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Soil Moisture Content as a Determining Factor for Machinery Selection

III. Estimation of field workdays for machinery selection under dry farming conditions

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ABSTRACT

By applying the soil moisture content (SMC) prediction model to the weather data for the period from 1981-1993, the suitable workdays were obtained. Testing these results from the Rahad Scheme data records showed high significance. The correlation coefficient was found to be .0.99show the effect of timeliness cost, a utilization factor (Ut) was determined by dividing the available working days by the total days. The utilization factor is then adjusted using a range of reliability from 30-80% depending on spare part availability and skilled labour. Further analysis were made to demonstrate the effect of workable days on the selection of implement width and cost using good, bad and average rainy seasons and different levels of reliabilities. It was found that the machine width was by the rainfall frequency.

INTRODUCTION

Since the primary tillage operation. to a large extent, dictates the total requirement on arable farms, the estimation of suitable days for tillage and crop establishment forms an important input for farm planning decision and an essential part during machinery selection (Simalenga,1989).

Thus, one management problem that faces the farmer under arid conditions is to select and utilize equipment in such a way as to take maximum advantage of his good luck with the weather and to suffer the minimum loss when his luck is bad.

It has been well established in literature that timeliness in performing a field operation is an important part of successful crop production (Burrows and Siemens, 1974; Hunt, 1977; Kepner *et al.*, 1978).

Hunt (1977) stated that timeliness costs arise because of the inability to complete a field operation in reasonably short time. There are no out- of-pocket costs but reductions in potential return, as when the yield and quality of a crop are reduced because of delays in harvesting. He has developed an equation to predict timeliness cost as follows:

$TC = (KYVA)/ (XU_tZ)$……………………(1)

Where:

TC = Timeliness cost ($).

K = timeliness loss rate factor {indicates the rate at which potential crop value decreases with time (l/day).

Y = Potential yield (kg/ha).

V = Crop value ($/kg).

A = Area (ha).

X = Scheduling factor (4 for balanced operations and 2 for delayed or premature operations).

U_t = Utilization factor (expected working days divided by the total days). This factor is location specific.

Z = Effective machine capacity (ha/day).

The utilization of a machine for a specific operation is the ratio of the time available for the operation to the total number of days in the farming season and it is called the utilization factor (Hunt, 1977).

Hunt (1977) included the timeliness cost in his optimum machine width equation as follows:

$W = \{(2.78A)/FC\%\ PmSeY\}\ \{L+ T+TC\}^{0.5}$

Where:

W = Machine width (m).

A = Area (ha).

FC% = Fixed cost (percentage of the purchase price).

Pm = Purchase price of the machine per meter($).

S = Travel speed (km/hour).

e= Field efficiency (percentage).
L = Labor cost ($).
T = Tractor cost ($).
TC = Timeliness cost ($).

Other researchers (Von Borgen, 1967; Eradat Oskoui, 1981, Witney and Oskoui, 1982; Hertz and Esmay, 1983) have developed machinery selection models based on traction, plow draft, weather possibilities available workdays for a given climate, soil type, labour and time penalty cost framework.

The objective of this research is to develop a computer model based on meteorological data and soil characteristics to estimate the optimum field work days for the purpose of selecting. planning and scheduling farm machinery in Rahad Scheme.

MATERIALS AND METHODS

Model Development

In order to develop a computer model to predict the daily fluctuations of soil moisture content. the water balance equation.(l) was used. The components of the equation were modeled using Pascal language. And the input data were as follows:

(l) Soil physical properties: Field capacity (EC), perminant wilting point (PWP), soil type, initial soil moisture content and some correction factors: Rain distribution factor (kr), soil cover factor (ks) and percolation coefficient (DC).

(2) Record of the daily rainfall and potential evapotranspiration.

The general features of the model can be summarized as f

(3) Input data entry is made directly to the screen.

(4) Output data will be displayed on the screen and they include the actual evapotranspiration (AWT) runoff, percolation and moisture content Initially, evapotranspiration is obtained by entering the meteorological data which include radiation, hours of sunshine. wind velocity, saturation vapor pressure and energy in the soil.

The operational steps of the soil moisture prediction model were as follows:

Step l:

This involves entering the soil moisture content on previous day (SMp), soil physical properties (FC, PWP), potential evapotranspiration (PIE). rainfall and correction factors and constants. Then the model will calculate the actual evapotranspiration (AET) according to equation (5)of part II of this series of papers. The correction factors used were kd = 0.55,ks = 1 and 0.55

step II:

If the amount of rainfall is enough to cause runoff, then the model will calculate the runoff from equation (7).

Runoff curve number (RCN) was determined from estimates of Schwab el al. (1966) as shown in Table (2).

The model will determine the value of the maximum potential difference between rainfall and runoff as follows:

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

step III:

The model, then, calculates percolation according to equation (10).

step IV:

From SMP, AET, Ra, Pe and runoff the model will calculate the soil moisture content of a specified day.

By taking 0.80FC as the maximum soil moisture content for ploughing, the program will write (No) if the soil moisture content is above 0.80FC (non-workable day), and (Yes) if the soil moisture content is below 0.8FC (workable day).

Then the workable days are summed in each month, ranked ascendingly, and probability of occurrence was calculated as well as the return period.

Model Verification

Using the Model, the average number of working days for the month of June, July and August for the penod from 1981-1993 were determined from the meteorological data. The results were then compared with the actual working days on records for-those months in the block number I, 5 and 9 of the Rahad Scheme.

Machinery Selection and Scheduling

The economic selection of equipment is a complex problem that has some unique characteristics compared with other industries. First, most farms are rather small-scale operations, have diversified enterprises and are subject to many special location conditions, thus each farm must be treated as a special problem. Second, since agricultural production is seasonal, equipment will necessarily stand idle most of the time. Also, most field implements are operated by a shared power unit, the tractor, and a change in one tractor-implement operation will affect the whole system. Consequently, the complete system of implements must be considered. Third, the supply and ability of farm labour, which usually includes management personnel, is quite varied. Finally, a characteristic that is widely recognized but difficult to analyze, is the need for timely operations because of the seasonal requirements of crops.

The machinery selection equation, in which the economic value for Timeliness is included, has been developed by Hunt (1977) and is shown in equation (2). The equation involves the estimation of a utilization factor in order to obtain the timeliness cost factor.

In this study, the time available for ploughing, ridging, planting and spraying and the total days available for these operations were found from the records in the Rahad Scheme. Then, the machine utilization factor was determined using a range of reliability factor (R) from 80% for best-case scenario to 30% for worst-case scenario, depending on workshop service facilities and spare part availability. Thus an adjusted utilization factor. U_t was obtained as follows:

$U_t = UR$ ……………………..(3) Where: U = Utilization factor.

Then, the adjusted utilization factor values were used to determine timeliness cost using equation (l).

The value of timeliness cost variable reliability and for a range of working days (bad, average and good seasons). were used to determine optimum machinery width. The results were statistically tested for significance using a hypothetical farm in the Rahad Scheme. Moreover, all field works were assumed to be done by one operator working effectively for 10 hours per day. The machine operation variables in this case, which were used in equation (2) to determine the optimum machine width, are shown in Table (l)

Table 1. Variables used in machinery selection

Variable	Symbol	Unit	Value	Source
Fixed cost	FC	$	0.1	Assumed
Purchase price	Pm	Din/m	500000	Agricultural Bank of Sudan
Effective speed	Si	M/s	2	Operating speed
Field efficiency	E	-	0.8	Assumed
Timeliness cost	TC	Din	Variable	Calculated
Tractor cost	K	Din	Variable	Calculated
Timeliness loss value	K	1/day	0.001	Assumed
Yield	Y	Kg/ha	174	Ministry of Agriculture
Yield value	V	Din/ha	20	Local market
Area	A	Ha	420	Assumed
Scheduling factor	X	-	4	Equation (l)
Utilization factor	U_t	-	Variable	Calculated
Labour cost/hour	L	Din.	33.5	Current salary
Operating time/day	Z	Hours	10	assumed

RESULTS AND DISCUSSION

The workable days prediction model was designed to predict the SMC status of the ploughed layer on daily basis, by incorporating the daily weather parameters (rainfall and PET) which affect the SMC. By incorporating a workability criterion in the soil moisture content model, the number of suitable working days can be obtained.

In this study, the workability criterion was used as 80% of the field capacity, i.e 30.7 moisture content when the slip and draft are acceptable as shown earlier. At that soil moisture content there was marked decrease in soil shear strength and bulk density, as well as acceptable soil tilth. The selected criterion (0.8 FC) contradicts with Simalenga (1989), Witeny and Oskoui (1982) and Selerio and Brown (1972), and this could be attributed to the fact that there were marked differences in the soil under consideration both in type and composition.

The result of correlation analysis between the predicted and observed workable days (Table 2) showed a correlation coefficient of

0.99, which is highly significant. Thus the model can predict the workable days precisely and accurately.

Table 2. observed and predicted workable days

Month	Observed workable days	predicted workable days
June	28.0	28.4
July	27.2	28.5
August	23.2	24.1

Using historical meteorological data (rainfall and potential evapotranspiration) for the period (1981-1993), the soil moisture content prediction model was used to predict the daily changes of the soil moisture content and the available workable days.

Table (3) shows the summary of workable days.

Referring to Table (3), it was clear that there was a wide variation in the number of workable days (ranging from 41-92) from one year to another. This indicated that some seasons had intensive rainfall (less workable days), some had witnessed drought (more workable days). while others had moderate rainfall (average workable day). Most of the variations occurred in the month of August, indicating that most rainfall occurred during this month, which is the normal trend of the rainy season in the Sudan.

Table 3. Predicted workable days.

Year	June	July	August	Total
1981	30	13	-	43
1982	-	-	-	-
1983	24	27	12	63
1984	30	26	31	87
1985	24	31	30	81
1986	30	31	31	92
1987	28	31	31	90
1988	28	-	18	46
1989	30	31	16	77
1990	30	31	31	92
1991	-	31	24	55
1992	-	31	10	41
1993	30	31	31	92
Mean	28.4	28.5	24	
SD	2.6	5.47	8.7	

For the purpose of this study, the time available for the mechanized operations of ploughing, ridging, planting and spraying was found to be 132days, while the total days were 138 days (from 15th March to 31st of July (Rahad Annual Reports, 1998). Accordingly, the utilization factor U_t was calculated as follows:

U_t = 132/138 0.88

This factor was adjusted to take into account the reliability of machinery in use. The values obtained from the adjusted utilization factor ($U^/$), using a reliability range from 30% to 80% are shown in Table 4 as well as the results of equations (l) and (2).

Correlation analysis to show the effect of timeliness cost on machine width gave correlation coefficient of 0.65 which indicates that timeliness cost have moderate effect on choosing machine width at 0.95 probability level.

Table 4. Effect of reliability and timeliness cost on machine width.

Reliability %	U_t	TC (SD)	Machine width (m)
30	0.26	140.5	3.67
40	0.35	101.5	3.59
50	0.44	83.1	3.55
60	0.53	68.9	3.52
70	0.62	58.9	3.50
80	0.70	52.2	3.48

To show the effect of workable days on choosing the width under variable reliability levels, using a bad rainy season (maximum workable days), good rainy season (fewer workable days) and average rainy season and employing equation (2) the results are shown in Tables 5, 6 and 7.

Table 5. Effect of workable days on machine width (good rainy season).

Reliability%	Ut	TC (SD)	Machine width (m)
80	0.56	65.3	3.50
70	0.48	76.1	3.54
60	0.41	89.1	3.56
50	0.34	107.5	3.60
40	0.28	130.5	3.63
30	0.21	174.0	3.70

Table 6. Effect of workable days on machine width (bad rainy season)

Reliability%	Ut	TC (SD)	Machine width (m)
80	0.8	45.7	3.47
70	0.7	52.2	3.48
60	0.6	60.9	3.50
50	0.5	73.1	3.53
40	0.4	91.4	3.56
30	0.3	121.8	3.63

Table 7. Effect of workable days on machine width (average rainy so
Reliability%

Reliability%	Ut	TC (SD)	Machine width (m)
80	0.68	53.7	3.49
70	0.60	60.9	3.50
60	0.50	73.8	3.53
50	0.40	91.4	3.57
40	0.34	107.5	3.60
30	0.23	146.2	3.68

The correlation analysis at 0.95 level of significance of the effect of timeliness cost on machine width at different levels of reliability and different rainy seasons variations results in a correlation coefficient of 0.22for good rainy season, and 0.53 for moderate rainy season. The results indicate that there is no significant effect of timeliness cost on machine width in the bad rainy season since there is no constraint on the number of workable days. On good rainy seasons. there is a significant effect of timeliness on machine width because of the effect of the lint number of workable days. As for average rainy seasons. the width moderately affected by the timeliness cost.

CONCLUSION

1- Using 0.8 FC as an index for workability, workable days can be predicted from the model.
2- Using the predicted workable days. the utilization factor at different levels of reliability was calculated.
3- In good rainy seasons there is a weak correlation between timeliness cost and the selected machine width.

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