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IRRIGATION SCHEDULING FOR SUSTAINABLE MAIZE PRODUCTION

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ABSTRACT

Lower water use efficiencies in most irrigated projects of Tanzania are caused by lack of appropriate irrigation scheduling practice, resulting in the use of more water than is actually required.

The present paper provides a practical irrigation scheduling for maize production in Kimani irrigation project of south west Tanzania. The computer based models such as CROPWAT, RAINBOW and IRSIS, has been used to determine, crop water requirements, effective rainfall and irrigation scheduling respectively.

Results show that the seasonal irrigation water requirements for maize production is 4323 m^3/ha (432.3 mm) with irrigation scheduling of 65mm as irrigation depth and 14 days (two weeks) as irrigation interval. Finally it is concluded that, irrigation scheduling with fixed interval and fixed depth is good planning. A farmer has to remember to irrigate using the right amount at right time . Also it is suggested to use rotational delivery system in order to obtain equity between water users.

INTRODUCTION

Most irrigation projects in Tanzania are operating at an overall efficiency of between 15% to 20% [1]. Low water use efficiencies are caused by poor irrigation methods and management skills. These include lack of appropriate irrigation scheduling practice resulting in the use of more water than is actually required.

Irrigation scheduling means planning of the timing and the depth of future irrigations [2]. The primary objective is to apply irrigation water at the right period and in the right amount. If water deliveries are untimely or not in the appropriate amount, irrigation efficiency decreases. Limited supply results in yield reduction due to percolation losses (which may leach relevant nutrients out of rootzone) but might also decrease the yield.

Maize is an efficient user of water in terms of total dry matter production and among cereals it is potentially the highest yielding grain crop. For maximum production a medium maturity grain crop requires between 500 mm and 800 mm of water depending on the climate [3]. To this, water losses during conveyance and application must be added.

Frequency and depth of irrigation and rain has a pronounced effect on grain yield. Maize appears relatively tolerant to water deficits during the vegetative and ripening periods. Greatest decrease in grain yields is caused by water deficits during the period that follows, which include tasselling, silking and pollination, due mainly to a reduction in grain number per cob. This effect is more pronounced when in the preceeding vegetative period the plant has suffered water deficits. Severe water deficits during the flowering periods, particularly at the time of silking and pollination, may result in little or no grain yield due to silk drying. Water deficits during the formation period may lead to reduced yield due to reduction in grain size. A deficit during the ripening period has little effect on grain yield.

Therefore the main objective of this study was to provide a practical irrigation scheduling for maize production in Kimani irrigation project of South West Tanzania.

DESCRIPTION OF THE STUDY AREA

Location

Kimani irrigation project is located at Latitude $8^{O}50$ South and Longitude $33^{O}54$ East at an altitude of 1145m above sea level in the Usangu plains in Mbeya Region, South west Tanzania, about 50 km from Mbeya town (Figure 1).

Climate

The study area is characterized by a mono modal rainfall pattern. The rainy season usually sets in by mid-November and ends in May, with peak rainfall

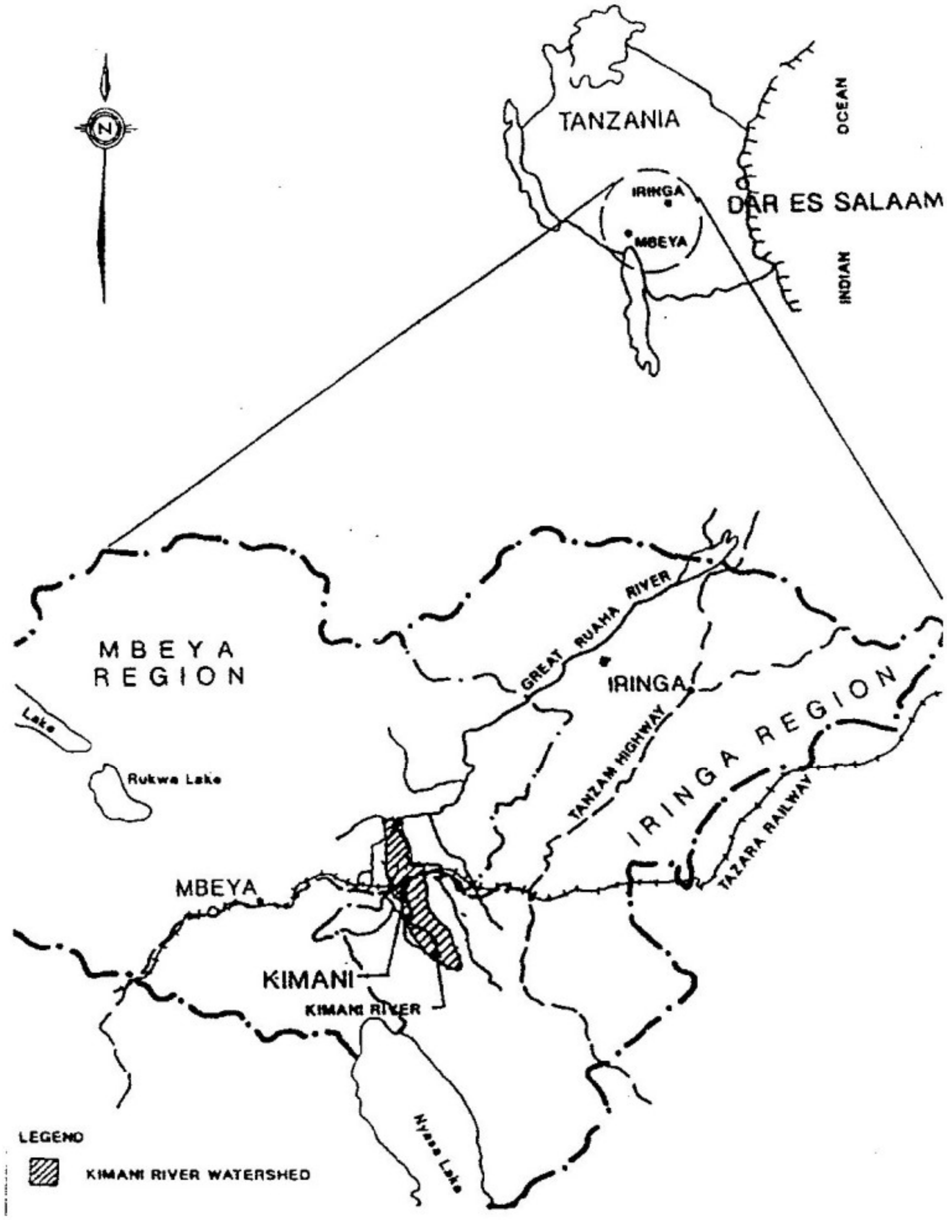

Figure 1. Loacation map of the study area

experienced from December to March. The mean annual rainfall is less than 750 mm, and the mean annual temperature is 23^{0} c.

Geology and Geomorphology

The Usangu plains forms part of the East African Rift valley which was formerly a lake. Subsequent drainage of the water from the lake to the North and North East turned the lake beds into plains. These plains received both alluvial and colluvial deposits from the rivers and adjacent mountain ranges respectively. A number of rivers flow northward from the ranges. Most of these however are seasonal and simply disappear before they have a chance to join the Ruaha river. Kimani and Ruaha rivers have perennial flow and deposit significant amounts of sediment to the basin.

Hydrology

The surface drainage of the study area consist of two main rivers Kimani and Makambalala which are the major tributaries of the Great Ruaha. Kimani river is subject to high flow rates during the wet season (December - May).

METHODOLOGY

Irrigation Scheduling Information System (IRSIS) which was used in this study, has been developed for solving problems concerning irrigation scheduling at field level [1]. It is a computer based model with the following capabilities:

1) calculation of net irrigation requirements;
2) calculation of the optimal water distribution resulting in the highest yield under conditions of limited water ;
3) calculation of the yield response under rainfed agriculture;
4) evaluation of past irrigation schedules using historical data;
5) planning irrigation schedules for different operational conditions; and
6) forecasting irrigation actions during the operational stage according to forecasted weather information.

In IRSIS, irrigation schedules are generated by means of scheduling criteria. One way to specify the scheduling criteria is by using a TIMING and DEPTH criteria. The Timing criteria determines when an irrigation has to be implemented and the Depth criteria determines the depth of the corresponding irrigation.

The irrigation water requirements for maize production were determined by IRSIS basing on the following steps:

STEP 1: Determination of crop water requirements by CROPWAT basing on the Penman monteith equation [5];

STEP 2: Determination of the effective rainfall from the multiplication of dependable rainfall obtained by the model called RAINBOW [6], with a fixed percentage to account for losses from runoff and deep percolation.

STEP 3: Determination of net water requirements by subtracting the effective rainfall from the crop water requirements

STEP 4: Determination of gross irrigation water requirements by dividing the net water requirements by the irrigation efficiency.

Therefore the computations were based on the following equations:

ETC = ETO * KC..(1);

ER = DR * FP..(2);

Inet = ETC - ER..(3) and

Igross = Inet/IE..(4)

Where:

DR = Dependable rainfall, FP = Fixed percentage, ER = Effective rainfall, ETO = Potential evapotranspiration, KC = Crop coefficient
ETC = Crop water requirements, IE = Irrigation efficiency
Inet = Net irrigation water requirements and Igross = Gross irrigation water requirements

Information on the models used

All the models used in this study are software packages which run on any IBM PC/XT/AT (or fully compatible) equipped with a 640 Kbyte RAM memory, under the PC/MS-DOS operating system (versions 2. or higher).

RAINBOW which was used in this study is a computer program which test the homogeneity of hydrologic records, executes a frequency analysis and makes a probability plot of hydrologic data. The test for homogeneity is based on the cumulative deviations from the mean. In the present version (1.6) the Gumbel and Normal distribution can be tested.

CROPWAT is a computer program used to compute evapotranspiration. This model was developed by FAO in 1992, [5], basing on the Penman

Monteith equation (after Penman modified equation)

IRSIS which was used to generate irrigation scheduling is a computer program which need information about the climate, the crop and the field.

The climatical data consists of information about crop water requirements and effective rainfall, which can be obtained from CROPWAT and RAINBOW respectively. The crop data consists of information about the different growth stages and the variation of the crop coefficient throughout those stages. On the other hand, field data consists of the volume water content at field capacity and at wilting point and the basic infiltration rate.

Limitations

IRSIS is restricted to uniform soil profiles, capillary rise from a groundwater table is disregarded and the irrigation and distribution system are not explicitly taken into consideration in IRSIS.

RESULTS

Dependable rainfall

The dependable rainfall which is defined here as the rainfall event which can be expected in a set number of years out of a total number of years. is presented in figure 2 basing on the historical rainfall (1961 - 1990) data of which the measurement were taken at the study area. By considering the growing period of maize (January to April), Figure 2 shows that 80% dependable rainfall exceeds 20 mm per month. Therefore this implies that in 8 out of 10 years the 20 mm rainfall depth per month will be exceeded during the growing season.

Irrigation water requirements

The irrigation water requirements for maize are presented in Table 1.

Table 1 Seasonal irrigation water requirements for maize

	Growth stages					
	January	February	March	April	May	June
ETO (MM)	102.3	95.2	105.4	99.0	112.0	120.0
ETC (MM)	42.9	47.6	118.0	113.9	123.2	108.0
KC	0.42	0.50	1.12	1.15	1.10	0.90
ER (MM)	90.0	76.0	89.0	18.0	0.0	0.0

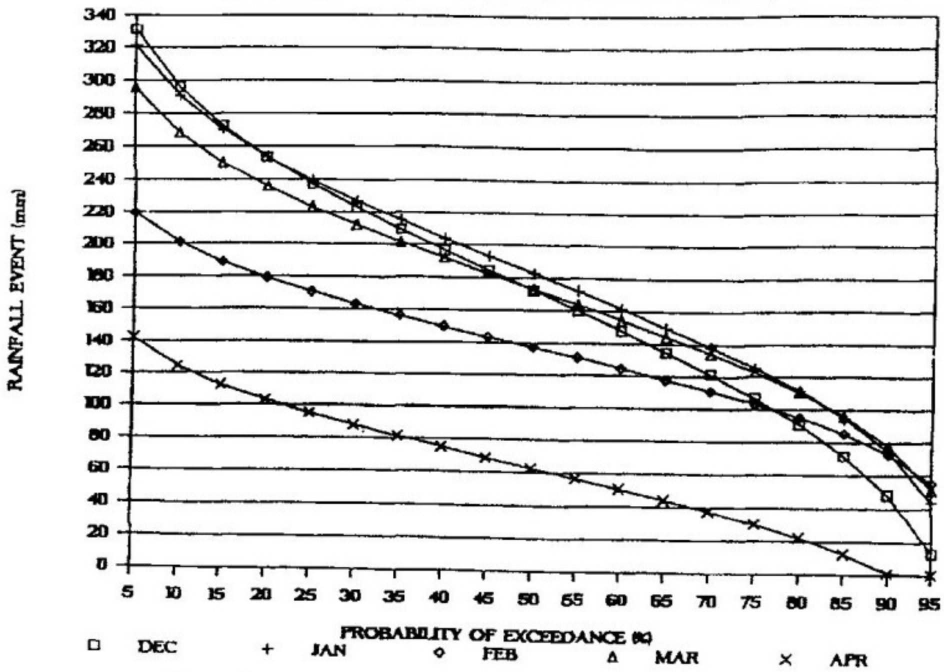

Figure 2. Frequency analysis of manthly rainfall in Kimani

Total ETC = 554 mm, Total ER = 273 mm, therefore from equation 3 and 4, the irrigation water requirements is as follows:
Net irrigation requirements = 554 - 273 = 281 mm = 1810 m^3/ha, and
Gross irrigation water requirements = 2810/0.65 = 4323 m^3/ha

The net irrigation water requirements (Inet) in Table 1 , indicates the amount of water needed to keep crop evapotranspiration at the potential rate. As long as there is sufficient effective rainfall, the water content in the rootzone is kept above the critical moisture content and consequently Inet will be zero. As soon as the water content in the rootzone drops below the critical level, the potential crop evapotranspiration (ETc) can no longer be sustained and Inet becomes positive. The critical water content is not a fixed value. If ETc increases, the readily available part of the total available water will decrease. Consequently Inet will be larger than the difference between ETc and effective rainfall. If ETc decrease, a larger part of the total available water becomes readily available and Inet will be smaller than the difference between ETc and ER. For furrow irigation with irrigation efficiency of 65%, the gross water requirements for maize production will be 4323m^3/ha.

Irrigation scheduling for maize

The irrigation scheduling for maize has been planned for two options as shown in Figure 3 and Figure 4, respectively.

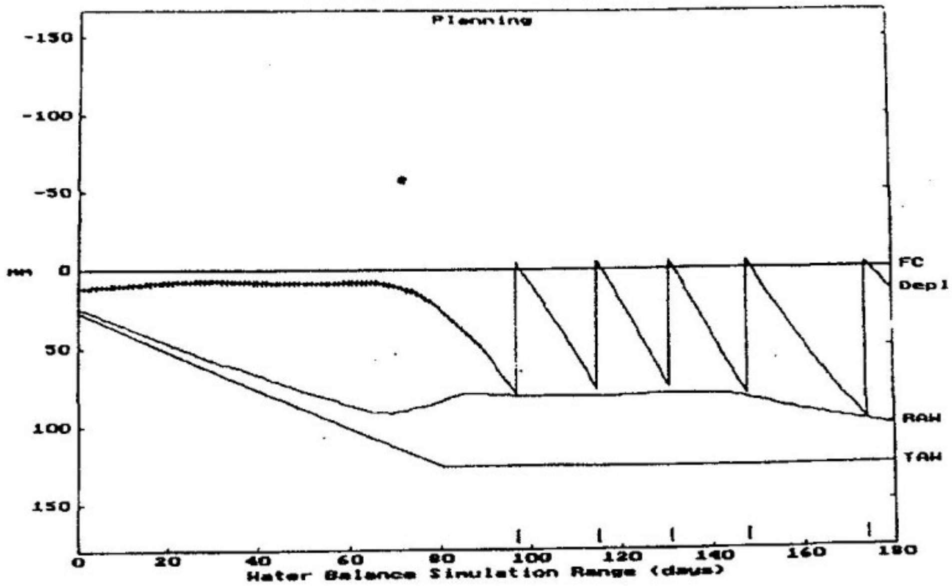

Figure 3. Optimal irrigation scheduling for maize

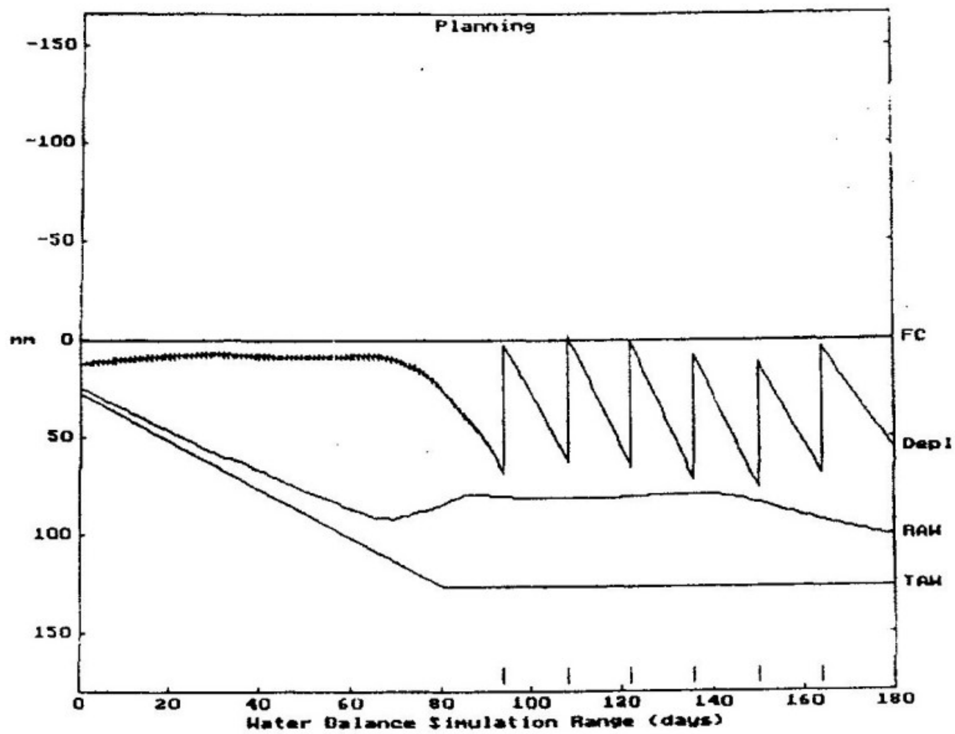

Figure 4. Practical irrigation scheduling for maize

Optimal irrigation schedule

The optimal irrigation schedule is achieved by using the optimal timing criteria, where 100% of Readily Available Water (RAW) can be consumed. This will secure irrigations before conditions of soil moisture stress occur. The optimal irrigation amount is the amount of water needed to bring back the soil moisture content of rootzone to field capacity. No losses occur and the soil status is restored at maximum level. The irrigation for this option is planned as indicated in Figure 3, which shows that the planned irrigation is such that the crop will not be under water stress (i.e., water below RAW) also there will be no wastage of water (i.e., water above FC). However this planning may be difficulty to be adapted by farmers as it indicates that there will be different irrigation depth with different irrigation interval, this situation is very difficulty for farmers to memorise exactly the time and amount of irrigation.

Fixed interval and depth

This is a practical irrigation schedule with a fixed interval and depth. This is achieved by applying irrigation at predetermined intervals, and the decision to irrigate is taken independent of the water content in the rootzone. This option is particularly relevant for practical scheduling where simple operational criteria are required. As it indicates in Figure 4, the planned irrigation will make the crop to be between RAW and FC throughout the growing period. This option is easy to be adapted by farmers because is simple for a farmer to remember when to irrigate at right time and the right amount.

CONCLUSION AND RECOMMENDATION

Climatically the Usangu plains are not suitable for rainfed agriculture especially for maize. This is due to the fact that about 273 mm of rainfall is available during the rainy season, and this amount can not support maize which requires about 432 mm. Therefore a practical irrigation scheduling, with irrigation depth of 65 mm and irrigation interval of 14 days provides optimal irrigation water requirements for maize production.

In this study it is suggested that rotational delivery system should be applied to obtain equity between water users. The details of rotational irrigation system is presented in Bishop et al, [7].

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