DEVELOPMENT OF A TIME CONTROLLED BASED SOLAR RADIATION TRACKING SYSTEM

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Abstract

The increase in daily use of electricity with limited in the amount of fossil fuel necessitated researchers to explore other methods of producing energy. Many renewable sources of electricity are in existence, one of the cheapest, free and the most abundant renewable source of energy is the electricity generated from the sun. Electricity from solar radiation is environmentally friendly as it poses no harmful hazard to the surrounding. Today, radiation from the sun can be harnessed with the use of the photovoltaic material like the solar panel. It was observed that the sun direction keeps changing during the day as a result of the rotation of the earth and obtaining maximum amount of solar energy from a fixed solar panel cannot be totally achieved throughout the day. To this extend, a time controlled base solar radiation tracking system was developed. The developed system is capable of continuously changing the direction of sun module as the sun transverse the sky with the use of an intelligent fuzzy rules base on input variations. The performance of the tracking system when compared with the fixed solar device gave an output of 19.54% increase in voltage output.

Keywords: Sun, Energy, Radiation, Tracking, Time, Panel

Introduction

Energy is the prime factor in the development of a nation. An enormous amount of energy is extracted, distributed, converted, and consumed in the global society daily. About 85% of energy production is dependent on fossil fuels. The resources of fossil fuels are limited and their use results in global warming due to emission of greenhouse gases (Rajan *et al*,2016). Worldwide shape adjustment and the energy crisis promotes the improvement of renewable energy. Solar electricity has gained a lot greater cognizance because of infinite and green capabilities (Xiaoshan *et al*, 2013).

Nowadays, the improvement of the electricity industry keeps changing with time. The change in methods of generating the power pushes the energy producing industry to a new level of using different means of energy generation from the earth surface and this also prompt mankind continually looked for environmental friendly kind of electric powered energy for sustenance (Shyngs *et al*, 2013). Today, it is closely observed that most of the energy from the sun is absorbed when the panels surface is perpendicular to the sun. Desk bound mounted PV (Photovoltaic) panel are usually perpendicular to the sun once a day and the principal research it is always to get maximum amount of energy base on motion from sun direction (Sharad *et al*, 2015). The apparent motion of the sun is shown in Figure 1. Solar energy is likewise a radiant light and heat from the sun harnessed the use of a variety of ever-evolving technology consisting of sun heating, photovoltaic solar thermal energy and artificial photosynthesis (Sivasakthi *et al*, 2016).

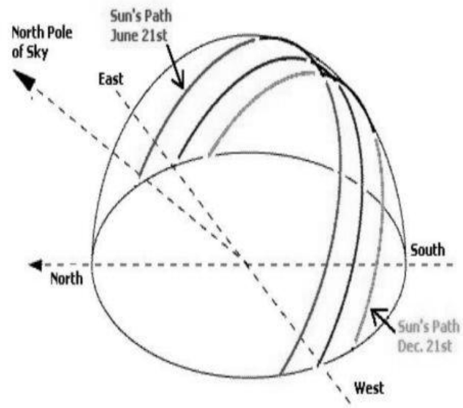

Figure 1: Sun's apparent motion (Narendrasinh, 2015)

Photovoltaic system is one of the most promising and active technology in the continuous development of an easy and dependable energy source with a totally low preservation rate, minimal ecological effect and nearly inexhaustible. PV conversion is not always new but enhancing its performance is still a top precedence in lots of academic and business studies companies all over the globe (Tudorache & Kreindler, 2010). In an effort to attain solar energy production, the performance of PV device is also a point of focus in the field of engineering. There are three (3) strategies to determine the performance of PV systems. The first technique is to obtain the efficiency of sun cells. The second is related to the energy conservation system consisting of maximum energy factor monitoring (MPPT) a manageable set of rules and the third method is to adopt sun monitoring gadget to obtain maximum energy from the sun (Gagari & Arijit, 2012).

Methodology

The use of Photovoltaic panels is to harness sun electricity by way of changing it to electric power thereby assembly the growing call for alternative energy resources by preserving the PV-panels perpendicular to the sun's radiation maximizes the output. The efficiency of the solar panel may be maximized if it can be aligned to constantly to face the sun direction, by means of so doing, the energy output might be maximized. To maximise strength output from the solar panels, a way of monitoring the sun's motion is essential. The systems which can be applied for this movement are called solar trackers and the technique of aligning the photovoltaic module to constantly face the solar is called solar tracking. The system block diagram of the actuation unit is shown in figure 2.

For tracking to take place, two conditions should be met; RTC (Real Time Clocking) time must suit with tabled cost and the sensor input from the solar radiation must be greater than the threshold value from the photo resistor. If these two conditions are met, motor can rotates to manipulate sun panel.

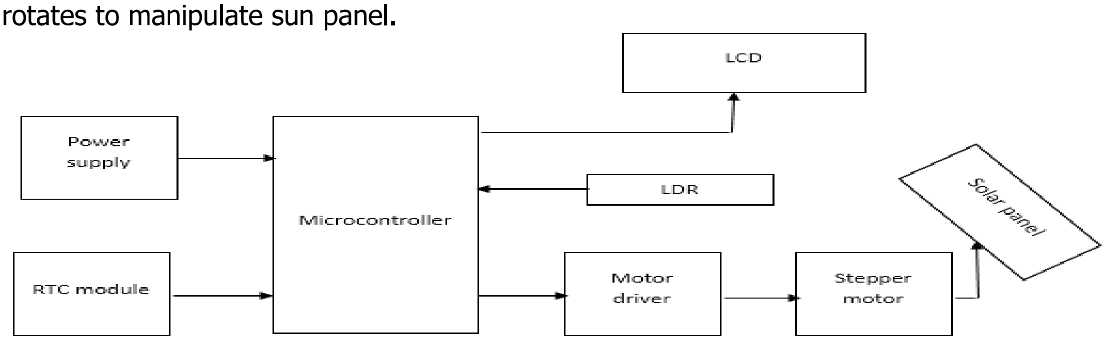

Figure 2: Actuation unit block diagram

Generally, the actuation unit is responsible for the alignment of the solar panel when a control signal is sent from the microcontroller. The 2N222 transistor is used as a switch, the base terminal of the transistor is connected to the microcontroller, this transistor is unable to drive the stepper motor because it has a small collector current. Therefore, the current is amplified by passing it to the base of a bigger transistor (TIP41C) and then it is used to power the MOSFET (*Metal Oxide Semiconductor Field Effect Transistor).*

The stepper motor used in this research is 2-phase 6-wire, 1.8A unipolar stepper motor. The two wires at the centre of the motor were connected to 12V supply and the remaining wires are connected to the source terminal of the MOSFETS as shown in Figure 2.8. The microcontroller is the main processing unit of the whole system upon which every other component depends. The microcontroller chip used in this research is the AT89S52 microcontroller. The processing unit consist of : 8KB of flash, 32 I/O lines, two data pointers, 256ytes of RAM, watchdog timer, three 16-bit timer/counters a full duplex serial port, and an on-chip oscillator.

Real time clock as the name implies, is a clock module. The RTC chip used in this research is DS1307. It is available in form of integrated circuits (ICs), it supervises timing like a normal clock and operates dates like a calendar. The RTC chip can operate in either 12 or 24 hour format. The chip has an in-built battery which serves as a backup power supply when the power failure occurs. The 555 timer IC is used in a variety of applications like timing function, pulse generation and oscillation applications. The 555 timer is configured in a bi-stable mode of configuration which acts like a flip-flop.

The microcontroller performs movement of the tracking system. The 11.0592MHz crystal is used in the microcontroller to help in the operation of the internal oscillator. LDR is connected to pin 2 (Trigger) of the 555 timer. When light falling on the LDR is of high intensity, the resistance of the LDR drops which increases the voltage going into the trigger pin and consequently results in a low output of pin 3. Conversely, when light falling on the LDR is of low intensity, a high resistance is developed in the LDR.

The fuzzy logic input for time and position with rules is develop to provide orientation and communication between the sun and solar panel which is shown in Figure 2.2, Figure 2.3, Figure 2.4, Figure 2.5 and Figure 2.6 respectively.

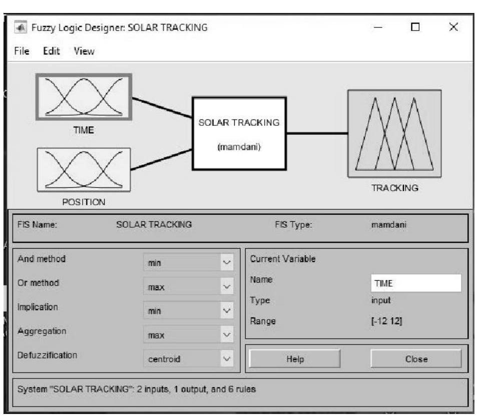

Figure 2.2: Fuzzy logic system

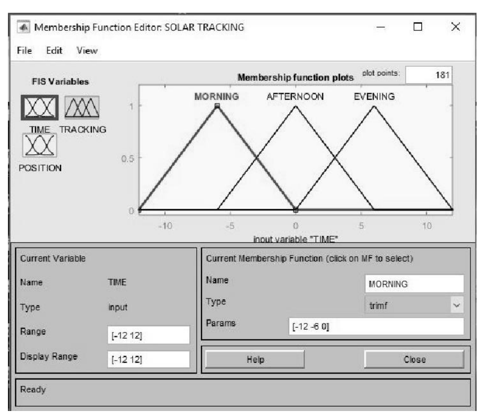

Figure 2.3: Time membership function

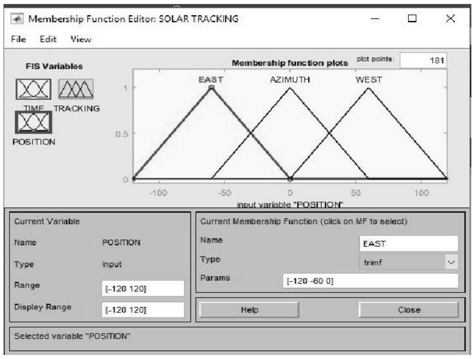

Figure 2.4: Position membership function

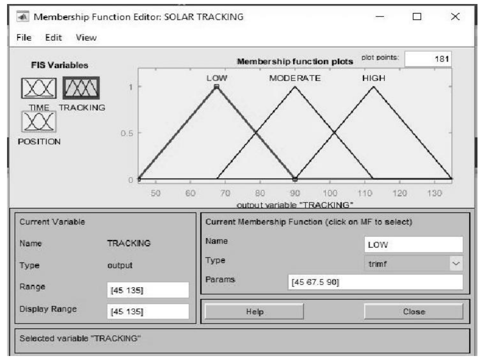

Figure 2.5: Tracking membership function

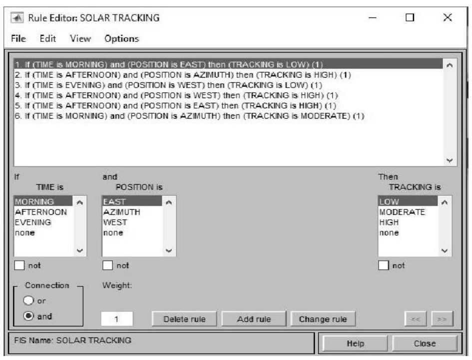

Figure 2.6: Fuzzy rules

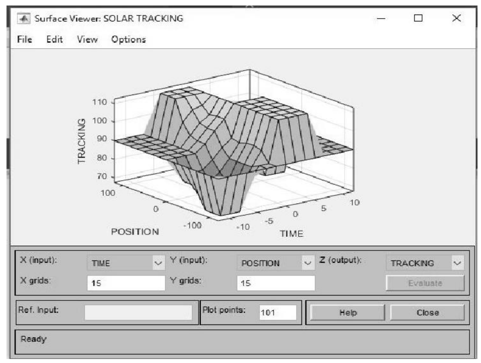

Figure 2.7: Output relationship

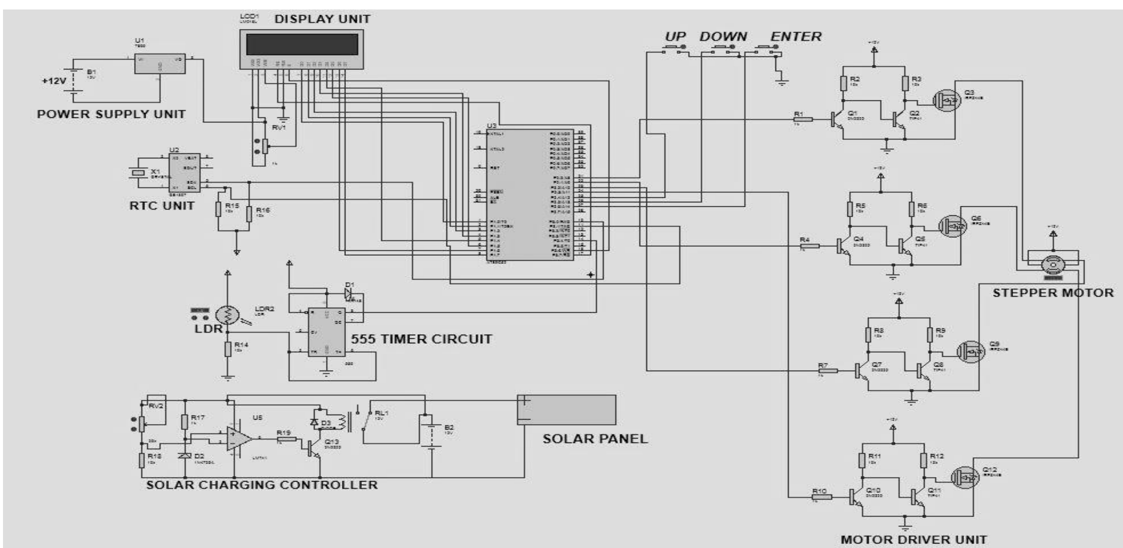

Figure 2.7: System circuit diagram

From the develop membership function of fuzzy logic in Figure 2.3, the negative values represent AM (Ante Meridiem) and the positive values represent the PM (Post Meridiem). The membership function for the position of the sun is develop with the negative values representing the east position of the sun and the positive value represent the west position of the sun as shown in Figure 2.4. The tracking movement of the solar panel from the fuzzy system from low, moderate and high angular position is shown Figure 2.5 together with the rules in Figure 2.6. The output relationship between time and position is also shown in Figure 2.6.

The display unit consists of a 16x2 Liquid Crystal Display (LCD). The 16x2 LCD is capable of displaying only 16 characters on two lines at a time. The purpose of LCD in this research is to display the tracking time at different tilt time.

Results and Discussion

The initial position is set to 8.00 AM in the morning which is achieved from the membership function time interval and the final time to reverse back to the initial position is 6.00 PM in the evening as shown in table 3.1. The voltage level output of the solar panel both the tracking and fixed system was recorded at different times of the day under the same atmospheric condition. Voltage measurement was taken on 26th January, 2017, 27th January, 2017 and 28th January, 2017.

Table 3.1: Voltage values for fixed and tracking mode of solar radiation system

S/N	Time	26th January, 2017		27th January, 2017		28th January, 2017	
		Fixed Mode (V)	Tracking Mode (V)	Fixed Mode (V)	Tracking Mode (V)	Fixed Mode (V)	Tracking Mode (V)
1	8:00 AM	12.3	17.6	12.1	16.4	12.0	17.3
2	9:00 AM	13.1	18.7	13.4	17.2	13.6	18.7
3	10:00 AM	16.4	21.9	16.0	20.5	17.0	21.8
4	11:00 AM	18.1	22.2	18.6	21.5	19.8	21.7
5	12:00 PM	23.3	23.5	23.4	23.6	22.4	22.9
6	1:00 PM	23.1	23.2	23.1	23.2	23.0	23.3
7	2:00 PM	18.4	21.1	18.0	20.2	19.2	21.8
8	3:00 PM	17.0	19.8	17.1	18.4	17.0	19.9
9	4:00 PM	13.0	17.1	13.4	17.2	13.4	16.8
10	5:00 PM	12.2	15.4	11.4	15.4	11.2	15.6
11	6:00PM	10.5	13.9	8.9	12.8	9.0	13.5

Average increase in output Voltage = $\frac{20.86+17.67+20.10}{3}$ = 19.54%

The relationship time with respect to voltage measurement taken in fixed and tracking mode for three different days are shown figure 3.1, figure 3.2 and figure 3.3. The overall assessment of the graphs shows that the voltage gain in tracking mode is higher than the fixed mode.

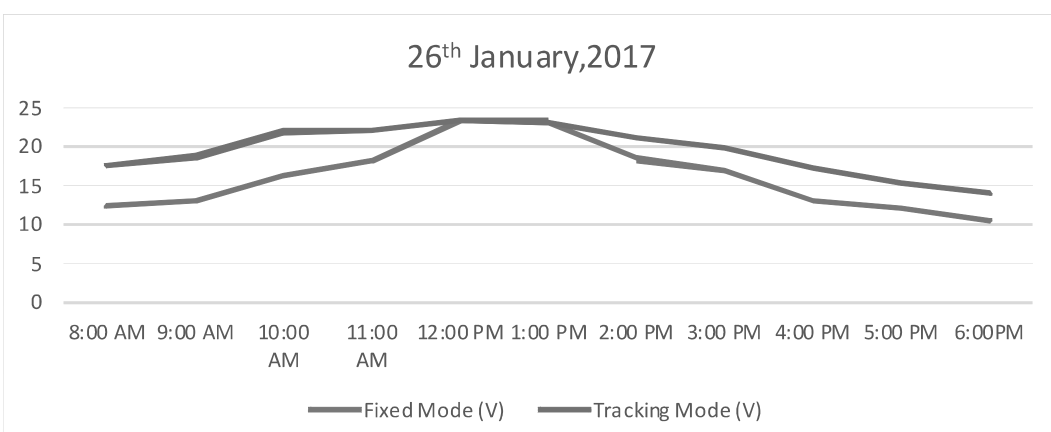

Figure 3.1: Time and voltage measurement for 26th January, 2017

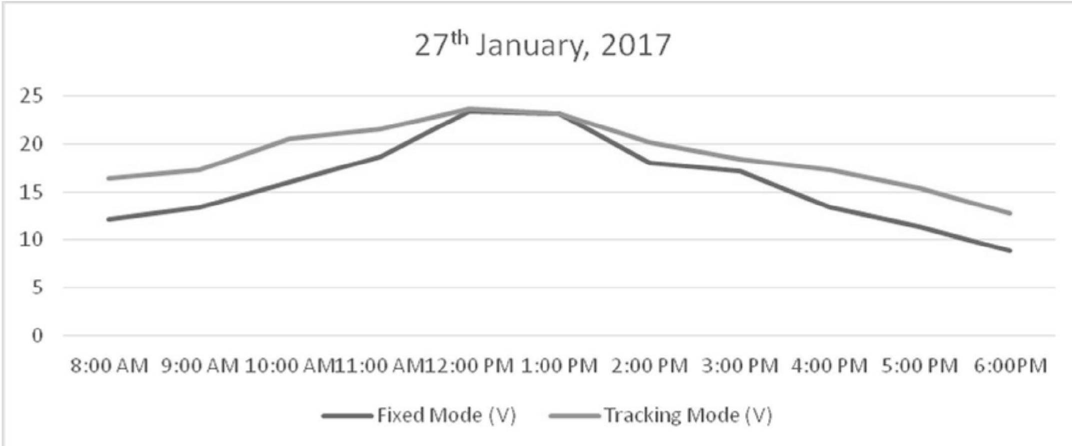

Figure 3.2: Time and voltage measurement voltage measurement for 27th January, 2017

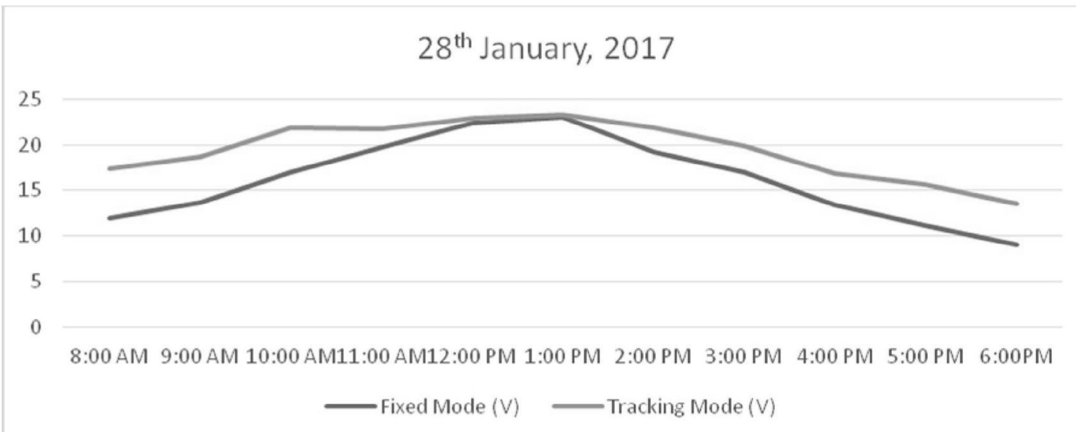

Figure 3.3: Time and voltage measurement voltage measurement for 28th January, 2017

The physical structure of the developed system is shown in figure 3.4 and the testing mode of motor driver that rotate the panel is shown in figure 3.5.

Figure 3.4: Solar tracking system

Figure 3.5: Testing the motor driver

Conclusion

This research provides a cost-effective means of harnessing the amount of sun radiation to be converted to electrical energy thereby meeting the excessive demand of electricity. The development of this system will continue to reduces the total dependence on fossil fuels for electricity delivery and lower the quantity of emission of gases like carbon monoxide which poses critical environmental threats. The precise steps required to constantly align solar modules to the course of maximum radiation of daylight have been carried out. The performance assessment of the device became completed through comparing the solar panel voltage output of the monitoring tracking system with the constant solar panel. After the assessment, there was 19.54% increase in the voltage output.

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CHARACTERIZATION AND CLASSIFICATION OF SOILS OF KWARA STATE UNIVERSITY TEACHING AND RESEARCH FARM, MALETE, NIGERIA

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Abstract

Proper soil use is inched on understanding its physical and chemical properties. To this end, the soils of Kwara State University Teaching and Research farm, Malete, situated in the Southern Guinea Savannah zone of Nigeria were characterized and classified according to the United State Department of Agriculture (USDA, 2014) Soil Taxonomy and Food and Agriculture Organization- World Reference Base (FAO – WRB, 2006). Soil survey was done to establish mapping units. Three profiles (0 -147 cm, 0-156 cm and 0-156 cm) were dug in each established mapping units along the toposequence of the area (upper, middle and lower slopes). Soil samples (0-19, 19-35, 35-86, 86-147 cm), (0-21, 21-41,41-61,61-156 cm), (0-40, 40-61, 61-91, 91-156 cm) were collected from the pedogenic horizons for soil characterization. The soils were deep (0-147 cm, 0-156 cm, depth) and well drained. The soil physical parameters like the textural classes identified ranged from sandy loam to sandy clay loam. The soils were moderately acidic to slightly acidic (pH 5.47 - 6.31). The macro nutrients (N, P), organic carbon (OC) and CEC of the soils were generally low with high base saturation (>50%). All the pedons had varying quantities of mottles and iron- manganese concretions. All pedons were classified as Alfisol, having ustic moisture regime and plinthite occupied more than half volume of soils within 150 cm depth. Therefore, they were classified as Typic Plinthustalfs (USDA) and as Plinthosol (FAO). At the soil series level, they were classified as Gambari series (Local classification by Smyth and Montgomery, 1962).

Keywords: Pedogenic horizons, Soil physical parameter, Plinthite, Toposequence

Introduction

Soil characterization provides useful information for assessment and monitoring of the behaviour of soils. It also provides an introduction to the management requirements of the major soils both in the present and future (Abdulkadir, 2008; Behzod, 2012). On that basis, soil is often regarded as the basic natural resource which determines the ultimate suitability and sustainability of any agricultural system. Raju et al. (2005), described the inherent ability of soils as virtual that determines the productivity of agricultural systems by supplying nutrients for crop growth and sustain soil physical conditions to optimize crop yields.

Again, it is through precise measurement and full understanding of the nature and properties of soils as well as proper management of the nutrient and moisture requirements that one can maximize crop production to the allowable potential limits (Esayas & Debele, 2014). In order to evaluate the quality of our natural resources and their potential to produce food, fodder, fiber, and fuel for the present and future generations, detailed information on soil properties is required.

This further pinpoints the need for good soil management as essential option for sustainable agriculture. In the development of sustainable agricultural systems the focus is to reduce degradation of natural resources and promote environmentally compatible ways to increase production and promoting broad-scale development (Ajiboye *et al.*, 2011).

Therefore, intensification of agriculture on land currently requires a thorough knowledge of the soil as a resource, material and according to intended uses. Thus, a good knowledge of the soil resources of any given territory is indispensable for planning its agricultural development (Eswaram *et al*., 2003). Soil surveys provide a scientific inventory of the soils occurring within a specified land area and involve the systematic examination, description, classification and mapping of such soils. According to Esu (2010), during a soil survey, sufficient information is gathered in order to help the surveyor to correlate and to predict the adaptability of soils to various crops, behaviour and productivity under different management systems.

Soils of Kwara State University Teaching and Research Farm, Malete have been used for several purposes with little or no information on the physical and chemical properties of the soil. According to Esu (2004), the lack of information on the soil resources of any region contributes to the problem of soil degradation and that of world food crises among others, due to wrong uses and poor management practices.

The information on the characteristics of the soils of University Teaching and Research Farm needs to be documented and it is on this premise that the study was carried out to obtain detailed characterization of the physical, chemical properties of the soil mapping units of Malete soils and give out a taxonomic classification of the soils based on the criteria of the USDA soil Taxonomy (Soil survey Staff, 2014) and the FAO/UNESCO (2006).

Materials and Methods

The Study Area

The experimental site used for this research was located at the Teaching and Research farm of Kwara State University, Malete, Nigeria. The farm has latitude 8°71′ N and longitude 4°44′ E at 365 above sea level. The Kwara State University Teaching and Research Farms, Malete consists of approximately 1,400 hectares. The climate is characterized by distinct wet and dry seasons with a mean annual temperature that ranges from 25 - 28.9 °C; the annual mean rainfall is about 1,150 mm, exhibiting a double maximal pattern between April and October of every year. The wet season is between April and October while dry season starts November and ends in March (Olaniyan, 2013).

Farming activities has destroyed the natural vegetation of the site. The area can presently be regarded as anthropogenic because it has suffered various degrees of human interference (ploughing, harrowing, ridging etc). The present vegetative cover of the site can now be regarded as savannah woodlands.

The Vegetation of site consists of arable crops like soyabeans, beeniseed ,cowpea etc. The dominant woody species include Baobab trees, acacia trees and Orupa trees. Grasses dominated the site include among others Spear grass (*Imperata cylindrical*), Andropogon gayanus, Elephant grass, Guinea gamba grass , while the dominant broadleaf is Siam weed, *Chromolaena odoratum.*

Field Studies

The experimental sites were selected to cut across major soil series of Smyth and Montgomery (1962) along a toposequence in farmer's plots, using soil and site descriptions from 0-100cm auger samples to establish the mapping unit. Three mapping units were established and three soil profiles were dug to represent the three mapping units. The profiles were described using the guidelines of FAO (2006) and Soil Survey Staff, 2014. Sampling of each profile was carried out according to the pedogenic horizons.

Soil Analysis

The 1 Kg of soil samples were collected from pedogenic horizons (0-19, 19-35, 35-86, 86-147 cm), (0-21, 21-41,41-61,61-156 cm), (0-40, 40-61, 61-91, 91-156 cm) on September, 2015 and air-dried at room temperature for 48 hours and passed through a 2 mm sieve to remove large particles, debris and stones. The soil samples were analyzed for soil texture, pH, organic carbon, total N, extractable P, exchangeable bases and exchangeable acidity and micro-nutrients. Soil texture was determined by the Bouyoucos hydrometer method (Gee & Bauder, 1986). Soil pH was measured electrometrically in a 1:1 in H_2O. Organic carbon was determined by Walkey-Black method (Olowoake & Ojo, 2015). Total nitrogen was determined by the Micro- Kjeldahl method (Foth, 2014; Ojanuga, 1975) and extractable P was determined by Bray 1 method (Bray). Exchangeable bases were determined by the atomic absorption spectrophotometer following the standard procedures. Micronutrients were extracted with 0.1 Ethylenediaminetetraacetic acids (EDTA) and determined using atomic absorption spectrophotometer.

Results and Discussion

Soil physical and morphological properties

The physical and morphological properties of soils of the study area are shown in Table 1. The first profile was located in the upper slope of the toposequence on a gentle slope. Pedon UPP had colour variations between reddish brown (5 YR 4/3) in the surface soil to a range of red (10 YR 4/6) and Yellowish red (5 YR 5/8) in the subsurface soils. This profile had a loamy sand epipedon overlying a sandy loam to sandy clay loam subsoil. This pedon had high sand, moderate silt and clay contents with clay content increased with depth indicating the evidence of argilluviation in the second, third and fourth horizons of this pedon. The iron- manganese concretions were identified in the subsurface horizon between depths 35 and 86cm and 86 to 147 cm. Generally, the soil was well drained at the time of sampling, but few, distinct dark reddish grey mottles (10 R ¾) were observed at a depth of 35 -86 cm. With increase in depth, the mottles became many, coarse and prominent with a colour change from dark reddish grey to black (5 YR 2/1) at a depth 86 -147 cm. The mottling observed in the soils may be attributed to the reducing condition of iron in the soil due to alternating wetting and drying conditions over a long period of time (Eswaram *et al*., 2003).

The pedon had medium sub angular blocky structure in both surface and sub surface soils. The profile had a consistency that ranged from friable, loose, slightly- sticky, to slightly-plastic (wet). The boundaries between the horizons were gradual and smooth throughout the pedon.

The second profile was located on the middle slope of the toposequence. The colour of the pedon also ranged from Dark brown (7.5 YR 4/2) on the surface to dark brown (7.5 YR4/4) to Yellowish red (5YR 4/6 and 5 YR 5/8) in the sub soils. The Pedon had loamy sand texture on the surface horizon and loamy sand, sandy loam in the sub surface soils. The epipedon were fairly stony and free of concretion while iron- manganese concretions were encountered at depth 41-61 cm and 61-156 cm. The soil was deep and well drained at the time of sampling. However, dark gray (5 YR 4/1), fine, medium and distinct to dark reddish brown (5 YR 3/2), many, common, coarse and prominent mottles were encountered between 41 and 156 cm depth, respectively which may be attributed to the oxidation-reduction processes in the soil.

Table 1: Physical and Morphological Characteristics of the soils of the study area

SS/TOPO	Horizon Depth (cm)	% Sand (g/Kg)	% Clay (g/Kg)	% Silt (g/Kg)	Soil Texture	Soil Structure	Consistence	Soil Colour (Moist)	Mottles	Concretion	Horizon boundary
UPP	0 - 19	846	60	94	LS	MSAB	Fr, s	Reddish brown (5YR 4/3)	Absent	Absent	gs
	19 - 35	766	120	114	SL	MSAB	Fr, shd	Reddish brown (5YR 5/4)	Absent	Absent	gs
	35 - 86	506	340	154	SCL	MSAB	Hd	Red (10R 4/6)	10R 3/4; f,fi,fn	Present	gw
	86 - 147	596	260	144	SCL	MSAB	Hd	Yellowish red (5YR 5/8)	5 YR 2/1, m,c,pr	Fe- Mn, f, r	-
MDD	0 - 21	846	60	94	LS	FSAB	Fr, shd	Dark brown (7.5YR 4/2)	Absent	Absent	gs
	21 - 41	826	80	94	LS	SG	Hd	Dark brown (7.5YR 4/4)	Absent	Absent	gs
	41 - 61	786	80	134	LS	CSAB	Hd	Yellowish red (5YR 4/6)	5YR 4/1 m,c,pr	Fe- Mn, c, r	gw
	61 - 156	706	140	154	SL	SAB	Hd	Yellowish red (5R 5/8)	5YR 3/2 m,c,pr	Fe - Mn, m, r	-
LS	0 - 40	806	60	134	LS	MSAB	Fr, l	Dark brown (7.5YR 4/2)	Absent	Absent	cs
	40 - 61	806	100	94	LS	SG	Fr, l	Reddish brown (5YR 5/4)	Absent	Absent	gs
	61 - 91	646	200	154	SCL	SG	Hd	Red (2.5YR 5/6)	5YR 2/1, m,c,pr	Fe – Mn, f, r	Gw
	91 - 156	706	180	114	SL	SG	Hd	Yellowish red (5YR 5/8)	5YR2/1	Fe-Mn,c,r	-

Keys: SL= Sandy loam; SC= Sandy clay; SCL= Sandy clay loam, LS= Loamy sand, SG= Single grained, UPP= Upper, MDD= Middle, LS= Lower slopes.
FSAB = Fine sub angular blocky; MSAB = Medium sub angular blocky; CSAB= coarse sub angular blocky**;** Fr = friable; Fm = Firm; l = loose; hd = Hard; shd = Slightly hard, s = soft, c=common, f=fine, d=distinct, s=sharp, m=many, cr=coarse, p=prominent, gw= gradual wavy, gs= gradual smooth, cs= clear smooth, Fe-Mn= iron-Manganese concretions, ss/Topo=slope or Toposequence,UPP= upper slope, MDD= Middle slope, LS= lower slope,

The structure of the pedon ranged from fine sub angular blocky to single grained on the surface and coarse subangular blocky to subangular blocky in the subsurface soils. Profile consistency ranged from friable, loose, non- sticky, non-plastic (wet) on the surface to firm, hard, very sticky, very plastic in the subsoil. The boundaries between horizons were gradual and smooth (Boundary is 6 – 12.5 cm wide in distinctness and nearly a plane in form).

The third profile (LS) was located on the lower slope of the toposequence. The surface and second horizon of this pedon were dark brown (7.5 YR 4/2) and reddish brown (5YR 5/4) respectively, while the subsurface horizons were red (2.5 YR 5/6) and yellowish red (5 YR 5/8). The pedon had loamy sand in the first and second horizons and sandy clay loam to sandy loam in the third and fourth horizons. There was evidence of argilluviation in the subsoils due to increase in clay content (Ojanuga, 1975). The profile was well drained. However, black (5 YR 2/1) fine, coarse distinct, prominent mottles were noticed between 61 to 156 cm depth. The profile had medium subangular blocky structure in the surface soils to single grained in the subsurface soils. The characteristics of the horizons ranged from firm, slightly- sticky, slightly- plastic in the surface to friable, loose, non-sticky, non- plastic in the subsurface soils. The horizon boundaries were gradual smooth in the surface horizon but gradual wavy in the sub surface horizon (boundary is 6 – 12.5 cm wide in distinctness and nearly a plane in form at the surface while it's shallow pockets are wider than they are deep in form at the subsurface).

Chemical characteristics of the soil

The soils had reactions ranging from moderately acidic to slightly acidic (5.47 -6.31) in distilled water (Table 2). However, the upper slope had a range between 5.80 and 6.01, the lower slope had the highest pH value in the second horizon (6.31) and the first horizon (6.16) while other horizons exhibited moderately acid condition. A similar pattern of pH variation was noticed in the middle pedon with the highest value in the first horizon and second horizons. The acidic nature of the soils indicated basement complex rocks as the parent material.

The total exchangeable acidity was moderate for all the pedons ranging from 0.15 - 0.35cmol/Kg. The total Nitrogen of all the pedons were generally low (0.09-0.24 %), but the middle pedon fell into medium class, having a range between 0.14 -0.24 %. This could be attributed to loss of organic nitrogen through leaching and crop removal due to cultivation. The first horizon of the middle pedon and third pedon had a very high organic carbon, while other horizons of the pedons had moderate to high content of organic carbon with the exception of third horizon of the upper slope pedon which was low (0.82 %). The high content of organic carbon exhibited by middle slope pedon was probably due to the presence of Baobab tree (*Adansonia digitata*) around the site; which shed leaves that formed litters on the ground. The available Phosphorus were generally low for all pedons (ranging between 0.77 and 2.96 ppm).

The extractable Zinc (Zn), copper (Cu), Manganese (Mn), Iron (Fe), (Micro nutrients) contents of the soils were moderate to high. The highest value of Fe and Mn was probably due to the presence of Iron- Manganese concretions found in all profiles and which increased with increasing soil depth. The value of Fe ranged from 22.7and 104.0 mg/Kg while value of Mn ranged from 95 – 202 mg/Kg. The content of Cu and Zn also followed the same trend.

The percentage base saturation of the soils was consistently higher than 90%. It ranged from 92.0 -97.5%.

The low CEC of these soils coupled with low organic matter, low total Nitrogen and available Phosphorus were indications of low inherent soil fertility status, which under- scored the need for improved soil management techniques. All deficient nutrients are macro nutrients which are needed in large quantities by plants. Therefore, there is the need to practice appropriate fertilizer use on the farm. Combination of organic manure and inorganic fertilizer is suggested.

Table 2: Chemical Characteristics of the Soils of the study area

Profile	Horizon Depth (cm)	pH (H_2O)	OC (%)	TN (%)	Av. P (mg/Kg)	K^+ (Cmol/Kg)	Ca^{2+} (Cmol/Kg)	Mg^{2+} (Cmol/Kg)	Na^+ (Cmol/kg)	TEA (cmol /Kg)	CEC (Cmol /Kg)	% B.S	CEC Clay	Fe (mg/Kg)	Cu Mg/kg	Zn mg/kg	Mn mg/kg
Upper slope	0 - 19	5.96	1.48	0.15	2.55	0.29	3.03	0.89	0.31	0.25	4.77	94.8	78.63	104.0	1.67	0.77	181.0
	19 - 35	5.89	1.68	0.17	2.98	0.19	2.79	0.83	0.26	0.35	4.39	92.0	36.11	81.7	9.75	0.55	202.0
	35 - 86	5.80	0.82	0.09	2.71	0.57	2.67	0.52	0.43	0.30	4.49	93.3	13.12	74.1	10.64	0.71	124.0
	86 - 147	6.01	1.31	0.14	1.02	0.34	2.09	0.66	0.38	0.20	3.67	94.6	13.94	55.7	10.61	0.43	110.0
Middle slope	0 - 21	6.17	2.29	0.24	5.11	0.54	3.92	0.99	0.33	0.15	5.93	97.5	97.50	95.1	10.24	0.72	124.0
	21 - 41	6.11	1.92	0.20	5.96	0.43	2.23	0.74	0.26	0.15	3.81	96.1	46.79	79.6	10.17	0.49	95.0
	41 - 61	5.88	1.35	0.14	1.28	0.76	3.64	0.66	0.29	0.20	5.55	96.4	68.78	57.5	10.14	0.39	117.0
	61 - 156	6.08	1.27	0.14	1.42	0.42	2.29	0.57	0.31	0.20	3.79	94.7	25.55	22.7	10.29	0.44	110.0
Lower slope	0 - 40	6.16	2.17	0.23	1.70	0.44	5.54	0.81	0.32	0.20	7.31	97.3	118.2	138.0	11.05	0.47	186.0
	40 - 61	6.31	1.51	0.16	5.67	0.48	6.47	0.79	0.36	0.25	8.35	97.0	81.29	116.0	11.18	0.83	125.0
	61 - 91	5.47	1.28	0.13	0.96	0.54	2.18	0.97	0.41	0.20	4.3	95.3	20.54	86.3	11.17	0.88	183.0
	91 - 156	5.66	1.52	0.16	0.77	0.51	2.86	0.79	0.37	0.25	4.78	94.8	25.45	87.0	1.55	0.58	171.0

Keys:

SL= Sandy loam; SC= Sandy clay; SCL= Sandy clay loam, LS= Loamy sand, SG= Single grained, UPP= Upper, MDD= Middle, LS= Lower slopes.

FSAB = Fine sub angular blocky; MSAB = Medium sub angular blocky; CSAB= coarse sub angular blocky

Fr = friable; Fm = Firm; l = loose; hd = Hard; shd = Slightly hard, s = soft, c=common, f=fine, d=distinct, s=sharp, m=many, cr=coarse, p=prominent; gw= gradual wavy, gs= gradual smooth, cs= clear smooth, Fe-Mn= iron-Manganese concretions, ss/Topo=slope or Toposequence, UPP= upper slope, MDD= Middle slope, LS= lower slope,

Soil Classification

Pedon 1(upper slope) had Argillic B horizon (Bt_1, Bt_2). Pedon 2 and pedon 3 (middle and lower slopes) had no either an Argillic or Kandic horizon.

All the Pedons (Upper, middle, lower slopes) had CEC of clay < 16 cmol kg^{-1} clay; base saturation > 50% by NH_4OAc at pH 7.0, this was in agreement with the requirements of soil order Alfisols. The moisture regime was Ustic moisture regime and this qualified these pedons into the sub-order Ustalfs. All pedons had 65% or more plinthite by volume on a horizon which was at least 15 cm thick within 50 cm of the surface that is, Plinthic subsurface horizons and mottling which occupied more than half volume of the soils.

Based on the above properties, with the predominance of plinthite in the sub-surface, all the pedons were classified as Typic Plinthustalf (According to USDA, 2014 and FAO/ UNESCO, 2006). The soils were classified as Plinthosol; Cutanic and Hypereutric. At the Soil Series level, all pedons belonged to Gambari series.

Classification at the family level could not be undertaken because the mineralogy was not determined. This gives direction for further studies.

Conclusion and Recommendation

Due to low cation exchange capacity, organic carbon contents and plinthic sub-surface horizons of the soils, the arable crop yield will be low and tree crops cannot be planted. Therefore, the surface soils should be protected from erosion and practices that improve organic matter content of the soils should be adopted.

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