Determination of Length of Growing Season in Samaru Using Different Potential Evapotranspiration Models

Rita Ngozi Edoga

Soil Science Department, Ahmadu Bello University
Zaria, Nigeria
<edochem2005@yahoo.com>

Abstract

Empirical evapotranspiration models were used in computing onset dates, termination dates and duration of growing season. Other rainfall data (daily, monthly, and annual) were analyzed using several statistical methods. The onset dates were determined using rainfall data and evapotranspiration models developed by Kowal and Knabe (1972), Blaney-Morin Nigeria (BMN) (Duru 1984), Penman (1948) and Walter (1967), while the termination dates were determined using a model developed by Zargina (1987). Climatological data were obtained from the Institute for Agricultural Research (IAR), Ahmadu Bello University (ABU), Zaria database, for twenty years of daily data (1981 – 2000).

Using Blaney-Morin Nigeria (Duru 1984) model, the mean onset date during the period of study is 26th April and the earliest starts are 23rd April and 6th June, respectively. Rainfall terminates in the month of October. The result shows that about two third of the onset dates are in May and the rainfall regime is marked by a peak in August with about 24% of the annual total rainfall received in this month.

The comparison, shows that Walter (1967) and Blaney-Morin Nigeria (Duru 1984) models predict earlier onset than Penman (1948) model while Penman (1948) predicts late termination than the other two models. Therefore, Walter (1967) and Penman (1948) have longer length of growing season than BMN (Duru 1984).

Keywords: *Empirical evapotranspiration, onset date, termination date, duration of growing season, Blaney-Morin Nigeria model.*

Introduction

The availability of sufficient water at appropriate times is the most crucial factor determining the type and productivity of crops (Yayock and Owonubi 1986). Davey *et al.* (1976) observed that water is the most important nutrient of a crop, which does not just need water to grow, but requires it as a vehicle in which other nutrients are transported. Knowledge of the amount available and its distribution in relation to other nutrients in the soil is therefore of fundamental importance in the study of crop growth and production.

Over large parts of West Africa, the crucial problem is water. The scarcity of water because of uncertainties of the rainfall receipt, presents a major obstacle to the rational development of Agriculture (Dennett *et al.* 1981) in other parts, excess water creates pressing problems of drainage and flood control for about 6-8 months of the year. Crops are usually planted during the rainy season, implying that crop productivity is largely a function of rainfall. Irregularities in rainfall reliability and spread have therefore contributed significantly to the poor yields and high variability in production from year to year (Mortimore 1989).

The start of the rains, is seldom abrupt, but is usually foreshadowed by a succession of isolated showers of uncertain intensity with intervening dry periods of varying durations

(Walter 1967). Agriculturists require a reasonable guarantee that after a given date the rains will become fairly continuous and enough to ensure sufficient moisture in the soil at the time of planting and that this level of moisture will be maintained and even increased as the season advances.

The main concern of an agriculturist is the start, end and length of the rainy season, the distribution of rainfall amounts throughout the year and the risk of dry spells. These parameters have been observed to affect the growing season. Variations in agricultural production have been related to deviation from normal seasonal climate best described by the term "growing period".

Therefore, a farmer who practices agriculture in a rain-dependent environment has to be contended just with the amount and distribution of rainfall received annually but also with the problem of variability in onset, duration and termination of the rainy season (Mortimore 1989; Walter 1967). The arrival of the first rain is a signal for tremendous farming activities. The first heavy shower helps to loosen the soil from its hard dry season consistency.

Several definitions have been proposed for determining the date of onset of the rainy season. This ranges from traditional to semi-empirical and scientific techniques (Ati 1995). Koppen and Geiger (1936), cited in Hulme (1987), used the monthly rainfall minimum threshold of 60mm and 30mm, respectively, to determine the onset of the rainy season. Davey *et al.* (1976) defined the onset of growing season as the first ten days period of 20mm of rain but they did not consider the possibility of a dry spell following its determined date. Stern *et al.* (1981) improved on it by defining the onset of the rains as 20mm in one or more date(s) within the next thirty days.

Furthermore, the risk of having a false start was reduced by Jolliffe and Sarria-Dodd (1994) following Stern *et al.* (1981). They defined the onset of the wet season as period of five days (pentad) with at least 25mm of rainfall occurring.

Awadulla (1981), cited by Hulme (1987), designed a water balance model using pentad rainfall potential evapotranspiration (PET) and certain assumptions about the soil moisture capacity. He defined the onset as the first pentad where 80% of the evaporative demand of the germinating sorghum was met by rainfall and soil moisture provided that the succeeding two pentads also met this condition.

Hulme (1987) used a simple water balance approach consisting of daily potential evapotranspiration (PET). This approach, as Hulme (1987) reasoned, is acceptable for it does not vary with annual rainfall totals and it is calculative on year to year basis.

Kowal and Knabe (1972) used the rainfall and evapotranspiration to calculate the date of onset. They defined it as the decade in which the rainfall is greater than 25mm and where subsequent decades of rainfall are greater than 0.5 potential evapotranspiration.

A related rainfall evapotranspiration model for Nigeria is the one proposed by Benoit (1977). He used the daily data to define the onset as the date when accumulated rainfall exceeds and remain greater than 0.5 potential evapotranspiration for the remainder of the growing season provided that no spell longer than five days occurs immediately after this date.

Termination of the Growing Season

The termination date according to Madeoye (1985) is defined as the last date on which a threshold amount is exceeded. Zargina (1987) used the minimum daily rainfall threshold of 25mm to determine the termination of the growing season.

In the procedure, the soil is assumed to be at field capacity of 100mm on the last day of rain that is greater than 0.5 PET provided that the date is not proceeded by a dry spell (less than 1mm average daily rainfall) or more than five days (Benoit 1977; Stern *et al.* 1982); it is assumed that the depletion of available soil moisture below 40% of its field capacity will cause rapid reduction in water availability to crops.

Growing Season

Many definitions are in use to define growing season (Walter 1987; Singh 1986; Hulme 1987). Hulme (1987) classified the numerous approaches to growing season determination into two categories. The first group are those formulated in terms of absolute daily or monthly total (Walter 1967; Davey *et al.* 1976; Stern *et al.* 1981; Stern *et al*. 1982; Olaniran and Sumner 1989; Singh 1986; Ananthakrishnan and Soman 1988). The other category of definitions includes those that are formulated in relation to standardized parameters, such as evapotranspiration and magnitude of annual rainfall (Ilesanmi 1972; Benoit 1977; Shaw 1986; Hulme 1987).

The Hulme (1987) method is a simple water balance model, consisting of daily rainfalls and daily potential evapotranspiration (PET).

In this study, a related rainfall/potential evapotranspiration model for Nigeria developed by Benoit (1977) is used to compute the annual dates of the onset, termination and duration of the growing season in Samaru, northern Guinea Zone of Nigeria.

Length of the Growing Season

The duration of the growing season can be determined by subtracting, for each year, the date at which the rains start from the date that it ends. This was used by Madeoye (1985) and Zargina (1987).

Analysis of the Growing Season

Oladipo and Kyari (1993) and Zargina (1987) in their studies of growing season of the Northern Nigeria indicated that the onset, termination and duration of the growing season show latitudinal progress but with some disruptions due to orographic effect in the central (Jos).

Oladipo and Kyari (1993) using the water balance method computed the onset, termination and duration of the growing season for northern Nigeria and they found that in most of the stations the time series for these parameters are homogenous and random, and can be taken to be normally distributed. They also found that there is no statistically significant trend in series of onset dates but there is some evidence for statistically significant decreasing trend in the termination and duration of the growing season. These findings were in agreement with that of Olaniran and Sumner (1989). Ati (1995) in his study found out that there is no statistically significant difference in the onset series for eight stations (in old Kano state). Zikirullah and Edoga (2001) determined the length of growing season using different potential evapotranspiration models, i.e., Penman (1948) and Blaney-Morin Nigeria (Duru 1984) models. They found out that the Penman (1948) model has longer growing season than the Blaney-Morin Nigeria (Duru 1984) model.

Relationship between Onset Date and Annual Rainfall

Ati (1995) in his study of the onset dates showed that there is statistical decreasing trend in the series of annual rainfall while there is no statistically significant trend in that the of onset date. He also found that there is strong negative correlation between the rainfall series and onset series. The effective rainfall is the amount of rainfall all of which neither evaporated early in the season, nor percolated beyond the reach of roots and, therefore, is available for crop production.

Materials and Method

Climatic data were obtained from Institute for Agricultural Research (IAR), Ahmadu Bello University (ABU), Zaria data base. Twenty years (1981-2000) of daily data were available for Samaru. Data available include rainfall, temperature (minimum and maximum), relative humidity, vapour pressure, sunshine hours, wind speed and radiation. Data collections were done by IAR trained personnel and weather instrument installations conform to the World Meteorological Organization (WMO) standard.

Method

Empirical methods were used in computing onset dates and the termination dates and other rainfall data (daily, monthly and annually) were analyzed using several statistical methods, which include: mean, standard deviation, coefficient of variation, interannual variability and annual rainfall distribution.

Determination of the Growing Season Parameters

The onset dates are determined using a rainfall and evapotranspiration model developed by Kowal and Knabe (1972). They defined it as the decades in which rainfall amounts are greater than 0.5 potential evapotranspiration.

The potential evapotranspiration was computed using the formulas developed by Blaney-Morin Nigeria (Duru 1984) and that of Penman (1948) as given below:

$$PET = r_f(0.45T + 8)(520 - R^{1.31})/100 \text{ mm/day}, \quad (1)$$

where:
r_f = radiation ratio/fraction = r_{daily}/r_{max};
r_{daily} = daily radiation;
r_{max} = maximum annual radiation;
T = temperature (^{0}C);
R = daily relative humidity (%).

Penman (1948) equation:

$$E_o = (\Delta R_a / \lambda + \gamma E_a)/(\Delta + \gamma), \quad (2)$$

where:
Δ = slope of saturated vapour pressure curve of air (mb/ ^{0}C);
R_a = net radiation (cal cm^{-2} mm^{-1});
γ = psychrometric constant (0.66 mb/^{o}C);
E_a = aerodynamic term = $0.35(e_a - e_d)(0.5 + 0.0062U_2)$;
e_a = vapour pressure at air;
e_d = vapour pressure at dew point temperature;
U_2 = wind speed at a height of 2m (Km / day);
λ = latest heat of vaporization of water (cal cm^{-2} mm^{-1}) (59.59 – 0.55T m.p. cal cm^{-2} mm);
T = air temperature (^{0}C).

Kowal and Knabe (1972) equation:

Onset of rains: start of rains (decade) = 1.16 + 1.34 (LA) + 0.0 of (LO) (r = 0.94) (3)

where:
LA = latitudinal position (latitude) for Samaru = 11^{0}11' = 11.18^0;
LO = longitudinal position (longitude) for Samaru = 7^{0}38' = 7.63^0;
r = regression coefficient.

Walter (1967) formula:
Onset of rains: The actual date is given by:

$$\text{Actual Date} = \text{Days in month x } (2 - Y)/n = N(2 - Y)/n, \quad (4)$$

where: N = Days in the month; Y = accumulated total of the previous months; n = Total for the month.

Termination Date

This is determined using a method developed by Zargina (1987) where the minimum daily rainfall threshold of 25mm was used to determine the termination of the growing season.

From Kowal and Knabe (1972): Termination date of rains is given by:

End of rains (decades) = 35.18 – 0.57 (LA) – 0.07 (LO) (r = 0.84),

where: r = regression coefficient. Also:

The length of rainy period (decade) = 36.34 – 1.91 (LA) – 0.14 (LO) (r = 0.94);

End of growing season (decade) = 40.58 – 0.82 (LA) – 0.01 (LO), (r = 0.89);

Length of growing season (decade) = 41.74 – 2.16 (LA) – 0.01 (LO), (r = 0.94);

E_o (annual) = 99% + 95.26 (LA) + 4.44 (LO) mm, (r = 0.69);

E_t (annual) = 758 + 74.53 (LA) + 3.46 (LO) mm (r = 0.70);

E_o growing season) = 1,407.5 – 59.6 (LA) – 4.9 (LO) mm, (r = 0.86);

E_o per day = 2.18 + 0.28 (LA) - 0.009 (LO) mm (r = 0.79).

Difference between rainfall and E_t is given by:

P - (E_t growing season) = 1,062.4 – 71.3 (LA) – 4.71 (LO);

E_o (dry season) = 803.3 + 170.5 (LA) + 9.6 (LO) mm (r = 0.89);

E_t (dry season) = - (625.9+132.8 (LA) +7.5 (LO) mm, (r = 0.89);

where: E_o = open water evaporation; E_t = evapotranspiration.

Central Tendencies and Variations

The arithmetic mean (X), standard deviation (SD, or S), variance and standard error of mean (SEMEAN) were used as measures of central tendencies:

$$\text{Mean } (X) = (\Sigma\, y)/n, \quad (5)$$

where: y = each item given; n = total number of items given. Also:

$$\text{SD } (S) = \sqrt{\Sigma\, [\, f\,(Y - X\,)\,]\,/fY}; \quad (6)$$

$$\text{Variance} = (S)^{2}; \quad (7)$$

$$\text{SEMEAN} = S/n^{1/2}. \quad (8)$$

The variations, that is, coefficient of variations and interannual variability are derived for the series of different variables. The formulas used for measure of variation are given below:

$$\text{Coefficient of variation (CV)} = (S/X) \times 100; \quad (9)$$

$$\text{Interannual variability (IV)} = \Delta S/X = (S_1 - S_2)/X, \quad (10)$$

where: ΔS = change in standard deviation; X = mean.

Results and Discussion

Monthly Rainfall

The mean monthly rainfall during the period of study is 264mm. Table 1 shows the percentage distribution of monthly total and monthly means during the period of study. Extreme values up to 5,280mm were received but generally 82.3% of the recorded monthly totals are between 600mm – 4,000 mm.

In the month of May, the coefficient of variation (58.6) suggests a relatively low variation for the mean. The rainfall regime is marked by a peak in August. About 24% of the annual total rainfall is received in this month. The months of November to March hardly recorded any amount. Therefore, the rainy season of Samaru extends up to seven months though the April and October rainfall are little and highly variable. Some statistical parameters of the seven months are instead in Table 1.

About two thirds of the onset dates during the period of study are in May using both Blaney-Morin Nigeria (Duru 1984), Penman (1948) and Walter (1967) models. The mean May rainfall is 113.90mm but amount up to 2,277.52mm was received. The difference between June and August rainfall is 47.7%.

Annual Rainfall

The means annual rainfall during the period of study is 938.53mm. The maximum and minimum values are 608.2mm and 1262 mm in 1983 and 1998; respectively, some statistical characteristics of the annual rainfall are listed in Table 2.

Table 1. Some statistical parameters of monthly rainfall distributions (1981-2000).

Month	Mean (mm)	SD	CV	Annual percent-ages
Apr.	69.02	49.9	78.65	7.4
May	113.9	58.6	51.4	12,1
Jun.	151.8	51.2	37.7	16.2
Jul.	222.8	47.8	21.5	23.7
Aug.	264	105.2	39.9	24
Sep.	122.3	66.5	54.4	13
Oct.	33.20	39.1	117.1	3.5

Table 2. Statistical characteristics of annual rainfall.

Parameters	Values
X (mm)	938.53
SD (mm)	138.61
CV (%)	14.77
IV	10.77

The interannual variability (IV) shows a relatively low year to year variation in the time series and the low coefficients of variation

(CV) suggested a relatively low variation from the means.

The growing season: In the tropics, growing season is an attribute of rainfall and it is derived from and reflects the general pattern of rainfall. Therefore, rainfall data is used in the determination of the parameters (onset and termination dates) that describe the growing seasons.

Onset Dates

Actually, the rainfall starts in the month of April, amount up to 57.3mm have been received and about 23.9% of the April rainfall is above 10mm. But generally, the amount is small for planting. There were five (using Blaney-Morin Nigeria (Duru 1984) model), seven (Penman (1948) model) and six (Walter (1967) model) effective starts of the growing season in April throughout the period of study. Table 3 below shows percentages of occurrence of onset in April, May and June.

Table 3. Percentages of occurrence of effective onset dates in April, May and June.

Month	Percentage of occurrence
April	25.0
May	70.0
June	5.0

Using Blaney-Morin Nigeria (Duru 1984) model, the mean onset date during the period of study is 26th April and the earliest and latest starts are 23rd April and 6th June, respectively.

In contrast to the BMN (Duru 1984) model, the mean onset date during the period of study using Penman (1948) model is 28th April while the earliest and latest starts are 24th April and 8th June respectively. For Walter (1967) model, the mean onset date is 11th May, the earliest and the latest starts are 16th April and 1st June. The interannual variability suggests a relatively low year to year variation and the coefficient of variation also suggests a low variation from the mean onset dates. The highest variability is witnessed during the year 1982 with onset dates of 26th April, 30th April and 5th May for Blaney-Morin Nigeria (Duru 1984), Walter (1967) and Penman (1948) models, respectively. The Penman (1948) model predicts late onset than the other two models.

Termination Dates

The rainfall terminates in the month of October, there were 11 (Blaney-Morin Nigeria (Duru 1984) model), 10 (Penman (1948) model) and 11 (Walter (1967) model) effective terminations of the growing season in October during the period of study.

Using Blaney-Morin Nigeria (Duru 1984) model, the mean termination dates are 28th September and 26th October, respectively.

The Penman (1948) model, shows the mean termination date as 2nd October and the earliest and latest termination dates are 28th September and 20th October, respectively.

The Walter (1967) model has the mean termination date as 11th October, the earliest and latest termination dates are 19th September ad 28th October, respectively.

The interannual variability suggests a relatively low year to year variation and the coefficient of variation also suggests a high variation from the mean termination dates with the highest variation during the year 1992; with 25 days difference between Penman (1948) and Blaney-Morin Nigeria (Duru 1984) models, 3 days between Penman (1948) and Walter (1967) models and 20 days between Blaney-Morin Nigeria (Duru 1984) and Walter (1967) models.

The Walter (1967) model predicts early termination dates, followed by the Penman (1948) model and lastly by the Blaney-Morin Nigeria (Duru 1984) model.

Duration of the Growing Season

This is the number of days between the onset and the termination dates. The mean duration of the growing season during the period of study using the Blaney-Morin Nigeria (Duru 1984) model is 146 days, the minimum and maximum durations are 121 and 171 days, respectively.

The mean duration of the growing season for the Penman (1948) model is 148 days with minimum and maximum durations of 123 and

172 days, respectively. The mean duration for the Walter (1967) model is 271 days, minimum and maximum duration of growing season are 116 and 173 days, respectively.

When the onset date, termination date and duration of growing season of the three models are compared with the Kowal and Knabe (1972) model, which is used as a standard as it was developed in Samaru, the Walter (1967) model predicted termination date of 11th October close to Kowal and Knabe (1972) model of 10th October. The Walter (1967) model predicted duration of the growing season closest to the Kowal and Knabe (1972) model (173 days) followed by the Penman (1948) model (172 days) and lastly is the BMN (Duru 1984) model with duration of growing season of 171 days.

The BMN (Duru 1984) model predicted short duration of growing season while the Walter (1967) and Penman (1948) models predicted long duration of growing season. The BMN (Duru 1984) and Penman (1948) models are almost the same in predicting the growing season. Considering the variability in duration of growing season with highest variability in the years 1992 and 1993 between the Blaney-Morin Nigeria (Duru 1984), Penman (1948) and Walter (1967) models, the Penman (1948) and Walter (1967) models predicted almost the same equal duration of growing season.

Conclusion

The onset of the growing season is commonly in the month of April but the amount is small for planting. From the four models used in the comparison, the effective start of rains is in the month of May and the latest is in June. The effective termination date is in the month of October as determined by the four models.

From the comparison, it can be concluded that the Blaney-Morin Nigeria (Duru 1984) and Walter (1967) models predicted onset earlier than the Penman (1948) model, while the Penman (1948) model predicted late termination date than the other models.

Therefore, plants with high moisture requirement during that early stage of growth and shallow rooted crops such as tomatoes, onion and cowpea are favored by the BMN (Duru 1984) model prediction of early onset while late termination date predicted by the Penman (1948) model favors crops that can withstand low moisture deficit and crops having tap root system such as sorghum, maize and millet.

Plants with long duration of growing season and crops that require high moisture up to their vegetative and reproductive stages of development (millet, for example) are favoured by the Penman (1948) and Walter (1967) models prediction of long duration of growing season, while short duration plants (maize, cowpea, and groundnut, for example) are favoured by the BMN (Duru 1984) model prediction.

References

Ananthakrishnan, R.; and Soman, M.R. 1988. Onset of the south west monsoon over Karala: 1901-1980. J. Climatol. 8: 283-96.

Ati, O.F. 1995. A comparison of methods to detect the onset of the growing season and its trends for some section in the Sudan Savannah of the Northern Nigeria. Unpublished M.Sc. Thesis, Department of Geography, Ahmadu Bello University, Zaria, Nigeria.

Awadulla, S.A. 1981. On climatic classification for Sudan and short term soil moisture conditions in the Central region. Unpublished Ph.D. Thesis, University of Sheffield, Sheffield, England.

Benoit, P. 1977. The start of the growing season in Northern Nigeria. Agric. Meteorol. 18: 91-99.

Davey, E.G.; Mattie, F.; and Solomon, S.I. 1976. An evaluation of climate and water resources for the development of agriculture in the Sudan Savannah zone of West Africa. World Meteorological Organization (WMO) Special Environment Report No. 9, Geneva, Switzerland.

Dennett, M.D.; Elliston, J.; and Speed, C.B. 1981. Climate and cropping systems in West Africa. Geoforum 12 (2):193-202.

Duru, J.O. 1984. Blaney-Morin Nigeria evapotranspiration model. J. Hydrol. 70(1-4): 71-83.

Hulme, M. 1987. Secular changes in wet season structure in central Sudan. J. Arid Environ. 13: 31-46.

Ilesanmi, O.O. 1972. An empirical formulation of the onset, advance and retreat of rainfall in Nigeria. J. Trop. Geog. 34:17-24.

Jolliffe, I.T.; and Sarria-Dodd, D.E. 1994. Early detection of the start of the wet season in tropical climates. Int. J. Climatol. 14: 71-6.

Kopper, W.P.; and Geiger, R. 1936. Handbuch der Klimatologi. Fondation Internationale pour la Science, Berlin, Germany.

Kowal, J.M., and Knabe, D.T. 1972. An agro-climatic atlas of the northern states of Nigeria. Ahmadu Bello University Press, Zaria, Nigeria.

Madeoye, I.J. 1986. The statistical characteristics of rainfall in Lagos state. Unpublished B.Sc. Project Report, Department of Geography, University of Jos, Jos, Plateau State, Nigeria, pp. 2-15.

Mortimore, M.J. 1989. Adopting to drought: Farmers, famines and desertification in west Africa. Cambridge University Press, Cambridge, UK.

Oladipo, E.O.; and Kyari, J.D. 1993. Fluctuations in the onset, termination and length of the growing season in northern Nigeria. Theor. Appl. Climatol. 47(4): 241-50.

Olaniran, O.J.; and Sumner, G.N. 1989. A study of climatic variability in Nigeria based on the onset, retreat and length of the rainy season. Int. J. Climatol. 9: 253-69.

Penman, H.L. 1948. Natural evaporation from open water bare soil and grass. Proc. Roy. Soc. London, Series A (Mathematical and Physical Sciences) 193(1032): 120-45.

Shaw, A.B. 1986. An analysis of rainfall regimes on the coastal region of Guyana. J. Climatol. 7: 291-302.

Singh, N. 1986. The duration of the rainy season over different parts of India. Theor. Applic. Climatol. 37: 51-62.

Stern, R.D.; Dennett, M.D.; and Garbutt, D.J. 1981. The start of the rains in West Africa. J. Climatol. 1: 59-68.

Stern, R.D.; Dennett, M.D.; and Dale, I.C. 1982. Analysis of daily rainfall measurements to give agronomically useful results. 1. Direct Methods. Exp. Agric. 18: 223-36.

Walter, M.W. 1967. Length of the rainy season in Nigeria. Nigerian Geogr. J. 10: 123-8.

Yayock, J.Y.; and Owonubi, J.J. 1986. Weather sensitive agricultural operations in groundnut production. The Nigerian situation agrometeorology of groundnut. Proc. Int. Symp. International Crop Research Institute for the Semiarid Tropics (ICRSAT) Sahelian Center, Niamey, Nigeria, 21-26 August 1985.

Zargina, A.B. 1987. Onset of effective rainfall and characteristics of dry spell in Nigeria savanna. Unpublished B.Sc. Project Report, Department of Geography, Ahmadu Bello University, Zaria, Nigeria, pp. 1-20.

Zikirullah, M.M.; and Edoga, R.N. 2001. Determination of the growing season using different potential evapotranspiration models. Unpublished B.Sc. Project Report, Department of Soil Science, Ahmadu Bello University, Zaria, Nigeria.