Predicting of Field Working Days of Planting and Harvesting Operations for Sorghum Crops Damazeen Area (Sudan)

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Abstract— *Prediction model was developed to predict suitable field workdays for planting and harvesting operations in South Central Sudan (Damazeen). Predictions were made from a computer model which simulates daily soil moisture in the top 30 cm of soil depth using 11 years of daily meteorological records. The model was tested and validated by comparing its output with the observed workdays during the 2004 farming season on Clay soil types. Results show that there was good agreement between the observed and predicted values using established tractability criteria. A study was conducted to determine the appropriate number of working days in mechanized planting and semi-mechanized harvesting of Sorghum in Damazeen, Sudan in 2010. The number of working days for mechanized planting was estimated about 20 days, and for harvesting was about 23 days with 99% confidence. The allowed limit of soil moisture in clay-loam texture, for having the capability of running field operations was determined to be 14.5% of the weight. In this limit, soil has acceptability of 6.34 mm of water (rainfall) for sowing and 10.62 mm for harvesting at the depth of operation in each turn of rainfall or irrigation. At sowing and harvesting times, 19.3% and 7.5% of the rainfall is converted to runoff. Therefore, the maximum allowable rainfall in a situation that doesn't change the soil condition from the proper situation for mechanized sowing and harvesting operation is 7.6 and 11.41 mm, respectively, in each rainfall turn. For the drainage of excess moisture after rainfall, in sowing and harvesting operations, five and seven days are required, respectively.*

Keywords— simulation model, drainage, proper working days, runoff, soil profile tractability.

I. INTRODUCTION

The most uncontrollable variable in agricultural operations is the number of proper working days in a cropping year. A method for determining the appropriate working days is to obtain a reasonable relationship based on the previous year's temperature and rainfall. This method of probability distribution clarifies the appropriate dates for each key activity throughout a year. Field capacity and climate conditions are the main factors for determining the appropriate time for agricultural operations during the year. The required time for working with field machinery depends on the machine capacity and the number of appropriate working days. Each region of the country has its own climate pattern. Working days of the field is determined by two factors. First, the soil moisture content should not exceed the plasticity limit; second, the rainfall on that day should not be greater than 10 mm. The effect of other climate conditions such as freezing occurrence probability or snowing are not included in the analysis of soil working days (Witney 1988).

Adverse soil condition makes it difficult or impossible to perform some field operations. Suitable days, being related to random weather related events, are thus also random in nature. Information about the probability distribution of suitable days during critical production periods would help farmers determine their optimal machinery complement and crop mix. Probability of a working day (PWD) is the fraction of workable days to all days in a work season, which often is used in management of agricultural mechanization. For example it is used to determine timeliness cost, optimum capacity of a machine and the required machine capacity (Saglam and Ibrahim, 2011). Accurate information on the number of suitable days for field operations is important in design, development, and selection of efficient machinery systems for crop production (Khan et al., 2011). In order to predict the amount of work that can be accomplished, the time available within the optimal period for the required operation must be known. The time available varies considerably from year to year as weather conditions vary. Selection of the optimal machinery set for long-term production on the farm depends upon accurate assessment of the days available for performing each field operation (Rotz and Harrigan, 2005). The most restrictive factor for harvesting operation is the soil moisture. Soil moisture content and the vagaries of weather are the two major factors which determine the amount of time available throughout the year for field operations (Witney, 1988).

In a poor season, little time may be available for performing one or several field operations under acceptable conditions. A favorable weather pattern and a friable soil, provide available or possible time within which the field work can be completed without working excessively long hours, or working in unsatisfactory conditions he weather interacts both with the soil to vary soil workability for tillage operations and with the crop to vary yield and moisture content at maturity for harvesting operations, whilst the influence of the weather on soil tractability affects all operations to a greater or lesser extent. The workability / trafficability of the soil is dependent on the soil moisture content which can be evaluated from soil and weather variables (Witney, 1988).Provided that all the relevant operating conditions can be specified for the soil and the crop, suitable workdays can be identified. As a preliminary stage, commonly accepted operational times are used to provide workday data for strategic planning purposes. It is common practice with respect to farm operations within the savannah agro-ecological zone of Nigeria to find farmers using their intuition and traditional knowledge acquired from their mentors, using unconventional methods in estimating suitable field workdays rather than the scientific methods which are more reliable and dependable. The scientific methods are more useful in estimating suitable field workdays for better farm yield or benefits. Thus, it is the aim of this paper to collated useful weather, soil moisture and soil conditions (soil liquid and plastic limits) parameters using soil moisture budgets empirical methods which was then programmed using Virtual Basic 2008 to segregate the suitable and non-suitable workdays for planting and harvesting operations on a mechanized maize farm. Available time for any field operation is a function of a suitable workday. Cooper et al., (1997) stated that the time available for completion of field work depends on such factors as weather, soil characteristics, hours worked per day, number of days allowed for completion of field operations, scheduling efficiency, machine reliability and field efficiency. Principally, soil moisture budget.

A significant part of the annual rainfall occurs in summer during sorghum sowing and the sowing date has a significant influence on final yield and in case of delay in operation, the farmers face the extra costs as a result of not performing operations in a timely manner. Dura is a staple food crop, highly delicious and balanced nutritiously. It is a good source of carbohydrates, Vitamins and Irion etc. According to Dura Swing and harvesting operations, there is an optimum time. Period for swing and harvesting to ensure maximum crop yields. If the crop is planted at a time other than within the determined periods this will lead to reduction in yield. When the crop matures, and is not harvested within the optimum time, this will lead to field losses that may increased by unfavorable weather conditions. Therefore, it is very important for farmers to be aware of the number of the days in which mechanized sowing and harvesting can be planned. The most important factor which limits the time of sorghum sowing and harvesting, in farming calendar, is the soil moisture (Bazyar2004).

The general objective of this study was

To determine the number of appropriate working days for sorghum sowing and harvesting in Damazeen area.

The specific objectives are:

1- To determination of the threshold for allowable limiting factor (soil moisture) in sorghum sowing and harvesting

2- Determination of the effective parameters which may change the limiting factor.

3- Determination of the appropriate number of working days for sorghum sowing and harvesting according to limiting factor.

II. METHODOLOGY

The approach used in this study was to study agro-meteorological data obtained from Damazeen Meteorological Station and discuss the usefulness of these in agricultural watershed management. In particular, the problem of predicting suitable field workdays (SFW) was addressed. A model was developed for this purpose based on soil moisture budgeting and established tractability criteria. The model was applied to the watershed under study using agro-meteorological and other data for a period of time. The predicted results were compared with actual observed data on SFW. Details of this procedure are presented subsequently.

2.1 Agro-meteorological and Other Observations

The determination of SFW requires agrometeorological and hydrological data which must be obtained on a daily basis over a period of time. Some data were obtained from the meteorological station while others were obtained by direct measurements.

Since the meteorological station at Damazeen agrometeorological data have been recorded on a continuous basis. These include time, amount and duration of rainfall, wind speed and direction, sunshine hours, open pan evaporation, air temperature and soil temperature. Other measurements include runoff, soil moisture, field capacity, permanent wilting point and actual available field workdays. Runoff at various seasons was obtained from standard runoff plots under conventional tillage practice for the area. Daily soil moisture was obtained by sampling from Damazeen experimental farm. The moisture content was determined by the gravimetric method. Actual observed SFW were obtained by following the activities of the Farm Management Unit of area of the study. Days in which field work could not be done due to rain, too high moisture or too low moisture were recorded. These observations started in August 2004 and are on a continuous basis in order to generate a long term data.

2.2 The Water Balance Model

A model was developed based on the concept that the available soil moisture is a function of previous precipitation, irrigation, drainage, evapotranspiration and surface runoff. The soil moisture content on

any particular day is the difference between what it was the previous day plus any addition through precipitation or irrigation and the losses through runoff, drainage, and evapotranspiration. Thus, daily soil moisture was estimated.

2.3 Soil Tractability Criteria

Soil tractability is the ability of a farm land to permit a machine to operate and perform its function efficiently without damaging the soil. For operations that involve soil engaging, such as planting and harvesting , the soil is tractable if it has sufficient bearing strength to support the weight of the machine, can develop adequate shear resistance to avoid slip and soil damage and can produce a good soil tilth without the formation of large clods. This soil behavior varies with soil types and the operation being carried out. It is also dependent on the soil moisture status. Based on literature and actual field observation of machinery operations at DAMAZEEN, the following criteria were used for deciding when soil is tractable:

a) Moisture content in the top 30 cm of soil depth not more than 80% of field capacity

b) Moisture content in the top 30 cm of soil depth not less than permanent wilting point.

C) If the previous day was a workday and today's precipitation was no more than 10mm.

Any day in which the soil is tractable using the above criteria is regarded as a suitable or available workday.

TABLE 1
RESULTS OF ANALYSIS ON SOME PHYSICOCHEMICAL PROPERTIES OF THE SOIL IN THE STUDIED AREA.

OC%	P ppm	EX.Ch.Cations Meq/100g			CEC Meq/100g	ESP	$Caco_3$	Texture (%)		
		Na	K	Ca+Mg				Clay	Silt	Sand
0.3	6	4	0.8	38	43	6	4	72	18	10

The following equation calculates the maximum soil moisture capacity

Step one:-

Actual Evapotranspiration (AET) according to (equation no 1):-

$$AET = ETP \times KD \times KR \times KS \quad (1)$$

By this equation we can determine the Evapotranspiration (for type of soil clay – loamy) at rainfall area where:

ATE = actual evapotranspiration (mm/day).

Kd = 0.55 (soil dryness factor) according to Adam and far brother (1977).

Kr = 0.55 (rain fall correction factor) according to schwabe (1966).

Ks = 0.4, 0.5, 0.8 in June, July, August) respectively (Soil Cover factor) assumed.

Step two:-

Determine runoff (Q):-

If the amount of rain fall (Ra) is enough to cause runoff then calculate runoff by equation no (2) with excel.

$$Q = (Ra - 0.2S)^2 / (Ra + (0.8S) \tag{2}$$

where:

Q = Runoff (mm / day) depth.

Ra = annual of rainfall (mm/day).

S = soil storage parameter was determined according to

$$S = (25400/RCN) - 254 (3)$$

Where:

RCN = runoff curve number was 89 as per schwabe (1966).

$$S = (25400/89) - 254 = 31.39$$

Step three:-

Calculate drainage:-

Determine maximum Soil capacity (W or FC):-

The soil capacity to accept moisture up to field capacity (fc) / mm.

$$w = (c - pwp) \times z \times d) / 100 \tag{4}$$

Where:

W =height of water (cm) until Z cm of the soil depth. i.e. the soil capacity to accept moisture in the appropriate mode of operation. = the weight of the soil moisture storage capacity (field capacity).

C=soil moisture in appropriate mode for machine operation which was estimated between 14 to 16% for heavy textured soil (Bakhtiari 1997).

Pwp=weight of soil moisture at permanent wilting point which was considered 10.2% in study (ZarinKafsh 1998).Z = soil root zone depth (cm).D = soil depth (cm), Drainage is calculated using the equation No (5).

$$D = (smp + Ra + Fc)/(2 \times pwp) \tag{5}$$

Where:

D = drainage (mm/day).

Smp = soil moisture potential (percentage) 80%.

Pwp = permanent wilting point.

Step four:-

From Smp, Ra, AET, D and Runoff the program will calculate the soil moisture content (Sm) of a specified day according to equation no (4)

Calculate soil moisture content (Sm) (mm/day).

$$Sm = Smp + Ra - Ru - D - AET (6)$$

(All parameters define above).

Equation no (4) which has been developed from the equation

Ma = Mp + Qp + Qr + Qd + Qe as given by witney, B.(1988) where

Ma = soil moisture of a specified day.

Np = soil moisture in the previous day

Qp = daily rainfall

Qr = Runoff

Qd = drainage

Qe = actual evapotranspiration

Step five:-

To determine the soil work ability for planting and harvesting operation in particular day, the following criterion was adopted:-

If the soil moisture content (Sm) of that day is > 80% of the soil capacity (Fc) the program will write (No) (no working day) and if it is <=80% of the soil field capacity it will write (Yes) (working day).

Step six:-

The output data include all the input data as well as estimated soil moisture, an indication of whether the day is a good or bad workday (1 or 0), and the total SFW for the time period studied. The programme was designed to be interactive and allows the user easy access to the input data file so that records can easily be updated or changed.

2.4 Computer Implementation

A computer program was written in Visual Basic 2008 language designed to compute daily soil moisture content for the period beginning May and to ending October for each year of the ten years of the study period and to further apply tractability conditions to the soil moisture balance to estimate good machinery field work days and days best suited for planting and harvesting at damazeen farms. The computer program used climate and soil information for the area to estimate suitable workdays for agricultural machinery. The flow chart for the programme is shown in Fig. 1. It starts by initializing control parameters namely the starting date for the simulation, moisture content on the starting date, and time frame for the simulation. The meteorological data of interest are then read from a data file. These include rainfall, pan evaporation, relative humidity, maximum and minimum temperature, and soil temperature. The ractability conditions are set as described earlier. The next stage in the programme is to estimate daily soil moisture. First, the moisture content of the soil on the previous day is established. This is followed by establishing the precipitation for the present day from the values already read. Runoff is next determined followed by drainage (equation 3).

2.5 Model Validation and Application

Daily meteorological data for the period April through October, 2004 were used to validate the model. These were the months for which there was available data, especially soil moisture and actual observations of suitable field workdays. It was very important to test the predictive ability of the model before it could be adopted in any further study. Once an acceptable prediction is obtained on available data, projections can be made into the future by incorporating probability principles in predicting the relevant model parameters. Thus, the model was tested by comparing its predicted with observed suitable field workdays for heavy clay soils of south Central Sudan. For statistical confidence, the predicted and observed SFW were subjected to regression and correlation analyses.

III. RESULTS AND DISCUSSIONS

3.1 Number of appropriate working days for planting machine

According to Table 4, sowing calendar of Sorghum (April) was divided into 5 days groups, and in each group, number of the days in which rainfall was more than 7.6 mm (allowable rainfall) in addition to 5 days needed for field capacity differed in the number of the days in that group. The remained days were working days and in the same way, working days were calculated for different years. Then, the statistical parameters were estimated for each group. Since the t value for confidence level of 1% and degree of freedom of 10 (number of years minus one) were obtained from Table t, appropriate working days for each group were placed between the high and low levels ($p<0.01$). Therefore, average sum of the two categories thresholds was determined in calendar ($p<0.01$). In this study, estimated number of these days was 19.69 days (Table 2).

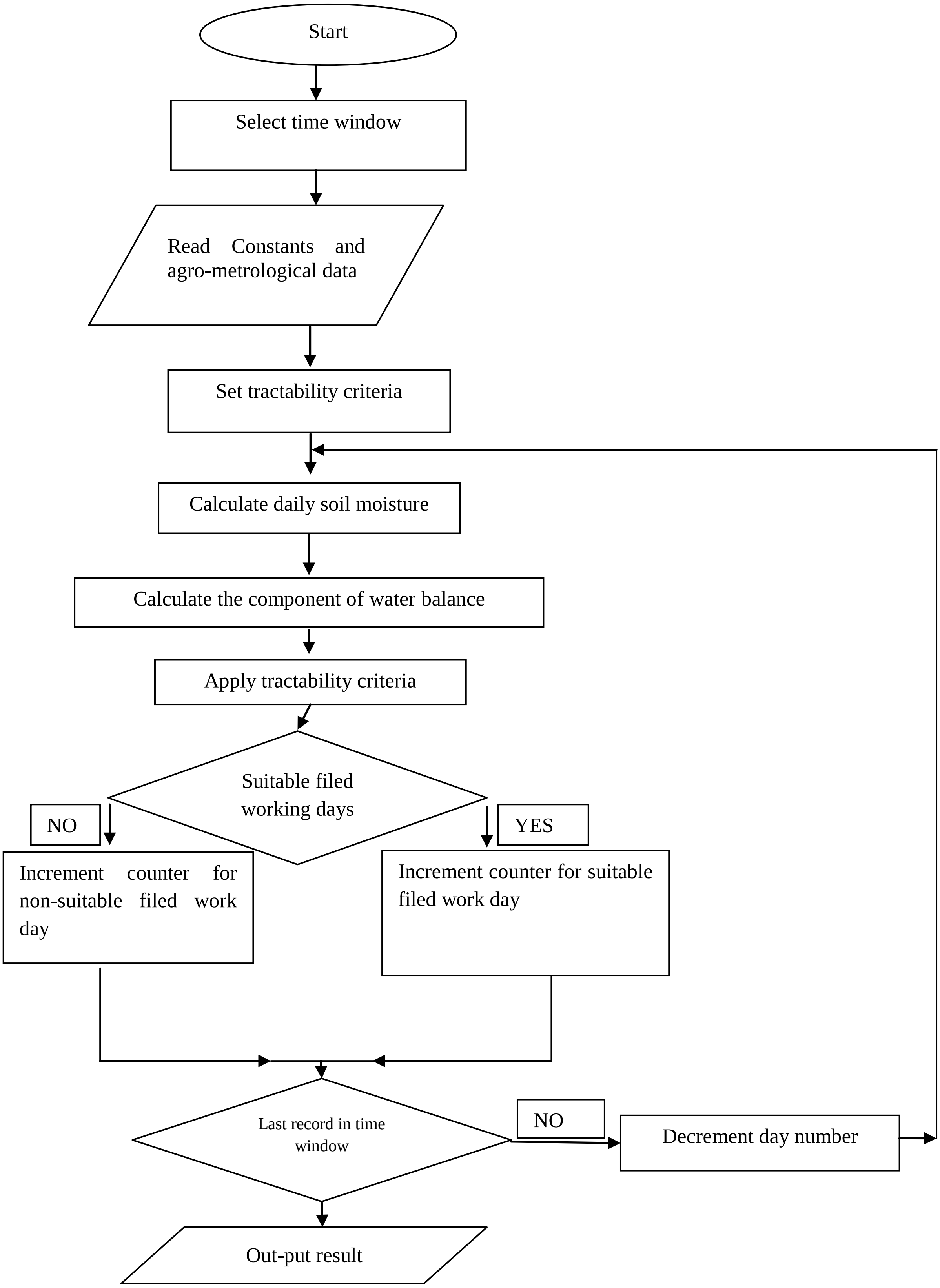

FIG. 1: Flow Chart of Suitable Field Workday Programme

3.2 Proper working days for harvesting machine

According to Table 3, number of the days in which rainfall was higher than 11.41 mm (allowable rainfall) at harvest (November) plus seven days for soil moisture to reach the appropriate mode of operation differed from the number of days in each group and remained days were considered as working days for that group. Number of working days for each year took the same way. Then, mean and standard deviation for appropriate working days in each category were obtained and t value with 1% probability and 18 degrees of freedom were obtained from Table t and upper and lower limits of each category were deter-mined. Appropriate working days are between these two limits ($p<0.01$). Therefore, considering the grand mean of the two categories thresholds, with 99% probability, proper working days for machine will be determined in farming calendar. Based on Table 3, number of these days was 23.22. Estimated t value at 1% probability and 11 degrees of freedom was equal to 1.33. Number of working days for mechanized planting and semi-mechanized harvesting operations in Damazeen province were 19.69 and 23.22, respectively, with 85% probability in clay-loam soil. To predict the number of machines in order to timely complete the operation and prevent the costs due to failure in timely operation, it is essential to be aware of the planting acreage and the machine working capacity as well as the number of proper working days.

TABLE 2
NUMBER OF APPROPRIATE WORKING DAYS IN A CALENDAR FOR MECHANIZED SORGHUM SOWING IN DAMAZEEN AREA

Source		Number of working days in mid-April in 5-day groups			Number of working days in second late-April in 5-day groups		
	Symbol	16-20	21-25	26-31	1-5	6-10	11-15
Average	X	4.11	3.27	3.16	2.77	2.83	3.55
Correction factor	Cf	304.22	193.38	180.5	138.88	144.5	277.55
Sum of squares	SS	45.78	77.62	98.5	67.12	74.5	62.45
Degree of freedom	DF	10	10	10	10	10	10
Variance	S^2	2.69	4.56	5.79	3.94	4.38	3.67
Standard deviation	S	1.64	2.13	2.4	1.98	2.09	1.91
Higher threshold	L	8.86	9.44	10.11	8.5	8.88	9.08
Lower threshold	L^-	-0.64	-2.9	-3.79	-2.96	-3.22	-1.98
Number of working days for each group	Medium	4.11	3.27	3.16	2.77	2.83	3.55

TABLE 3
NUMBER OF PROPER WORKING DAYS IN AGRONOMICAL CALENDAR FOR SEMI-MECHANIZED SORGHUM HARVESTING IN DAMAZEEN AREA.

Source		Number of working days in mid-April in 5-day groups			Number of working days in second late-April in 5-day groups		
	Symbol	16-20	21-25	26-31	1-5	6-10	11-15
Average	X	5	3.69	3.69	3.23	3.15	3.46
Correction factor	Cf	407.57	320.2	222.36	183.21	236.26	195.84
Sum of squares	SS	26.43	51.79	88.64	89.79	72.74	73.16
Degree of freedom	DF	10	10	10	10	10	10
Variance	S^2	1.46	2.87	4.92	4.98	4.04	4.06
Standard deviation	S	1.19	1.69	2.21	2.23	2	2.01
Higher threshold	L	8.42	9.55	10.05	9.64	8.9	9.24
Lower threshold	L^-	1.57	-0.17	-2.67	-3.18	-2.6	-2.32
Number of working days for each group	Medium	5	4.69	3.69	3.23	3.15	3.21

IV. SUMMARIES AND CONCLUSION

A simulation model was developed to predict suitable field workdays for soil tillage operations in Ilorin, south Central Sudan using established tractability criteria. The model was validated by comparing its predictions with observed suitable field workdays data for Ilorin on two soil types, namely sandy loam and clay. There was good agreement between the predicted and observed field workdays data. Despite the minor deviations of the predictions from the observed data, it can be inferred that the model is a veritable tool for predicting suitable field workdays for tillage operations. Because information on suitable field workdays may be crucial to farm managers during those periods of the farming season when weather and soil conditions might cause delay in farm operations, the need for this information becomes imperative for planning purposes. Equipped with this information, the farm manager could make better decisions with respect to machinery/equipment selection and scheduling of field operations in order to optimally utilize available time. A major strength of this prediction model is that virtually all the input parameters were either measured or determined at the experimental site.

ACKNOWLEDGEMENTS

This work would not have been possible without the financial support of the Sudan, Sudan University of Science and Technology and "Grassland Outstanding Talent" Project-Xilingol Vocational College, Inner Mongolia – China. The authors express their sincerest gratitude to all of them.

REFERENCES

[1] Adam, H.S. and Farbrother, H.G. (1977). Crop water use in irrigated and rain fed agriculture in the Democratic Republic of Sudan. Paper presented at the UN water conference, Mar Del Plata, Argentina, March (1977).

[2] Anatolia project (GAP) area. African Journal of Agricultural Research. 6, 30: 6416-6424 www.academicjournals.org/ajar/PDF/.../Saglam%20and%20Tobi.pdf.

[3] Bakhtiari MR. Investigation and selection of the most suitable combination of common tractors and moldboard plows. Thesis, Master of Science, Mechanics of Agricultural Machinery in Shiraz. 1997. (in Persian)

[4] Bazyar K. Determination on number of working days of mechanized planting of sugar beet in Islam Abadegharb. Thesis, Master of Science, Islamic Azad University Science and Research Campus in Tehran. 2004. (in Persian).

[5] Khani, M., Keyhani, A., Parsinejad, M.andAlimardani, R., 2011. Verification and sensitivity analysis of a model for determination of probability of a working day for tillage. International Agrophysics, 25: 27-35.

[6] Rotz, C., A and Harrigan, T., M 2005. Predicting suitable days for field machinery operations in a whole farm simulation Appl. . Eng. Agric, 21, 4: 563-571.

[7] Saglam, C. and Ibrahim, T., 2011 Distribution of tractor available workdays over the southeastern

[8] Schwab, G.O.; Frevert, R.K.; Edminster, T.W. and Barnes, K.K. (1966).Soil and Water Conservation Engineering, 3PrdP edition, John Wiley and Sons, 1966.

[9] Witney B. Choosing and using farm machines, Longman Scientific and Technical. New York. 1988.

[10] ZarinKafsh M. Fundamentals of soil science and environment in relation to plant. First edition. Islamic Azad University Publication 1998.Vol. 1.