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COMPUTER SIMULATION MODEL OF AVAILABLE FIELD WORKDAY FOR NSUKKA FARMING ENVIRONMENT.

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ABSTRACT

Information on available field workdays (AFW) for agricultural operations in general and tillage operation in particular is required for optimum management and scheduling of operations. This data vary from place to depending on the weather, soil and crop types. Agro meteorological Data and actual AFW for tillage operation were obtained for 10 years (1992-2001) at Nsukka, Nigeria. A simulation model was developed for estimating AFW for tillage operations. The model is based on estimating field soil moisture using a soil moisture budgeting technique. This technique takes into consideration precipitation, drainage, surface runoff and evapotranspiration. The soil moisture estimated is compared with established tractability criteria to decide whether a particular day is a good working day or not. The model was used to predict AFW for tillage operations in Nsukka from 1992 to 2001 planting seasons.

Over the ten - year period, the mean AFW observed were 9, 23, 20, 16 for April, May, June and July respectively. Good agreement between predicted values and actual observations was obtained. The overall mean percent deviation of the predicted values compared to observed values was 16.9% thus, the model developed can be used for predicting AFW for tillage for the area.

KEY WORDS: Simulation Model, Available Field Workday, Soil Tractability, Soil Moisture Budgeting.

INTRODUCTION

Available field workdays have become important as part of the necessary tool in scarce resource allocation to profitable agriculture and farm management. Farm machinery planning and operations require decisions as to when the soil is tractable or non-tractable. Tractability by definition is the ability of a soil to support the movement of farm machinery and allow satisfactory performance of its intended functions along with the associated implement without significant damage to soil structure (Hassan and Broughton, 1975). During critical periods of the growing season, the days in which weather and soil conditions permit field work to be done are referred to as workdays. The time spectrum for field operation may be up to three months but the actual good working days may be limited to one month since for some days may be too wet, too dry or there may even be precipitation. If the soil moisture is too high, working the soil ill lead to puddling compaction, soil quality deterioration and the general loss of soil strength. For other operations this condition will lead to increased wheel slip, impaired traction and an increase in the time spent for fieldwork. If the soil moisture is too low, ploughing may lead to large clods formation, excessive energy demand and poor quality of work. These will eventually lead to non-sustainability in our agricultural production.

Good working weather is time-dependent especially as it affects the operations of tillage during seedbed preparation and harvesting of the early crops characterized by their tendency to ripen into the rains. Therefore, planning for timeliness (Hahn, 1971), which is critical to successful farm operation, depends on the knowledge of the work time available. This available time for field work is an important factor in agriculture that greatly influences farm management decisions on size of operation, cropping system, machinery and labour requirements, and even routine management. Lack of accurate and reliable records of available field operation time can result in poor utilization of the optimum time giving rise to under- and/or over- sized equipment use. When this occurs, the probability of profitable farm operations decreases.

Information on available field workdays for different operations, crops and agro-ecological zones are useful to agricultural administrators, managers and farmers for planning purposes. The knowledge is applicable to the specialist areas of traction, drainage, soil meteorology, agronomy, and machinery selection. It may also be useful to farm management decisions and it is a necessary input into many computerized economic model of farm management.

Soil moisture status, sometimes combined with probability analysis (Baier et al; 1978) is perhaps one sure way of estimating available field workday. The exercise may be purely on soil moisture characteristics and/or weather and weather derived variables. Whichever method is adopted, the soil moisture status is estimated, compared to some established tractability criteria and used to predict the available field workdays (AFW). If the soil moisture status meets the criteria, the day is considered an AFW and if evaluated over a period of time, the AFW record for the specific operation is established. Several researchers (Elliot et al., 1977; Idike et al., 1982; Witney and Eradat, 1982; Simlenga and Have, 1994) used soil moisture balance models to estimate the moisture status. While investigators (Russell, 1971; Brown and Van Die, 1974; Baier et al., 1978; Dyer et al., 1978; Dyer and Baier, 1979) applied weather based models to estimate the moisture status. In both cases, the models followed their peculiar principles of estimating soil moisture, though from researcher to investigator, there may be variations in the calculation of the

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components of the model. In spite of the importance of this information on available field workday in our farming system, the study has not yet been integrated into the Nigerian agricultural planning system. For now, works on the determination of AFW are few and isolated (Gwarzo et al., 1989; and Ahaneku et al., 1996). As part of the effort to spread out this important study, this work for the Nsukka ecological zone is undertaken. The work aims at developing a computer based simulation model that can predict available field workday and validating it.

METHODOLOGY

Agro – meteorological and other observations.

As observed above, the determination of AFW requires agro–meteorological and other data that must be obtained on a daily basis over a period of time. Some data were obtained from the meteorological station at the University of Nigeria, Nsukka, while others were obtained from direct measurements. Data were obtained for 10 years (1992 – 2001). Some of the information from the meteorological station included time, amount and duration of rainfall using the Tilting Dine Recording Rain Gauge. Air temperature was measured with maximum and minimum thermometers. Soil temperature was measured by earth thermometers located at 5, 10, 20, and 30cm soil depth.

Other measurements include runoff, soil moisture, drainage, permanent wilting point (PWP), extracted information of field capacity (FC), and the actual observed available field workdays. Runoffs at various seasons were obtained from standard runoff plots under conventional tillage practice for the area. Daily soil moisture was obtained by sampling from Faculty of Agriculture production/experimental farm. The soil moisture content was determined using the gravimetric method. Actual observed AFW were obtained by actual field inspection and trials. Days in which field work could not be done due to rain, too high soil moisture or too low soil moisture were recorded as non-available workdays, the rest of the day was considered as AFW for tillage.

The Soil Moisture Balance Model

A model was developed based on the concept that the available soil moisture is a function of previous precipitation, drainage, evapotranspiration and surface runoff. The concept of the soil moisture balance model is illustrated in Figs. 1 and 2. The soil moisture content on any particular day is the difference between what it was the previous day plus any addition through precipitation and the losses through runoff, drainage, and evapotranspiration. Thus daily moisture was estimated as:

$$Sm_{(i)} = Sm_{(i-1)} + Ra_{(i)} + Ir_{(i-1)} - Ru_{(i)} - D_{(i)} - Et_{(i)} \quad (1)$$

where;

$Sm_{(i)}$ = soil moisture content of soil on day i, mm.

$Sm_{(i-1)}$ = soil moisture content on day i-1, mm.

$Ra_{(i)}$ = rainfall on day i, mm

$Ru_{(i)}$ = surface runoff on day i,mm.

$D_{(i)}$ = drainage on day i, mm.

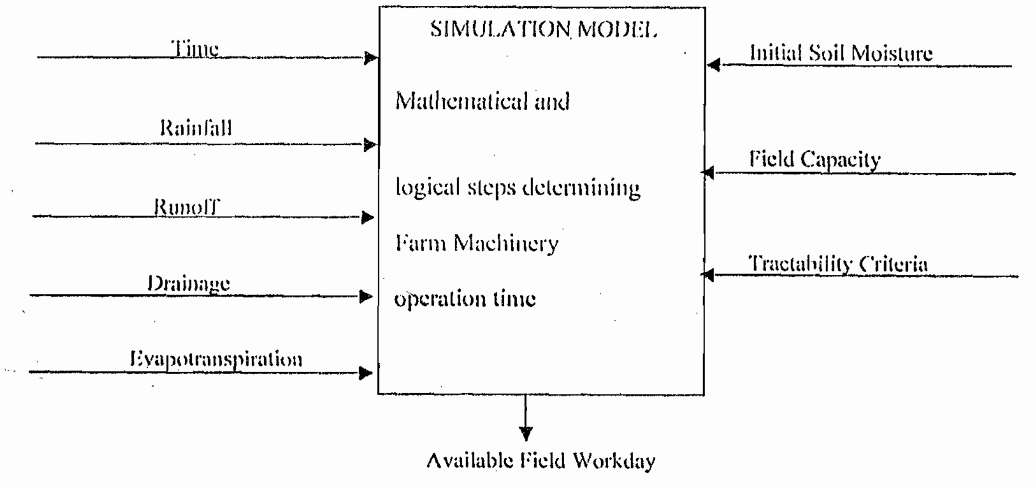

Fig. 1 Soil moisture balance model with various input parameters

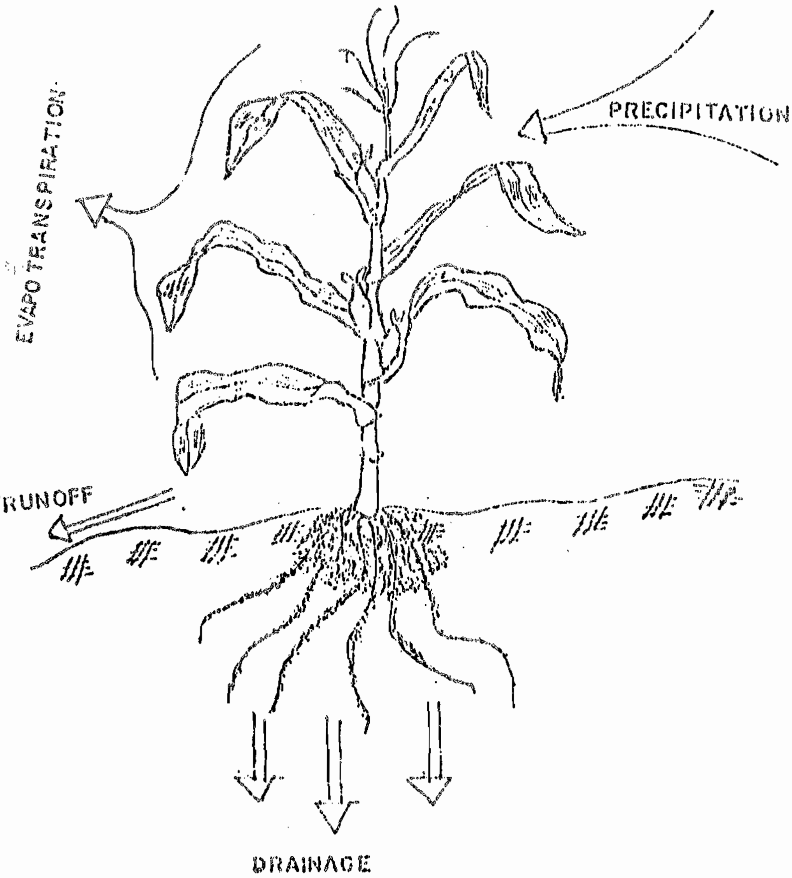

Fig. 2 : Conceptual diagram of the Soil moisture balance model

$Et_{(i)}$ = evapotranspiration on day i, mm.

$Ir_{(i-1)}$ = irrigation water, mm

Surface runoff was computed as a function of current rainfall using an analysis by Mockus (1969). In this technique, runoff is designated by numbers called runoff curve numbers (RCN) and calculated as follows;

$$Ru_{(i)} = \frac{(Ra_{(i)} - 0.2s)^2}{Ra_{(i)} - 0.8s} \quad \text{.......... (2)}$$

where:

s = watershed storage parameter expressed as

$$s = \frac{25400}{RCN} - 254 \quad \text{.......... (3)}$$

$$PD = \left[\frac{OV - PV}{OV}\right] \quad \text{.......... (6)}$$

where

PD = percent deviation;

OV = observed value;

PV = predicted value.

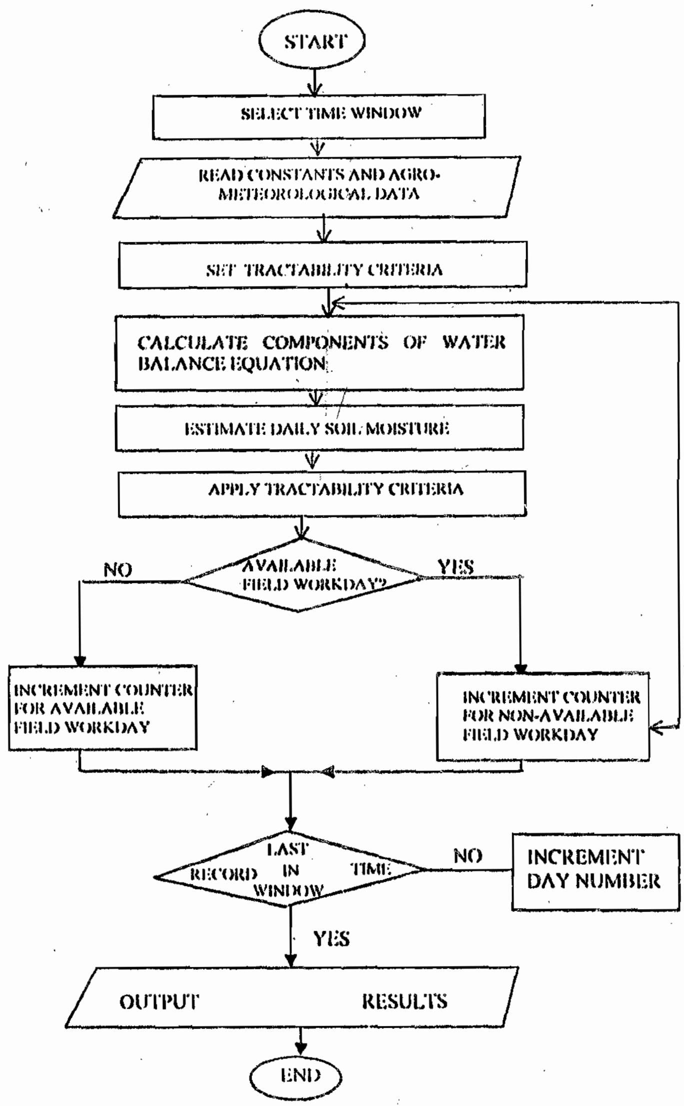

Fig 3. Flowchart of Available Field Workday Computer Programme.

RESULTS AND DISCUSSION

Meteorological Observations

Some of the meteorological data obtained are summarized in Tables 1-3. The mean annual rainfall for the 1

Table 1. Observed monthly rainfall (mm), 1992 – 2001 at Nsukka

Month	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Mean
Jan.	2.1	-	48.3	-	32.3	-	-	23.11	1.27	0.25	10.7
Feb.	-	-	-	-	16.9	-	-	36.22	-	-	5.3
Mar.	13.1	23.3	33.6	9.5	37.3	66.1	18.6	28.2	21.08	33.27	37.0
April	13.7	103.8	143.8	132.6	110.1	130.4	160.6	260.61	136.4	143.5	142.5
May	183.6	82.1	222.7	155.9	200.1	332.5	91.3	151.8	161.29	102.1	168.4
June	146.4	158.0	305.3	328.6	217.7	264.9	278.3	177.3	413.01	262.13	255.1
July	126.6	83.1	377.9	271.7	162.2	91.0	133.3	182.63	258.39	109.45	179.6
Aug.	113.7	207.4	221.5	460.0	291.7	310.6	81.6	232.2	314.17	126.26	235.9
Sept.	413.8	188.6	433.2	235.2	234.4	297.5	317.2	333.0	235.72	305.03	299.3
Oct.	137.7	286.7	129.7	120.0	170.9	259.8	190.7	144.24	172.22	126.22	173.8
Nov.	61.3	16.0	4.2	135.3	11.3	58.2	8.3	11.18	3.05	45.72	35.5
Dec.	-	43.3	-	-	-	3.8	-	-	-	-	4.7
Total	1302	1192.3	1920.2	1934.3	1484.9	1814.8	1280.1	1580.6	1716.6	1253.9	1547.8

Table 2. Observed mean monthly relative humidity (%), 1992 – 2001 at Nsukka

Month	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Mean
Jan.	75.4	53.4	62.1	56.7	66.7	66.5	58.5	56.72	65.72	62.01	62.4
Feb.	64.7	62.2	63.5	61.4	66.5	58.7	63.8	62.7	65.34	63.42	63.2
Mar.	69.3	67.1	70.9	71.6	69.2	71.8	64.2	68.52	69.12	70.82	69.3
April	73.4	72.1	73.5	73.9	71.4	75.9	73.6	74.32	70.23	73.46	73.2
May	75.5	75.6	76.6	75.3	73.3	76.8	73.7	75.44	71.92	75.94	74.9
June	76.7	76.8	76.9	77.2	73.4	76.9	76.4	78.35	73.20	76.87	76.3
July	77.1	78.6	78.2	77.4	73.9	78.5	77.3	76.50	73.82	77.46	76.9
Aug.	77.6	77.6	78.6	77.9	76.7	78.1	78.1	77.64	75.86	78.60	77.7
Sept.	76.9	77.0	78.3	77.8	76.1	77.3	77.3	78.25	77.02	78.27	77.6
Oct.	77.2	76.6	77.3	81.1	76.4	77.5	77.3	77.63	78.32	77.34	77.6
Nov.	63.3	76.0	71.4	74.2	72.8	74.8	72.4	74.33	72.76	71.24	72.3
Dec.	63.9	67.3	65.6	67.8	69.5	66.9	65.6	62.47	68.72	57.61	64.5
Total	72.6	71.7	71.9	72.7	72.2	73.3	71.5	71.9	71.8	71.9	72.2

Table 3. Observed mean monthly temperature °C 1992 – 2001 at Nsukka

Month	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Mean
Jan.	25.5	24.8	25.3	26.8	25.6	24.9	25.5	25.4	24.9	26.7	25.6
Feb.	27.1	26.6	26.5	27.2	27.6	25.6	25.5	26.3	25.4	27.2	26.5
Mar.	27.8	27.2	28.1	27.6	27.1	25.1	25.4	28.1	25.1	27.5	26.9
April	27.2	26.8	26.4	26.8	26.8	25.2	25.6	26.4	25.2	26.8	26.3
May	25.8	26.11	25.4	25.9	25.9	25.1	24.1	25.4	25.1	25.9	25.5
June	24.9	24.8	24.7	24.6	25.1	25.3	25.8	24.6	25.3	24.6	25.0
July	23.5	23.9	24.2	24.4	24.3	25.3	25.4	24.2	25.2	24.4	24.5
Aug.	23.2	23.7	23.7	24.1	24.2	25.1	25.5	23.5	25.1	24.1	24.2
Sept.	23.7	23.9	23.9	24.6	25.2	25.3	26.0	23.6	24.6	24.6	24.6
Oct.	24.6	24.9	24.6	24.9	25.0	25.2	26.2	24.6	25.6	25.0	25.1
Nov.	24.2	25.2	24.5	24.5	23.3	25.1	26.4	24.5	24.3	24.8	24.8
Dec.	24.2	23.7	23.8	24.8	25.1	25.6	26.6	23.7	25.1	24.7	24,7
Mean	25.1	25.1	25.1	25.6	25.4	25.2	25.7	25.0	25.1	25.5	25.3

years is 1547.8mm the minimum total rainfall occurred in 1993 (1192.3mm) while the maximum occurred in 1995 (1934.3mm). The monthly variation shows that the rains start by April, get to the peak by June or August and beings to decline (Table 1). The relative humidity does not fluctuate extensively as shown in Table 2. The mean monthly relative humidity was lowest in January (62.4%) and highest in August (77.7%). Data for monthly temperatures are shown in Table 3. The overall mean temperature was 25.3^{0}C. The lowest mean monthly temperature occurred in August (24.2^{0}C) while the highest occurred in March (26.9^{0}C).

The planting season for the area follows the above pattern of variation, especially rainfall. In most cases, crops are planted from late March, at the inception of the rains. Some times a second cropping season is observed from September, especially where irrigation water is available. The above observed pattern of meteorological data variation affects to a great deal, the soil trafficability and hence available field work days (AFW), as can be seen later.

Observed Available Field Work Days

The observed available field workdays data are presented in Table 4. The data are presented for only April – July for the ten years (1992 – 2001). The months April – July were chosen because that is the period that tillage occurs (the emphasis in this study is tillage).

Table 4. Observed available field workdays (AFW) for Nsukka, 1992 - 2001

Year	Month	TND*	AFW	POT%
1992	April	30	10	33.3
	May	31	20	64.5
	June	30	23	76.7
	July	31	14	45.2
1993	April	30	8	26.7
	May	31	22	70.9
	June	30	20	66.7
	July	31	18	58.1
1994	April	30	9	30.0
	May	31	20	64.5
	June	30	22	73.3
	July	31	19	61.3
1995	April	30	6	20.0
	May	31	24	77.4
	June	30	17	56.7
	July	31	15	48.4
1996	April	30	7	23.3
	May	31	24	77.4
	June	30	22	73.3
	July	31	16	51.6
1997	April	30	8	26.7
	May	31	25	80.7
	June	30	18	60.0
	July	31	16	51.6
1998	April	30	12	40.0
	May	31	26	83.9
	June	30	20	66.7
	July	31	13	41.9
1999	April	30	9	30.0
	May	31	23	74.2
	June	30	20	66.7
	July	31	16	51.6
2000	April	30	10	33.3
	May	31	20	64.5
	June	30	26	86.7
	July	31	14	45.1
2001	April	30	8	26.7
	May	31	22	70.9
	June	30	24	80.0
	July	31	15	48.4

TND*=Total Number of days; AFW = Available field work days;

POT= Percentage of Total

Table 5. Performance of the model in predicting Available Field Workdays (AFW) f or Nsukka, 1992 - 2001

Year	Month	Obsersed	Predicted	Percent Deviation
1992	April	10	8	20.0
	May	20	23	-15.0
	June	23	19	17.4
	July	14	16	-14.3
1993	April	8	7	12.5
	May	22	25	-13.6
	June	20	22	-10.0
	July	18	21	-16.7
1994	April	9	8	11.1
	May	20	18	10.0
	June	22	19	13.6
	July	19	21	-10.5
1995	April	6	7	-16.7
	May	24	26	-8.3
	June	17	15	11.8
	July	15	12	20.0
1996	April	7	9	-28.6
	May	24	28	-16.7
	June	22	20	9.1
	July	16	17	-6.3
1997	April	8	6	25.0
	May	25	21	16.0
	June	18	19	-5.6
	July	16	13	18.8
1998	April	12	16	-33.3
	May	26	28	-7.7
	June	20	17	15.0
	July	13	14	-7.7
1999	April	9	12	-33.3
	May	23	20	13.0
	June	20	17	15.0
	July	16	15	6.3
2000	April	7	8	-14.3
	May	25	27	-8.0
	June	22	23	-4.5
	July	17	19	-11.8
2001	April	6	8	-33.3
	May	24	26	-8.3
	June	17	16	5.9
	July	16	14	12.5

Absolute average percent deviation = 14.4

The mean over the ten year period, shows that AFW was highest in May (32.9%) of total number of days. This was followed by June (31.1%), July (22.9%) and April (12.8%). This pattern of trafficability can be explained by the variation in rainfall (Table 1). In April, the rains have just started and so the soil is too dry and hard for tillage. As we enter May, rainfall intensity and frequency increase, thus increasing the chances of AFW. However, as we enter June and July, the soil gets saturated and frequency of the rains gets so high that many days are not suitable for field work.

The results above have serious implications for machinery and field management. It means that in planning, the farm manager should note that only 12.8% of the days in April are actually available for field work. This enables him to plan ahead of time by allocating adequate number of machines and personnel for whatever tasks are to be performed.

Model Prediction of AFW

The performance pf the model in predicting Available Field Workday (AFW) is shown in Table 5. In 1992, the maximum percent deviation of predicted compared to observed was 20% which occurred in April. The corresponding values for 1993, 1994, 195, 1996, 1997, 1998, 1999, 2000, 2001 respectively are 12.5%, 11.1%, 16.7%, 28.6%. 25%, 33.3%, 33.3%, 14.3%, and 33.3%. Thus, the predicted values are in cose agreement with experimental observations. The deviations can be attributed to errors in estimating the various components of the water balance equation such as runoff, drainage, evapotranspiration, etc.

The performance of the model is not sores han hat of other models applid to difeent environments (Ahaneku et al; 1997; Simalenga and Have, 1994; Gwarzo et al; 1989). The usefulness of this model in machinery and farm management are enormous. Firstly, it can be used to develop farm calender for the area. Secondly, it can be used for efficient allocation and management of machinery for tillage operations. Knowing the actual number of days suitable for field work and knowing the field capacity of the relevant tillage machinery, it is possible to estimate the number of machines required to prepare a particular size of farm for planting. The results are already being incorporated in a bigger model for machinery allocation and management.

CONCLUSIONS

By observing days suitable for field work for April – July, 1992 – 201, it was conclude that the actual number of days available is about 50% of the total number of days. A simulation model developed based on soil moisture budgeting technique and some tractability criteria were able to predict AFW for tillage operations. The maximum percent deviation of predicted values compared to experimental observations was 33%. The results are useful in planning farm operations and machinery management for tillage operations.

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