European Journal of Food Science and Technology
Vol.2, No.1 pp.8-18, June 2014
Published by European Centre for Research Training and Development UK (www.ea-journals.org)

ESTIMATION OF SUITABLE FIELD WORKDAYS OF PLANTING AND HARVESTING OPERATIONS OF MAIZE PRODUCTION IN BAUCHI STATE NIGERIA

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ABSTRACT: *Estimation of suitable field workdays were determined in Bauchi LGA based on soil moisture content and vagaries weather. A ten year metrological weather information were obtained at Federal Ministry of Aviation, Bauchi from 1999-2009. A computer program was written in Visual Basic 2008 to compute daily soil moisture content for the period beginning May to ending October for each of the ten years and apply tractability conditions to the soil moisture balance to estimate good machinery field workdays and days best for tillage. Out of the 184 days working season for each of the years assessed for trafficability conditions, the year (2001) had the lowest suitable workdays (56 days) with 30.43 percent of the total time. The year (2000) had the highest suitable workdays (100 days) with 54.35 percent. The year (2001 & 2008) had the lowest number of best tillage workdays (29days) with 15.76 percent of the total time and the year 1999 had the highest number of tillage workdays (68days) with 36.96 percent.*

KEYWORDS: Suitable Field Workdays, Weather, Soil Moisture, Trafficability

INTRODUCTION

A suitable day for fieldwork is determined by weather- related events (primarily rainfall and temperature) that affect the condition of the soil in a field. 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.

The 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

and simulation models based on soil moisture regime and machinery parameters are used in estimating suitable field workdays. Gwarzo (1990) developed and used a simulation model based on soil moisture regime and machinery parameters to estimate suitable field workdays on a mechanized maize farm at Mokwa, Nigeria. It was reported that, the method could not be used in predicting suitable field workdays at critical periods of field operation. Thus, the soil moisture budget could be handy, when farm records are well kept. Hence, the method is suitable for tropical regions especially Savannah areas where there is no much rainfall and the soil is well drain even after a heavy down pour and the rate of evapotranspiration is expectedly high to warrant farm operation

METHODOLOGY

Climatological information that are required for the estimation of suitable workdays include complete daily records of relative humidity, air temperatures (maximum, minimum) and rainfall records. The data used were sourced from Federal Ministry of Aviation, Bauchi metrological station for a period of consecutive ten years (10 years) from 1999- 2009.

The procedure for the estimation of suitable field workdays was made in three main stages as follows:

(i) Obtaining the weather data or Climatological information for the area. Weather data for Bauchi area was collected from the weather records office of the Federal Ministry of Aviation, Bauchi.

(ii) Soil moisture content for the field was selected as a variable to describe soil condition for tractability. Computation of daily change in soil moisture for the period of the year beginning in May and ending in October was made.

(iii) Establishment of tractability conditions and application of tractability condition to soil moisture budget and the suitability of a workday based on data from reviewed literature and soil sample analysis were established. The established criteria was used with or applied to the soil moisture budget to differentiate between a “tractable” (workable) and a “non-tractable” (non-workable) soil condition.

The Soil Moisture Budget

The soil moisture budget (SMB) involves using the weather data for only the period regarded as the rainfall or growing season for the farm locality (May to October of 1999- 2009). Information on potential evapotranspiration, actual evapotranspiration, rainfall, runoff and drainage were required for the SMB. The commonest SMB consists of subtracting daily potential evapotranspiration from daily rainfall. This amount is then subtracted (or added when rain exceeds potential evapotranspiration) from moisture present in the soil to give the new soil moisture

storage. A simple soil moisture balance relationship as suggested by (Babeir et al., 1986) was adapted for the SMB. The relationship is expressed as Equation 1 below:

$$DSM \equiv R_a - E_{ta} - R_o - D_p \quad (1)$$

Where,

DSM = daily change in soil moisture, mm

R_a = amount of rainfall for the day, mm

E_{ta} = daily actual evapotranspiration mm day $^{-1}$

R_o = amount of run off for the day, mm

D_p = deep percolation, mm.

Daily Potential Evapotranspiration

Evapotranspiration has been defined as the combined loss of water from a given area by evaporation from the soil surface and by transpiration from plants. When there is sufficient moisture in the soil, the amount of evapotranspiration required to satisfy the atmospheric demand is known as potential evapotranspiration (Gwarzo, 1990). However, as the soil dries, the available moisture decrease, hydraulic tension increase and transport of water to soil interface is insufficient to meet the demand and actual evapotranspiration is short of potential evapotranspiration. The empirical methods normally relate Climatological measurements to evapotranspiration. These relationships are usually affected by location, stage of crop development and season. Duru, (1984) developed an empirical formula known as the Blarney-Morin-Nigerian evapotranspiration model which was expressed as in Equation 2 below:

$$E_{tp} \equiv \frac{r_f^{(0.45T+8)(520-R_h^{1.31}}}{100} \quad (2)$$

Where,

E_{tp} = Potential evapotranspiration, $mm\ day^{-1}$

r_f = Ratio of maximum possible radiation to the annual maximum

T = Mean temperature in ^{o}C ($\frac{T_{max} - T_{min}}{2}$)

R_h = Relative humidity in percent

T_{max} = Maximum daily temperature, ^{o}C

T_{min} = Minimum daily temperature, ^{o}C

The Blaney-Morin-Nigerian evapotranspiration formula was used to estimate daily potential evapotranspiration. The climatological data considered in the above equation are the mean temperature, radiation and relative humidity. Daily values of this Climatological parameter beginning May to ending October for each year for a period of 10 years (1999-2009) were determined and used in a computer analysis to estimate daily value of potential evapotranspiration.

Daily Actual Evapotranspiration

Crop coefficient as computed by (Adewumi, 1980) for maize crop was used to adjust values of potential evapotranspiration. Daily actual evapotranspiration is the product of daily potential evapotranspiration and crop coefficient as expressed by (Gwarzo, 1990).

$$E_{ta} = K_c E_{tp} \quad (3)$$

Where,

E_{ta} = daily actual evapotranspiration mm day $^{-1}$

K_c = Crop coefficient

E_{tp} = daily potential evapotranspiration mm day $^{-1}$

Daily Change and Daily Storage of Soil Moisture

Daily change in soil moisture was determined using equation (4) below. On any day there is rain, the amount of actual evapotranspiration for the day with the amount of drainage and surface runoff as a result of the day's rainfall is subtracted from the actual amount of rainfall to give the daily change in soil moisture. On a non-rainy day the daily change in soil moisture is only the day's actual evapotranspiration, E_{ta}.

The daily change in soil moisture was determined as shown below; daily soil moisture storage for the period beginning May to ending October for each of the ten years was computed.

$$\sum_{i=9}^{n} DSM \quad \ldots 4$$

Where

MS= daily soil moisture storage, mm

DSM= daily soil moisture change, mm^2

$\sum_{i=9}^{n}$ = Daily summation carried out from day i=1 to day i= n

Tractability Conditions

A soil is considered tractable if a machine can move on that soil to performs its intended function without damaging the soil, (Hassan and Broughton, 1975). Soil moisture content was selected as tractability criteria because field work when soil is too wet when operated on can result in serious soil damage and increased operating costs, while field work when soil is dry results in poor operations. Therefore, tractability conditions for machine operations during field work were established as a function of weather and soil moisture conditions. The amount of soil moisture within the top 30cm of the soil layer and the limits of daily rainfall were used as criteria for trafficability conditions.

This criterion was used to differentiate between a "tractable" (workable) and a "non-tractable" (non-workable) soil condition. For most farm soil conditions or type, a workable day is a field with soil moisture content within the 30cm soil profile layer of between 95 percent of field capacity and lower plastic limit. Maximum rainfall for a workday should not exceed 7mm on that day while the previous day rainfall should not exceed 14mm (Gwarzo, 1990). A non-workable day is that which has a soil moisture content in the top 30cm of the soil profile layer exceeding 95 percent of field capacity or has a soil moisture content below the lower plastic limit value. Maximum rainfall for a non-workday is above 7mm on that day and above 14mm the previous day. Best conditions for tillage are also described in Table 1.

Using parameters defining field conditions for tractability as in Table 1, the amount of soil moisture in the top 30cm of the soil profile at field capacity, liquid and plastic limits was determined using equation (5).

$$A_w \equiv \frac{B_d F_c D}{10} \qquad (5)$$

Where,

A_w = Amount of soil water, mm

B_d = Bulk density

F_c = Moisture content at field capacity

D = Soil depth, mm

This soil moisture values with rainfall values satisfying tractability conditions was then substituted into the soil moisture budget for the (equation 1 and 4) study period to segregate between good and bad field workdays by a computer analysis as reported by (Gwarzo, 1990).

Moisture content between lower plastic limit to upper plastic limit to solid state of the soil were considered as best suited for tillage, (Link, 1968). As a function of soil moisture and rainfall, Table 1 gives the parameters defining field conditions for tractability.

Table 1: Field Conditions for Tractability (light, medium and heavy textured soils)

PARAMETERS	CRITERIA
1. Tractable or Good Workday	top 30cm of soil profile not to exceed 98% of field capacity (heav Moisture content in the top 30cm of soil profile not exceeds 95% of field capacity (light to medium textured soils). Moisture Content in the top 30cm of soil profile to be not less than lower plastic limit value of the soil (heavy, medium and light textured soils). Maximum rainfall yesterday (14mm) heavy, medium and light textured soils Maximum rainfall today (7mm heavy, medium and light textured soils
2. Non-Tractable or non-workday	Moisture content in the top 30cm of soil profile above 99% field capacity (heavy, textured soils) Moisture content in the top 30cm of soil profile above 95% of field capacity (light to medium textured soils). Maximum rainfall today above (7mm) (heavy, medium and light textured soils)
3. Best Condition for tillage	Moisture content in the top 30cm of soil profile between lower plastic limit to upper plastic limit (liquid limit) light, medium and heavy textured soils) Maximum rainfall yesterday (14mm). (heavy, medium and light textured soils) Maximum rainfall today (7mm). (heavy, medium and light textured soils)

Source: (Gwarzo et al., 1989)

The Computer Program

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 tillage at Badala farms. The computer program used climate and soil information for the area to estimate suitable workdays for agricultural machinery.

RESULTS AND DISCUSSIONS

Table 2 shows the total number of suitable workdays and best tillage workdays for each of the years assessed (1999-2009). Out of the 184 days working season duration for each of the years assessed for tractability conditions, the year (2001) had the lowest suitable days with 30.43 percent of the total time as suitable for field workdays which is close to what (Gwarzo, 1990) reported 36.96 percent. The year (2000) had the highest estimated number of suitable work days with 54.35 percent of the total time as suitable for field work this is corroborated with (Gwarzo, 1990), who obtained 58.15 percent. The year (2001 and 2008) had the lowest number of best tillage workdays with 15.76 percent of the total time as best suitable for tillage work and (Gwarzo, 1990) obtained 17.39 percent. The year (1999) had the highest number of best tillage workdays with 36.96 percent of the time as best suitable for tillage which is greater than the value obtained 35.14 percent by (Gwarzo, 1990) based on similar work conducted. On the average the number of good field workdays of the ten years working seasons was estimated to be 40 days and the average number of best tillage workdays for the ten years was found to be 22 days and it is not in conformity with what (Gwarzo, 1990) obtained as 86 and 50 days as an average number of good field workdays and best tillage workdays respectively. This could be attributed to the location of the study area within the agro-ecological zone of the country. Locations vary in terms of rainfall intensity and evapotranspiration rate.The month of June is best suited for the tillage operations because, then, the soil friable with optimum soil moisture for tillage operations. All other months are suitable for all other field operations as the average within the Savannah agro- ecological zone of Nigeria. The number of suitable field workdays on a monthly basis for the period May through October for each of the years (1999) is presented in Figures 1. Similarly, the tillage workdays on a monthly basis are presented in Figures 2. The month of August have the lowest number of average working days. This was largely attributed to high soil moisture whereby the soil stays within field capacity range or mostly at saturation not allowing machine operations.

Table 2: Total Number of Suitable Field Work Days and Best Tillage Work Days and their Percentages in Total Time Assessed.

	No. of Days Assessed	No. of Good Field Workdays	Percent of Total Time	No. of. Tillage Workdays	Tillage Days as Percent of Total Time
1999	184	93	50.54	68	36.96
2000	184	100	54.35	55	29.89
2001	184	56	30.43	29	15.76
2002	184	89	48.37	61	33.15
2003	184	69	37.50	45	24.46
2004	184	62	33.70	34	18.48
2005	184	82	44.57	48	26.09
2006	184	82	44.57	44	23.91
2007	184	73	39.67	38	20.65
2008	184	67	36.41	29	15.76
2009	183	79	42.93	42	22.83

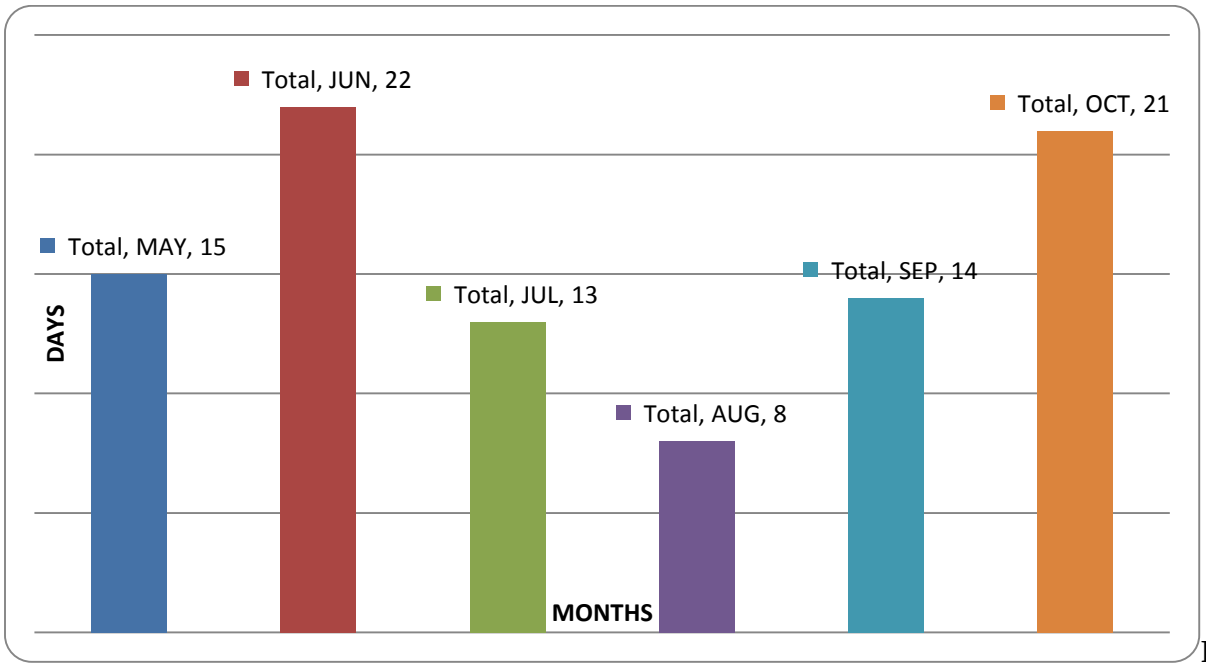

Fig 1: 1999 Estimated Number of Suitable Field Workdays for the Period Beginning May to Ending October

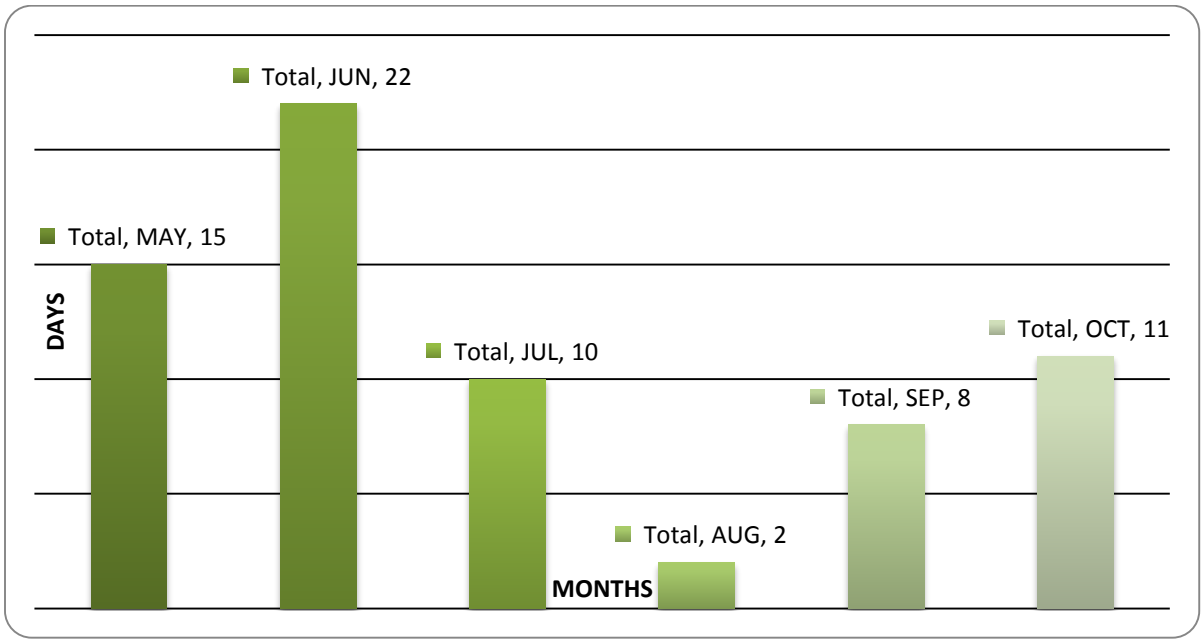

Fig 2: 1999 Estimated Number of Best Tillage Workdays for the Period Beginning May to Ending October

CONCLUSION

Based on a ten-year average, 43 suitable machinery field work days and 24 best tillage work days out of a total 184 days for a working season on the farm were obtained. The year (2000) with the highest number of suitable field workdays had 54.35 percent of the growing season time (May-October) as suitable for field work while the year (2001) with the lowest number of suitable field workdays had 30.43 percent of the growing season time as suitable for field work. The year (2001 and 2008) with the lowest number of best tillage work days had 15.76 percent of the flowing season time as best suitable for tillage work while the year (1999) with the highest number of best tillage work days had 36.96 percent of the time as best suited for tillage work.

A ten-year average of monthly suitable field work days obtained for Bauchi State has the months in descending order of number of suitable work days as July, September, October, followed by June, then and lastly August.

Total monthly and annual rainfall is not directly related to number of good field work days obtained during the period. Number of good field work days was more a function of rainfall time distribution with the moisture status of the soil.

Contribution to Knowledge

The study has elucidated the importance of a good farm record keeping and the data require for the estimation of suitable field workdays for the purpose of farm planning on a mechanized farms in Nigeria. Similarly, it was able to integrate the more of computers and mathematical empirical solutions in estimating suitable field workdays for farm planning ahead of the cropping season.

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REFERENCES

Adewumi, J.K., 1980 Re- calibration of the Blaney and Criddle Evapotranspiration Equation for selected crops at Samaru. A project Report for B. Eng. (Agricultural Engineering) Ahmadu Bello University, Zaria 78-101.

Babeir, A., Colvin, T. and Marley, S., 1986. Predicting field tractability with a simulation model. Transactions of the ASAE, 29(6): 1520-1525.

Duru, O.J., 1984. Blarney- Morin-Nigerian Evapotranspiration Model, Journal of Hydrology. 70, 71-83.

Gwarzo, M.A., Braide, F.G., Ramalan, A.A. and Mudiare, O.J., 1989. Computer Analysis for the Selection of Suitable Workdays for Agricultural Field Operations National Agricultural Extension and Research Liaison Services Ahmadu Bellow University,Zaria: 4-9.

Gwarzo, M.A.S., 1990. Capacitive Performance Study and Optimization of Power and Machinery on Large scale Farm. Unpublished PhD Thesis, Department of Agricultural Engineering Ahmadu Bello University Zaria, Nigeria.

Hassan, A. and Broughton, R., 1975. Soil moisture criteria for tractability. Canadian agricultural engineering.

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

Link, D., 1968. Research needs for farm machinery scheduling. Computers~ nd farm machinery manageI: 28-32.

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.

Saglam, C. and Ibrahim, T., 2011 Distribution of tractor available workdays over the southeastern Anatolia project (GAP) area. African Journal of Agricultural Research. 6, 30: 6416-6424 www.academicjournals.org/ajar/PDF/.../Saglam%20and%20Tobi.pdf.

Witney, B., 1988. Choosing and using farm machines. Harlow, Essex, England New York: Longman Scientific & Technical. Wiley.

ACKNOWLEDGEMENT

The Authors wish to acknowledge the assistance rendered by the Director Metrological Station of the Federal Ministry of Aviation in Federal Secretariat, Bauchi. The management of Badala farms for their assistance during the conduct of the research study. They allow the researchers to conduct their research in their farms using all the necessary tools and equipment. Your contributions would remain grateful