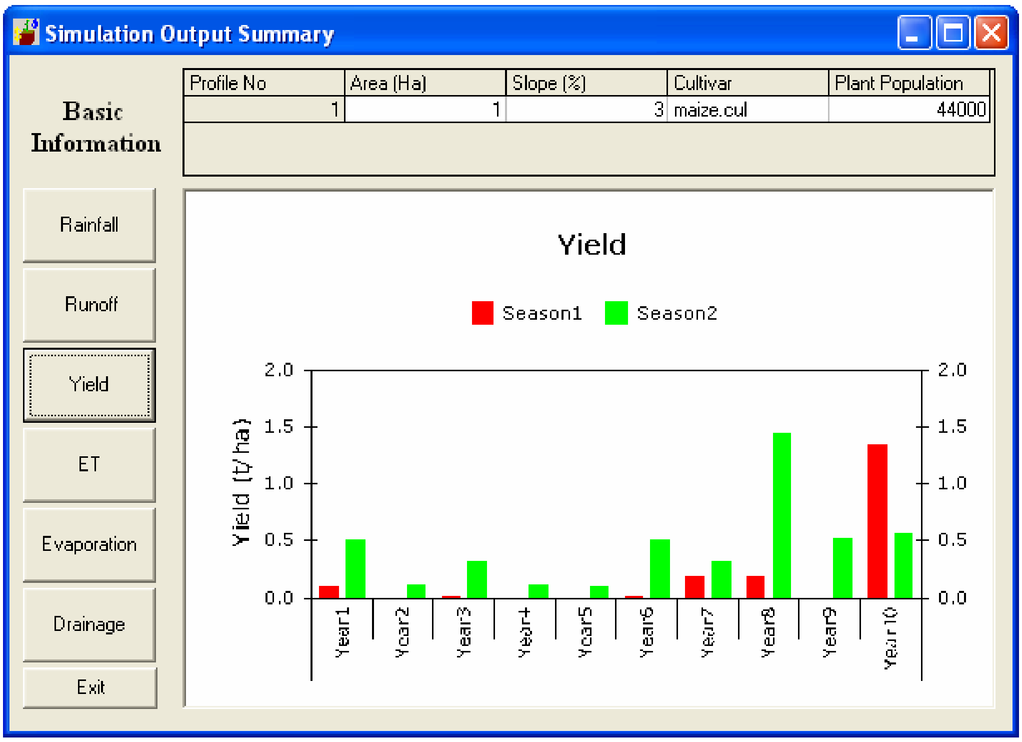


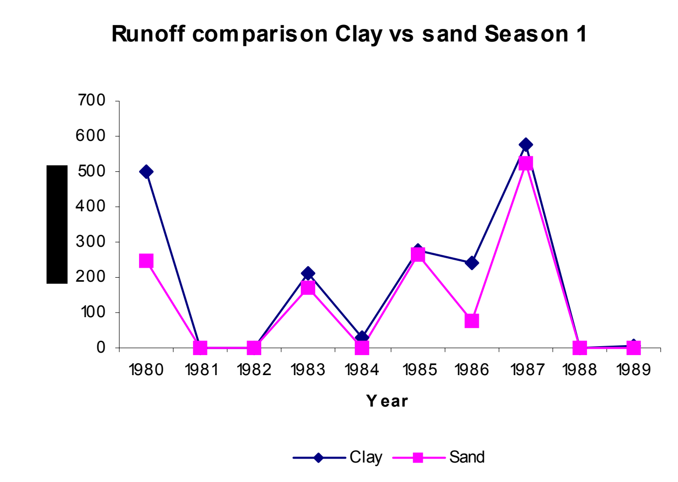
Figure 51: Yield for a Clay soil

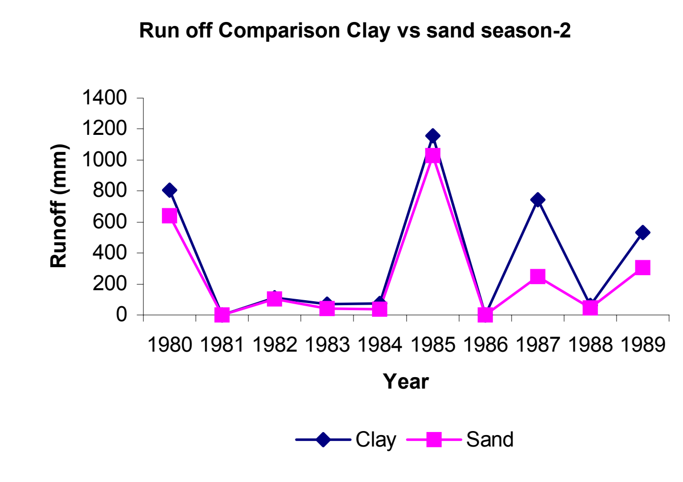
8. Copy the summary from all three worksheet to a new workbook (Copying is best done by highlighting the required block of values and then pressing Ctrl and C. Then move to the indicated location (bold text) and press Ctrl and V to paste the copied data). You can then draw the graphs of your output to interpret the results as shown in Figure 51 below.

Interpretation

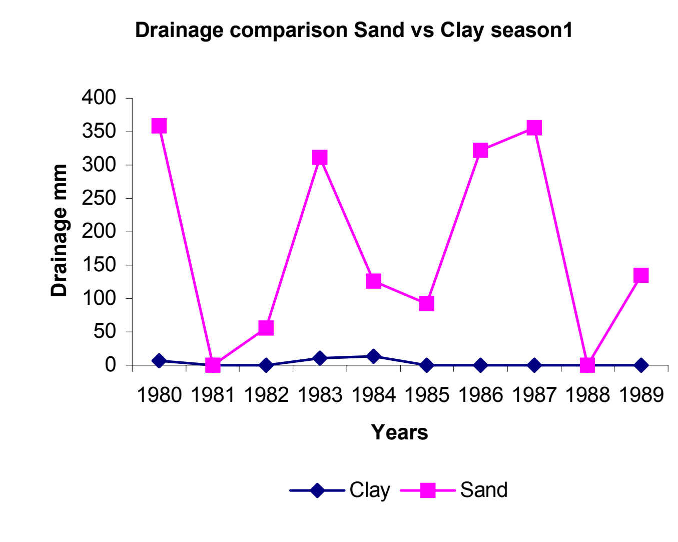
When interpreting the results of this exercise, consider the following questions:

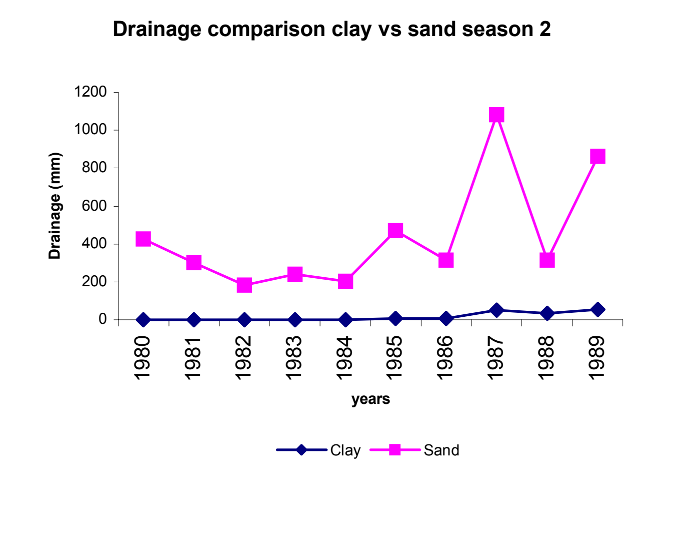
1. Is there a difference in yields between the two soils?
2. Is the yield difference stable across both seasons?
3. What differences in growth did you notice on the Run-Time Window?
4. How do you explain any differences you saw?



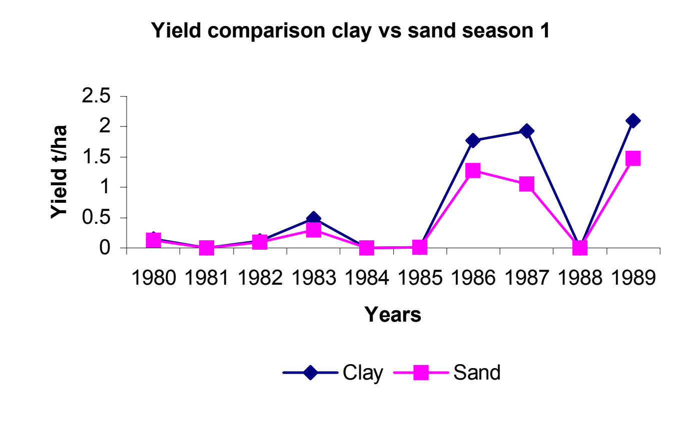


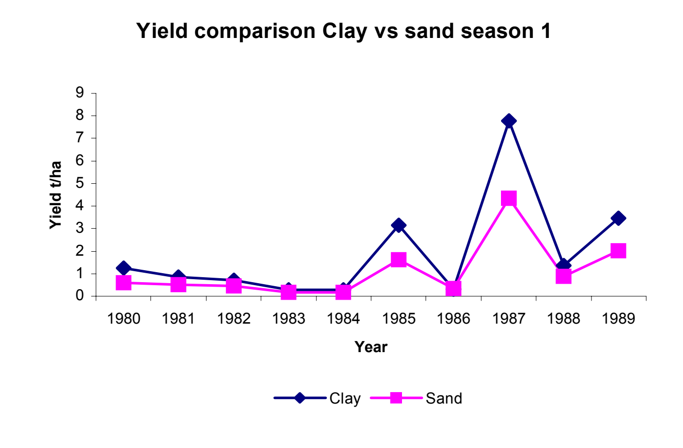
Runoff





Drainage





Yield

Figure 52: Comparison of Runoff, Drainage and yield for different soils and season.

Some of the Publications on PARCHED-THIRST model.

Young, M. D. B., Gowing, J. W., Hatibu, N., Mahoo, H. F. and Payton, R.W.(2001) Assessment and development of pedotransfer functions for semi-arid sub-Saharan Africa.Physics and Chemistry of the Earth(B), Vol.24, No.7, pp.845-849

Young, M.D.B. and Gowing, J.W., 1996. The PARCHED-THIRST model - A user guide. University of Newcastle upon Tyne, UK. 109pp.

Young M.D.B., Gowing, J.W., Wyseure, G.C.L., and Hatibu, N. 2002. Parched Thirst: development and validation of a process-based model of rainwater harvesting. *Agricultural Water Management*, 55: 121 – 14

Young, M D B, 2002. Development and application of PARCHED-THIRST: a user-friendly agrohydrological model for improving dryland cropping systems A thesis submitted in fulfilment of the requirements of the degree of Doctor of Philosophy,University of Newcastle upon Tyne, UK

Hatibu, N., M. D. B. Young, H. Mahoo, J. W. Gowing, O. B. Mzirai (In press). Developing improved dryland cropping systems in semi-arid Tanzania: Use of a model to extrapolate experimental results. *Experimental Agriculture*. In press.

Mzirai, O. B. M., Gowing, J. W., Hatibu, N., Rwehumbiza, F. B. and Young, M. D. B. (2001). Investigating the feasibility of rainwater harvesting (RWH) under semi-arid conditions: benefits of computer simulation in adding value to field experiments. Poster Presentation at the 10th International Conference on Rainwater Catchment Systems, Mannheim Germany, 10 – 14 September 2001.

Young M.D.B., Gowing, J.W., Wyseure, G.C.L., and Hatibu, N. (2002). Parched Thirst: development and validation of a process-based model of rainwater harvesting. *Agricultural Water Management*, 55: 121 - 140