A COMPUTER SYSTEM FOR PREDICTION OF FARM MACHINERY WORKABLE DAYS IN RAIN-FED AREAS OF SUDAN

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Abstract: Management of rainfed farm is a complex process, due to the nature of various factors involve in crop production; such as machineries selection and their available workdays. Computer systems can improve farm management through facilitating planning and decision making processes. The objective of this study was to develop a computer system to predict machinery workable days in rain-fed areas. The system was built in Excel-Visual basic computer software using soil moisture balance equation. Data entry is a step by step process. Input data include: starting month, starting decade and number of decades in which workdays needed to be estimated beside climate and soil parameters. The soil workability criterion, 80% of field capacity (FC) was used. The system calculates daily soil moisture content, evaluates them. Then it predicts workdays for any month and arranges them in decade order for period up to 100 years. As verification the system has the ability to predict workable days once entering input data. System validation showed a high correlation (R^2 = 0.89) between the predicted and actual workdays. The system was sensitive to changes in soil workability criterion reflecting it's dynamic. The system was applied for Gedarif rainfed area by using data from Sudan Metrological Authority for Gedarif Metrological Station, for period of 33 years (1977-2009). The

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average predicted workdays for seedbed preparation, seeding and weeding operations were 27, 24 and 23, respectively. These results help in selecting machinery and scheduling operations. Therefore, the system can be used for proper machinery management and decision making in rain-fed areas.

Keywords: computer system, machinery workdays, rain-fed agriculture, Sudan

1. INTRODUCTION

Accurate information on the days suitable for field operations is important in the design, development, and selection of efficient machinery system for crop production. The period of time when land is considered workable is expressed as machinery work-day. A work day depends upon the soil's ability to withstand loads applied by tractor and implement. The number of days suitable varies widely with climate, soil characteristics, and type of machine and operation. Thomason, (1982) reported that the effect of workability and machinery work days are complex and difficult to separate from other physical and management factors.

Different criteria were used to determine soil workability and working days. Godwin and Spoor (1977) mentioned that, the lower plastic limit is a condition frequently acceptable as upper moisture content for working soils in agriculture. Terzaghi, *et al*, (1988) stated that land quality "workability" expressed as the upper tillage limit; depend mainly on clay and organic matter content of the soil. Mohamed, (2001) studied the working days in the mechanized rainfed areas using the criterion that workable day is a day of no rains and if any, the amount is less than 5 mm.

On the other hand, several models are developed to predict available working days elsewhere (Rounsevell and Jones, 1993; ASABE, 2004 and Rotz and Harrigan, 2005). These models integrated soil properties with long-term weather records. Predicted work days are extremely sensitive to variation in the weather (Rounsevell and Jones, 1993), moderately sensitive to some soil characteristics and highly sensitive to the workability coefficients used to determine a suitable day (Rotz and Harrigan, 2005).

Witney, *et al.* (1982) modified and simplified the soil moisture balance equation to predict daily fluctuation in soil moisture content. This equation was further used by Simalenga and Have

(1994), Elfadil, *et al.* (2004a), and Mas'oud (2005) to determine the suitable field workdays for machinery field work.

The mechanized rainfed agriculture in Gedarif state is one of most important sector in Sudan for it secures food and cash crops. Farm management of a rainfed farm is a complex process. The complexity is a nature of various and interrelated factors which involve in crop production process. These factors include; selection of crops and agricultural machinery (tractors & implements), the expected available working time for field operation, inputs cost and outputs prices. It was trusted that promotion of farm management can be realized by the use of modern aids like computer systems which facilitate the process of planning and decision making. The main objective of this study was to develop a computer system to predict available workdays in the mechanized rainfed areas.

2. MATERIALS AND METHODS

2.1 Characteristics of the study area

The study was conducted in Gedarif State, Sudan, which lies in the Eastern part of the Sudan between latitudes 12.67º and 15.75º N and longitudes 33.57 º and 37.0º E, where about 3 million ha are put under mechanized agriculture. Rainfall is always in summer and effective rainfall occurs within June to October and the peak rainfall occurs in July- August. The soil is heavy cracking clay soils (Vertisols), which characterized by shrinking when dry and swelling when moistened. The clay content ranged between 65% and 75%.

2.2Type of Data Collected

The collected data include; Climatological and soil data. Daily rainfall and evapotranspiration data were collected from Sudan Metrological Authority for Gedarif Metrological Station, for period of 33 years (1977-2009). The average soil field capacity (FC), permanent wilting point (PWP) and initial soil moisture content; were taken as 42.18, 30.55 and 12.0%, respectively. Also optimum soil moisture content, at which machinery works, was taken at 20 cm depth.

2.3 System structure

The system was developed in Excel -Visual basic computer software. Data entry is a step by step process. Firstly the user has to enter starting month, starting decade and number of decades in which he need to estimate workdays. Then the user has to enter daily rainfall and potential evapotranspiration, some soil physical properties, correction factors and constants then the system calculates soil moisture content of specified day. After that the system evaluates the soil moisture content of the day, if the soil moisture content is < = 0.8 F.C., the system writes 1(one) (workable day), and if it is > 0.8 F.C., the system writes 0 (zero) (non- workable day). Finally, the system sums-up all the workdays in each ten days a month (decade). The system allows the user to predict available working days for the twelve months a year and for number of years up to 100 years for any location. The system flow chart is shown in Fig. 1. The system output can be displayed on the screen or print out.

The following equations were used to determine the daily soil moisture content.

$M = Mp + R – Q – D – AET$ ---------- (1)

Where:

M = Soil moisture content of a day (mm).

Mp = Soil moisture content of the previous day (mm).

R = Rainfall on that day (mm)

Q = Run off (mm)

D = Drainage (mm)

AET = Actual evapotranspiration (mm)

The system calculates actual evapotranspiration (AET) according to equation (2) as follows.

$AET = (PET)\ (K_d)\ (K_s)\ (K_r)$ ---------- (2)

Where:

PET = potential Evapotranspiration (mm)

K_d = Soil dryness factor = 0.55

K_s = surface cover factor (percent soil cover)

K_r = rain distribution factor = 0.55

$K_s = 1 – 0.005\ PSC$ ---------- (3)

Where:

PSC = percent soil cover = 0, $K_s = 1$

If the amount of rainfall is enough to cause runoff, then the system calculates the runoff according to equation (4).

$Q = (R - 0.25S)^2 / (R + 0.8S)$ ---------- (4)

Where:

S = maximum potential difference between rainfall and runoff (mm)

The model then, calculates drainage (D) according to equation (5)

D = (Free water above FC) / (2PWP) ---------- (5)

Where:

FC = Soil field capacity (mm)

PWP = permanent welting point (mm)

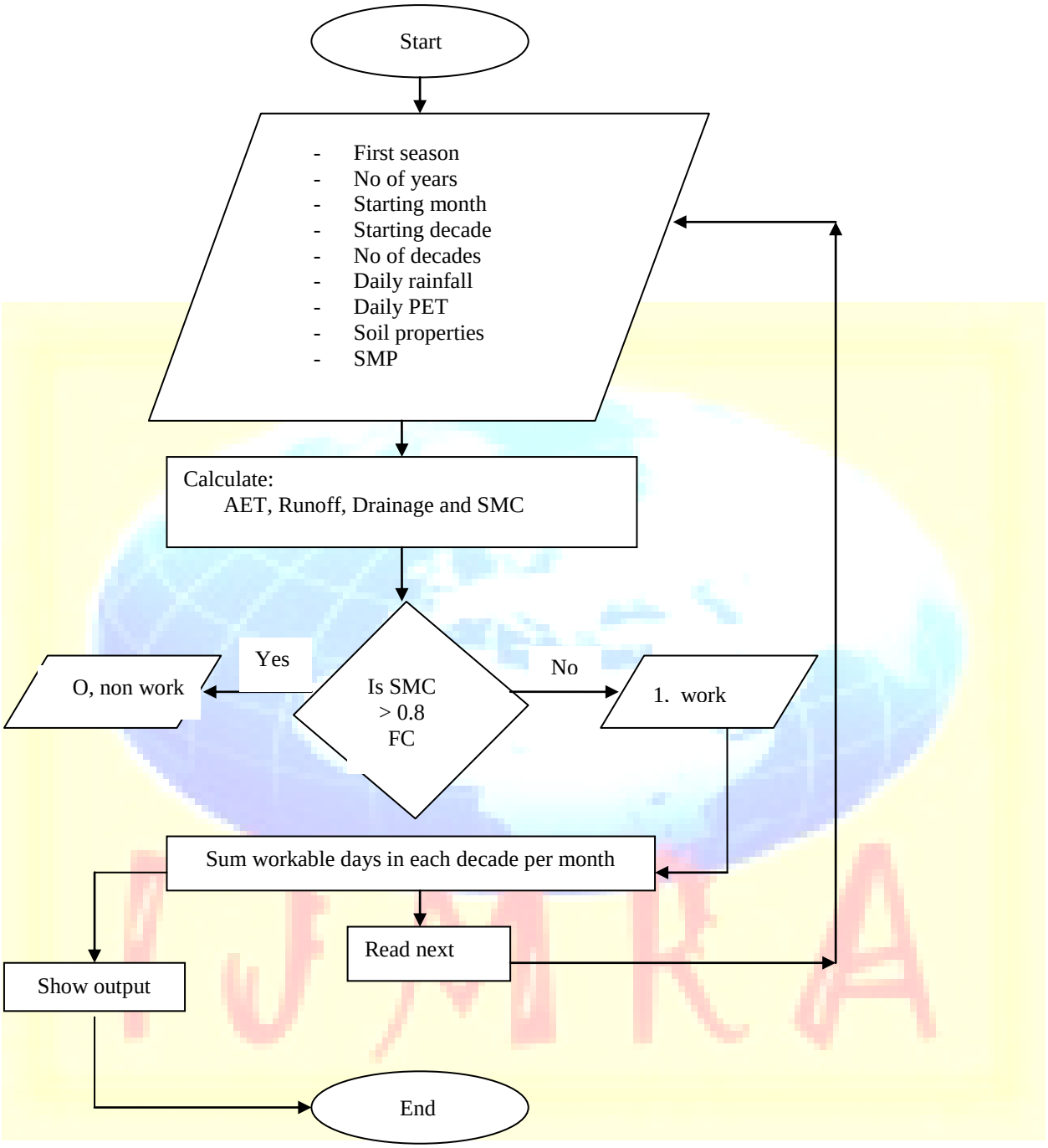

Fig 1. Available workable days system flow chart

3. RESULTS AND DISCUSSION

3.1System verification and validation

The developed system was used to predict workable days in the mechanized rainfed agriculture of .Gedarif State- Sudan. Soil criterion for machinery workability was taken as 80% of field capacity (0.8 FC) according to Elfadil, *et al.* (2004a), and Mas'oud (2005). Table1 shows average the estimated workdays for Gedarif for months from June to October for 33 years (1977 to 2009) on decade base. It was observed that, as soon as the user enters the required . data, the system estimates the number available workdays on decade base.

Table1. Average estimated field workdays in Gedarif (1977 - 2009)

Month	*Decade*	*Average*	*STD*	*C.V%*
	I	10	0	0
June	II	10	0	0
	III	10	1	12
July	I	10	2	20
	II	8	3	42
	III	7	5	63
August	I	5	4	93
	II	3	4	125
	III	3	4	140
September	I	3	4	132
	II	5	4	93
	III	8	3	35
October	I	10	2	18
	II	9	2	26
	III	11	1	13

As verification for the system, the same input data for the months June to August for the years from 1991 to 2000 were used for comparison with Mas'oud (2005). Statistical analysis showed close agreement between the two results with high correlation coefficient (R^2) of 0.84 (Table2). One limitation of the system which is worth noting is that it does not take into account the time of day when rainfall occurs. For example, a heavy rain in the late evening would result in a

nonworking day according to the system, even though the soil may have been dry enough to be tilled during the day time.

For system validation the system prediction and observed values of available workdays during seasons 2008 and 2009 in Gedarif showed close agreement (Table3). The correlation analysis between the predicted and actual workdays gave a correlation coefficient of (R^2 = 0.89). This proves that the system is able to estimate the available workdays with a high level of accuracy.

Table2. predicted workdays in 1991 to 2000 as compared with Mas'oud, 2005

Years	*June*		*July*		*August*	
	Mas'oud-2005	Model prediction	Mas'oud-2005	Model prediction	Mas'oud-2005	Model prediction
1991	30	30	31	27	24	27
1992	30	29	29	26	3	25
1993	30	29	31	30	12	24
1994	30	30	31	28	31	26
1995	27	26	5	22	14	25
1996	30	30	31	27	5	22
1997	30	30	18	26	11	25
1998	30	29	24	26	7	20
1999	30	30	13	22	12	25
2000	30	28	31	28	31	27

Table3. Observed and estimated field workdays in Gedarif (2008 - 2009)

Month	*Decade*	*Season 2008*		*Season 2009*	
		Observed	Estimated	Observed	Estimated
June	I	10	10	10	10
	II	10	10	10	10
	III	9	10	10	10

July	I	10	10	10	10
	II	9	10	5	4
	III	11	11	5	0
August	I	8	10	2	0
	II	4	10	8	0
	III	5	6	6	0
September	I	5	0	2	0
	II	6	0	3	0
	III	10	9	8	6

3.2 Sensitivity of the system

The sensitivity analysis was made to study the effect of changing soil workability criterion on the estimated workdays. The soil workability criterion 0.8 FC and 0.6 FC were used and keeping others inputs parameters constant for months August and September for season 2008. Changing soil workability criterion from 0.8 FC to 0.6 FC decreased the total number of working days from 26 to 20 and 9 to 1 days for August and September, respectively (Table4). This mainly due to the effect of the changed in soil workability criterion, and this means that the system is dynamic and can successfully estimate the number workdays according to careful definition of soil workability criterion and other input data.

Table4. Effect of changing soil workability criteria on the estimated workdays

Month	*Decade*	*0.8 FC*	*0.6 FC*
August	I	10	10
	II	10	10
	III	6	0
	Total	**26**	**20**
September	I	0	0
	II	0	0
	III	9	1
	Total	**9**	**1**

3.3 System application

The system was applied to estimate field workdays for three field operations, seedbed, seeding and weeding in mechanized rain fed sector of Gedarif State. The results in Table5 showed that the average workdays for the three operations were 27, 24 and 23 days, respectively. It is obvious that the system saves much of human efforts, time and even financial expenses that spend for obtaining such results.

Table5. Estimated workdays for three field operations in Gedarif area

Crops	*Seedbed preparation*	*Seeding operation*	*Weeding operation*
Sorghum	28	23	14
Sesame	28	18	23
Sunflower	20	25	20
Cotton	30	28	36
Average	27	24	23

4. CONCLUSONS

A computer system was developed to predict machinery workdays in rainfed areas, where soil workability criterion is known and soil and climate data are available. The system predicts days suitable for machinery field work in decade base for any month during the year and for years up to 100 years. As soon as the user enters the required input data, the system displays the results.

The system predictions were compared with actual workdays for two consecutive seasons. There were strong correlations between system predictions and actual data. The system was applied to estimate field workdays for three field operations, seedbed, seeding and weeding in mechanized rainfed sector of Gedarif area, the average workdays for the three operations were 27, 24 and 23 days, respectively.

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