International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

Investigating the Influence of Rainfall, Evapotranspiration and Temperature on Soil Moisture Content in Semi-Arid Region

[1*]Bitrus J.N., [2]Adigun J.O., [3]Samuel E.O., [4]Bamidele E.T., [5]Oluokun O.E., [6]Usman I.K., [7]Ogbobe J.C., [8]AdedejiP.O.

[1-8]Department of Civil Engineering, Federal University of Technology, Minna, Nigeria.

Date of Submission: 07-04-2024 Date of Acceptance: 17-04-2024

ABSTRACT: From recent times on to date, there has exist an inter-relationship between hydrological processes and this forms the hydrological cycle. The inter-relationship existing between these hydrological processes has been proven to have an influence on the immediate environment, especially the earth (soil). The investigation of the influence of hydrological process (rainfall, evapotranspiration and temperature) on the soil moisture by comparing field soil moisture content and meteorological data of the hydrological processes using statistical package thus, it is established that there exists a correlation between soil moisture content and meteorological data. The aim of the research is to investigate the influence of Rainfall, Evapotranspiration and Temperature on the Soil Moisture Content at the soil depths of 10 cm, 50 cm and 100 cm. The soil sample used in determining the moisture content was collected in triplicate from Federal University of Technology, Minna, GidanKwanu Campus and soil moisture test carried out on the collected samples. The daily Meteorological (rainfall, evapotranspiration and temperature) data used was obtained from the Nigeria Meteorology Agency (NIMET), Abuja and was used in the analysis, and the result of the analysis obtained shows that there exists proportionality between the hydrological processes and soil moisture content with depth, thus becomes a key influencing factor on soil moisture and the measure of this influence is dependent on the soil depth but this influence is more seen or appreciated at soil layer of depth 10 cm than depth of 50 cm. The peak rainfall depth experienced in 26th of May with depth 60.5 cm. With the available Rainfall, maximum, minimum and mean temperature data, radiation, Ra, the Hargreaves method of evapotranspiration estimation was used in this study. Using graphs to best represent how at depths of 10 cm 50 cm and 100 cm, rainfall, temperature and evaporation best affects the soil moisture and also SPSS 16.0 was used to estimate the significant effects the hydrological process has on soil moisture. This research work closes on the fact that with a careful study of the soil moisture content at varying depths, the pattern or behaviour of some hydrological processes can be forecasted as well as their impact. This project work recommends that the adoption of this integrated approach in the areas of irrigation, flood study and risk management, climate change, rainfall-runoff, crop production and ground water yield, provide useful information that`s applicable in aspects of early flood warning, drought monitoring, climate change studies and impact, rainfall-runoff forecasting, weather forecasting and yield monitoring.

I. INTRODUCTION

One of the great contributions of hydrology to the scientific world is the study and understanding of the hydrological processes and how their complete cycle forms the phenomenon regard as the Hydrological cycle. The Hydrological cycle on the other hand, is a term or expression that describes the respective inter-related process/phases (hydrological process) that the forms of water pass through (Raghunath, 2006).

Hydrological Processes are:

- Evapotranspiration - (Evaporation+Transpiration)
- Precipitation - (Rainfall)
- Percolation - Groundwaterrecharge
- Runoff.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

But on this project work, the rainfall, temperature and evapotranspiration would be looked at and studied on how they influence soil moisture.

Fig 1.1: Hydrological Cycle
Source: Civil Engineering Solution-wordpress.com

1.1.1 Rainfall

Rainfall as a form of precipitation can be measured taking into considerations the following characteristics; rainfall intensity, rainfall duration, rainfall frequency and rainfall areal extent (Nana Zhao, 2014). Rainfall is measured using recording or non-recording rain gauge and the information gotten can then be plotted into a Hyetograph which tells the duration and intensity of rainfall (Raghunath, 2006).

Rainfall enters into soil root zone of plant through infiltration due to the influence of gravity causing an increase in the degree of saturation of the soil thus resulting into an increase in soil moisture content of the soil. This increase in soil moisture content can be disadvantageous if not control.

Soil is a product of further weathering from rocks and also comprising micro-organisms. Water in the soil is held in the pore spaces of the soil and the amount of water that can be help in the pore space of the soil particles depends on the water holding capacity of the soil, known as “field capacity” (FC) before percolation begins. Soil moisture content is described as the volume of liquid water present in a soil and can be easily determined by laboratory approach.

In a more brief context it can be said that there is a relationship between measured rainfall characteristics and the soil moisture content of a particular area, as the lower the soil moisture content, the higher the depth of the rainfall required and the higher the soil moisture content, the lesser the depth of rainfall that will be required, also the influence of rainfall on soil moisture content is felt more within the soil root zone of the soil profile and decreases as we go down the soil profile. This implies that the study of this relationship between rainfall and soil moisture content is not only important but needed by civil engineers (water resource engineer), agricultural engineers and even down to the large scale and small scale farmers so as to ensure proper understanding in the area of irrigation, rainfall distribution, flood forecasting and management and boosting crop growth and crop production (Yong Zhang, 2010).

The relationship between Rainfall-Soil moisture is one that is dependent on the climate seasonality and the resulting hydrological processes/phases in each season, a climate season can be taken as the period from dry to wet or dry to dry or wet to wet, and within this seasons much variability results which affects soil, plant, environment (biomass) and the atmosphere (Jun Yin, 2014). Thus, water resources engineers engaged on research works in order to manage this variability and establish a correlation between rainfall and soil moisture which in turn will boost crop production, reduce poverty and increase government product index and also provides a hygienic environment (HO, 2016).

According to (Feng, et al,. 2012) with their research work on the effect of seasonality on soil water balance and plant growth, they analysed the seasonality of rainfall occurrence and its influence on soil and plant activity, upon which they concluded that, the variability in rainfall increase with longer dry season and results to increase in soil water storage capacity with rooting depth. In addition (Zhang et al., 2010) also researched on the response of soil moisture content to rainfall events in semi-arid area of Inner Mongolia, upon which they analysed the dynamics and the distribution patterns of the soil moisture caused by rainfall to reveal the relationship between rainfall events and soil moisture as one of the project objectives, they concluded that, there is a correlation between soil water storage and evaporation as a result of rainfall and also at the point where the soil moisture content equals field capacity run-off occurs.

In arid and semi-arid areas, water is the most active factor in environmental system. The impacts of topography, vegetation and soil on rainfall redistribution have been the hot issues for the studies on water use and ecological environmental protection in semi-arid areas. At present, a considerable amount of research which studies on spatial heterogeneity of the soil moisture and its influencing factors has made much progress. Apart from the nature of soil, rainfall characteristics, land use, terrain and other

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

environmental factors also affect the spatial variability of soil water Zhang et al., 2010).

According to (Jun Yin, 2014) with their research work on the Interplay of climate seasonality and soil moisture-rainfall feedback, they work on seasonal variations in precipitation which are included in a soil moisture-rainfall feedback (SMRF) model with the assumption of a soil moisture –dependent average rainfall frequency to explore their effects on the soil moisture of a semi-arid area, and they found out that a high increase in variability of dry to dry period of a climate season triggers an increase in soil water capacity with an increase in variability with soil rooting depth. For instance, (Lawrence A. Afolabi, 2009) studied the effects of rainfall patterns on soil moisture, soil temperature and plant growth in humid forest zone, Nigeria. They got results which showed that a reduction in the number of monthly rainfall events while maintaining monthly averages influence moisture and temperature dynamics, which ultimately affect the plant growth. It was finally concluded that the reductions in inter – rainfall frequency, while maintaining current monthly precipitation averages, decrease plant biomass production and soil moisture, while soil temperature invariably increases. In addition, soil moisture can serve as a reliable indicator of ecosystem productivity.

Furthermore, (Ufoegbune, et al., 2014) researched on the growth and development of watermelon in response to seasonal variation of rainfall, they discovered that there was a significant increase in watermelon and growth and production in the dry season due to constant and sufficient supply of irrigation and decreases during raining season due infrequent and unpredictable nature of rainfall. They concluded that the dry season should be maximally utilized and irrigation facilities should be made available for the quality growth and development of Watermelon in Nigeria. Also, during the rainy season, supplemental irrigation should be made available when rainfall is not frequent.

Study by (Enete and Ebenebe, 2009). showed that the trend suggested a general decline in rainfall values in recent times. Rainfall values for the years under study suggested values between 265.37mm and 320.21mm. This supports the findings following the pattern; they reported a noticeable and significant decline of rainfall frequency in September and October which coincide with the end of rainy season in almost every parts of the country especially in the Northern and Central parts of Nigeria.

Rainfall is the most important natural factor that determines the soil moisture content. The variability of rainfall and the pattern of extreme high or low precipitation are very important to agriculture as well as the economy of the state.

1.1.2 Evapotranspiration (ET)

Evapotranspiration is the combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration. Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominantly lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process. In Figure 2 the partitioning of evapotranspiration into evaporation and transpiration is plotted in correspondence to leaf area per unit surface of soil below it. At sowing nearly 100% of ET comes from evaporation, while at full crop cover more than 90% of ET comes from transpiration.

1.1.3 Temperature

Soil moisture and surface temperature are common factors used in all environmental engineering technology. The proper understanding of influence of temperature on soil moisture is very important in predicting the relationship between hydrological processes and soil moisture content which gives us better understanding of the interactions between land surface and the atmosphere (J.D. Kalma et al, 2001). Soil temperature and moisture at the surface and sub-surface influence many environmental, hydrological and agro-climatology processes within the soil. Because of this, models that can estimate soil parameters such as temperature and moisture are becoming more relevant. Good knowledge and timely prediction of the soil surface temperature and moisture content is helpful in tackling environmental challenges such as flood management and control (Wang et al., 2006).

However, according to Jia et al., (2006), the relationship between soil temperature and moisture content can be expressed using linear, quadratic, and exponential models.

The effect of temperature in the hydrological process particularly cannot be underestimated because water on the surface of the oceans, lakes, ponds and rivers is being warmed by heats (generated from the sun) as it goes up to the point at which it becomes gaseous (water vapor), the water vapor then rises to the atmosphere.

1.1.4 Soil Moisture

The amount of water associated with a given volume or mass of soil ("soil water" or "soil moisture") is a highly variable property. It can change on time scales of minutes to years. However, most soil properties are more stable, and should be referenced to dry soil weight.

Soil moisture is a key variable in the climate system. By controlling evapotranspiration, soil moisture impacts the partitioning of incoming radiation into sensible and latent heat flux. Furthermore, it represents an important water and energy storage component of the regional climate system. Regional simulations of recent and future climate conditions indicate that a projected increase in summer temperature variability and the occurrence of heatwaves in Central and Eastern Europe is mainly due to soil moisture atmosphere interactions (Seneviratne et al., 2006).

Soil moisture means different things in different disciplines. A farmer’s concept of soil moisture is different from that of a water resource manager or a weather forecaster. Generally, however, soil moisture is the water that is held in the spaces between soil particles. Positive feedback between soil moisture and rainfall has the potential to perpetrate and sustain anomalous hydrological conditions at the seasonal and sub seasonal time scale, improving the land atmosphere system predictability (Koster and Suarez, 2001). The important of rainfall on soil moisture is self-evident. It is harder to perceive and involved complex direct and indirect mechanism. (Eltahir, 2000). Soil moisture is difficult to define, because it is used in different discipline. Although it is a small component of the hydrological cycle, it plays a major role in understanding and predicting climatic conditions and influences a number of processes concerning land- atmosphere interaction. (Fischer et al, 2007).

Soil moisture measurement are important in predicting flood, by accessing how wet the soil is before a rainstorm; we can predict the potential for flooding occur. If the soil is already oversaturated, and its maximum water holding capacity, a rain event will not be absorbed adequately through the soil and flooding will likely to occur. Soil moisture is the key hydro ecological compartment responding dynamically to sequence of the complex processes in the soil. Field moisture is one of the general most important characteristics of the soil. Field soil moisture has extremely value over the time; it depends on the receipt of rainfall, irrigation, and groundwater in the soil and the water consumption from the soil by evaporation, transpiration and runoff. Soil moisture depends on the properties of soil, water permeability and wettability. To obtain accurate data needed, method based on the measurement of undisturbed samples is applied. Observation and modelling study have also shown how soil moisture can affect daily rainfall. (Clark et al, 2004).

1.1.5 Soil Moisture and Strength Index for Earthwork Construction Quality Control

For most earthwork compaction criteria to be accepted, there must be a specified target dry density of the earth materials, achieved through proper moisture content. According to this approach, by achieving a certain dry density using an acceptable level of compaction energy assures attainment of an optimum available level of structural properties and also minimizes the available pore spaces and thus future moisture changes.

1.1.6 Flood

Flood is described as a process characterised with extreme intensity of rainfall and surface runoff. Flood is majorly caused by excess runoff which occurs when there is too much rainfall. Flooding has become a major hazard in Nigeria in recent years due to a growing population, rapid urbanization and extreme weather events (Oladokun and Proverbs, 2016). Flooding has become a frequent hazard which is related to heavy precipitation, which can collapse the natural or man-made structures (Chigbu et al,. 2018).Flood can also occur in rivers when the flow rate exceeds the capacity of the river channel, mostly at bends or meanders in the waterway. Floods often have major adverse impacts to economic growth and can also be attributed to

- Loss of life and property
- Loss of agricultural land due to water logging and soil salinity

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

- Constant threat to engineering structures and public utilities.

The aim of this research is to investigate the influence of rainfall on the soil moisture content in semi-arid region at the soil depths of 10cm, 50 cm and 100 cm. and the specific objectives are:

1. To determine the soil moisture content at the depths of 10cm, 50 cm and 100cm and obtain their correlation analysis with the hydrological processes.
2. To determine the relationship between rainfall, evapotranspiration, temperature and soil moisture content at the depth of 10cm, 50 cm and 100 cm using statistical analysis.

II. MATERIALS AND METHOD

2.1 Description of study area

The study area for the research work is Federal University of Technology, GidanKwano campus, Minna, Niger State. Located within the basement complex terrain of north-central Nigeria at latitude 9˚31'58.57^{o}N and longitude 6˚26'41.63^{o} E (Figure 1) and is underlain by pre-Cambrian basement rocks of which granite are predominant (Alhassan et al., 2017). Minna is generally humid, with two distinct weather types which are: dry season and wet season. The basic lithology of the study area comprises of two rocks types; granite and schist with minor of quartz vein and quartzite. The basement complex includes the Meta sediments, such as Para gneiss, basic and calcareous schist and marble, it also includes Meta intrusive and older granites. The study area enjoys a steady heavy rainfall period from the month of May to September while the temperature ranges between 25 ^{o}C to 41 ^{o}C (Figure 2.2). The dry season lasts from October to April of every year. July, 2017 recorded the highest average rainfall depth as 253.3 mm while the highest average temperature was recorded in March as 40 ^{o}C (Figure 2.2).

Fig 2.1: Map showing the study Area.
Source: www.Google.com/Map-Hill

GidanKwanu campus is an area, which experiences rainfall of moderate intensity from the month of May to September with temperature ranging between 23^{o}C and 41^{o}C. It also experiences dry season within the period of October and May of every year.

The study area experiences annual average rainfall ranging between 1000mm and 1300mm, with maximum depth of rainfall experienced in August and the minimum depth of rainfall experienced in February. The rainfall distribution of the study area over the period of this research work (January to July) is shown in figure 3.2

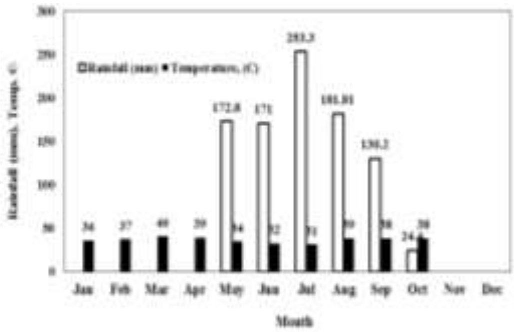

Fig 2.2: Annual Rainfall and temperature pattern of the study area
Source: Department of Geography, FUT, Minna

The basic lithology of the study area comprises of two rocks types; granite and schist with minor of quartz vein and quartzite. The basement complex includes the Meta sediments, such as Para gneiss, basic and calcareous schist and marble, it also includes Meta intrusive and older granites. The study area enjoys a steady heavy rainfall period from the month of May to September while the temperature ranges between 25^{o}C to 41^{o}C (Figure 2.2). The dry season lasts from October to April of every year. July, 2017 recorded the highest average rainfall depth as 253.3 mm while the highest average temperature was recorded in March as 40^{o}C (Figure 2.2).

2.2 Materials:

- Soil sample for determining moisture content
- Shovel: used for clearing and removing of soil and weeds.
- Hand driven auger: for collecting disturbed soil samples from the bored-hole.
- Steel measuring tape to measure the depth of hole that was advanced into ground.
- Electric oven: used for oven drying up sample at temperature between 100^{0}C and 106^{0}C for 16hrs-24hrs.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

- Electric weigh balance: used for taking the weight of sample.

The above-mentioned equipment's were used to collect soil samples at depths of 10 cm and 50cm and 100 cm below the ground surface in "triplicate" every day from February to July (six months). A picture of the field sample collection and laboratory test process, are as shown in Plate I, II and III.

2.3 Meteorological Data Collection

In the cause of this research project work, meteorological data on the following hydrological processes (rainfall, max and min temperature, relative humidity, evaporation, wind-speed above 2m and net radiation) captured by the Nigerian Meteorological Agency (NiMET) were used so as to ensure use of more accurate results and correlation between soil moisture and the hydrological process, and two or more hydrological process together.

2.4 Laboratory Soil Moisture Analysis (S.M.C.)

Soil moisture content test is an important and imminent method adopted to determine the moisture in the soil samples collected beneath the ground surface within the study area. The soil moisture content of samples taken is determined in the laboratory and the soil moisture content calculated using the formula;

S.M.C.=$\frac{(M2-M3)}{(M3-M1)}$ x 100[3.3]

Where;
M1: weight of the empty container,
M2: weight of the wet sample + container, and
M3: weight of the dry sample + container.
The respective soil moisture content results spanning from the dry season to the wet season (January to July) are plotted into charts/graphs.


Plate I: Boring Using Hand AugerPlate II: Bored hole

Plate III: Collected Soil Samples in Triplicate

2.5 Data Analysis

The International business machine (IBM) software was used to analyze the data's. Using the One-way Analysis of Variance (ANOVA) to check the statistical and compare means of the soil moisture content, at 10 cm and 100 cm, against evapotranspiration. For adequate results, 99 % confidence interval, (C.I) for the correlation of all the data's and 95% significance when comparing the dependent variables (that is, Soil Moisture at 10 cm and 100 cm) against the factor of interest, soil depth.

III. RESULTS

3.1 Results

3.1.1 Soil Moisture Content

The soil moisture content of the soil samples collected at depth of 10 cm for the first four (4) weeks, are presented in Table 3.1 and the remaining twenty (20) weeks shown in appendix B 4.1

TABLE 3.1: Soil Moisture Content at depth 10 cm

WEEK	DATE	M1 (g)	M2 (g)	M3 (g)	M2 - M3 (g)	M3 - M1 (g)	MC (%)
1	18/01/29	25.3	62.1	61.6	0.50	36.30	**1.38**
1	18/01/30	24.2	62	61.7	0.30	37.50	**0.80**
1	18/01/31	24.2	62.4	62	0.40	37.80	**1.06**
1	18/02/01	23.5	60.3	59.6	0.70	36.10	**1.94**

1	18/02/02	23.9	61.1	60.2	0.90	36.30	**2.48**
1	18/02/03	24.1	64.2	63.6	0.60	39.50	**1.52**
1	18/02/04	25.4	64.4	63.9	0.50	38.50	**1.30**
2	18/02/05	24.3	60.4	59.9	0.5	35.6	**1.40**
2	18/02/06	24.5	73.2	72.1	1.1	47.6	**2.31**
2	18/02/07	24.3	69.4	68.5	0.9	44.2	**2.04**
2	18/02/08	22.4	77.2	75.7	1.5	53.3	**2.81**
2	18/02/09	30.1	74.7	73.7	1	43.6	**2.29**
2	18/02/10	22.3	66.4	64.3	2.1	42	**5.00**
2	18/02/11	9.8	46.1	44.5	1.6	34.7	**4.61**
3	18/02/12	24.2	88.5	88	0.50	63.80	**0.78**
3	18/02/13	24.6	93.9	92.6	1.30	68.00	**1.91**
3	18/02/14	25.2	92.5	91	1.50	65.80	**2.28**
3	18/02/15	24.4	90	88.4	1.60	64.00	**2.50**
3	18/02/16	23.6	90.4	88.7	1.70	65.10	**2.61**
3	18/02/17	23.3	84.1	81.7	2.40	58.40	**4.11**
3	18/02/18	23.3	93.5	90.7	2.80	67.40	**4.15**
4	18/02/19	23.7	84.7	82.4	2.30	58.70	**3.92**
4	18/02/20	24.7	130	117.1	12.90	92.40	**13.96**
4	18/02/21	24.6	116.1	91.1	25.00	66.50	**37.59**
4	18/02/22	24.2	98.9	87.6	11.30	63.40	**17.82**
4	18/02/23	26	116.6	110.6	6.00	84.60	**7.09**
4	18/02/24	25.5	119.6	109.4	10.20	83.90	**12.16**
4	18/02/25	24.6	109.8	100.9	8.90	76.30	**11.66**

M1 = mass of can. M2 = mass of can+wet soil. M3 = mass of can+dry sample. MC % = moisture content

Table 3.1 shows the soil moisture content for the soil samples collected at depth 10 cm below the soil surface, with week 1, week 2, week 3 and week 4 having highest moisture contents of 2.48%, 5.0%, 4.11% and 37.59% respectively. The fluctuation in Soil Moisture Content within the first three weeks was due to the influence of evaporation rate on the soil layer and the abrupt increase from the third (3rd) week (4.11%) to the fourth (4th) week (37.59%) was due to sudden rainfall in the study area which results in a sharp increase in the Soil Moisture Content of the soil at the period. There exists to be water-uptake from the soil layer at depths` below 10 cm as a result of increase in evaporation rate which explains the reason why there is moisture in the soil even when there is rainfall, this process is also known as hydraulic lift and it continues until when the depth of water uptake becomes impossible by natural means (only) or when the soil surface gets rewetted in the raining season. The water uptake between the first week and second week is low, and that`s because it`s the beginning of the dry season of which soil layer still has more water obtained from previous rainfall period.

Soil Moisture Content of soil samples obtained at depth 50 cm below the surface for the first four (4) weeks are shown in Table 3.2 and the remaining twenty (20) weeks presented in the appendix B.4.2

TABLE 3.2: Soil Moisture Content data at depth 50 cm

WEEK	DATE	M1 (g)	M2 (g)	M3 (g)	M2 - M3 (g)	M3 - M1 (g)	MC (%)
1	18/01/29	24.4	55.5	53.8	1.70	29.40	**5.78**
1	18/01/30	24.1	60.1	58.4	1.70	34.30	**4.96**
1	18/01/31	22.2	62.5	61.7	0.80	39.50	**2.03**
1	18/02/01	25.1	62.8	60.5	2.30	35.40	**6.50**
1	18/02/02	22.9	62.5	62.1	0.40	39.20	**1.02**
1	18/02/03	24.4	62.4	61.1	1.30	36.70	**3.54**
1	18/02/04	24.4	64.8	63.3	1.50	38.90	**3.86**
2	18/02/05	24.4	73.9	71.8	2.1	47.4	**4.43**
2	18/02/06	25.5	64	60.6	3.4	35.1	**9.69**
2	18/02/07	26.7	81	74.4	6.6	47.7	**13.84**

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

2	18/02/08	24.2	72.8	68.2	4.6	44	**10.45**
2	18/02/09	26.1	59.9	56	3.9	29.9	**13.04**
2	18/02/10	10	63.5	59.5	4	49.5	**8.08**
2	18/02/11	22.2	82.5	77.6	4.9	55.4	**8.84**
3	18/02/12	24.8	89.3	87.7	1.60	62.90	**2.54**
3	18/02/13	25.6	98.7	95.6	3.10	70.00	**4.43**
3	18/02/14	26.5	92	87.1	4.90	60.60	**8.09**
3	18/02/15	25.4	90.2	85.1	5.10	59.70	**8.54**
3	18/02/16	25.1	89.5	84.5	5.00	59.40	**8.42**
3	18/02/17	25.6	96.3	91	5.30	65.40	**8.10**
3	18/02/18	24.6	86.7	80.4	6.30	55.80	**11.29**
4	18/02/19	25.3	79.9	76.8	3.10	51.50	**6.02**
4	18/02/20	24	104.1	93.3	10.80	69.30	**15.58**
4	18/02/21	25	133.4	110.6	22.80	85.60	**26.64**
4	18/02/22	24.8	97.4	87.3	10.10	62.50	**16.16**
4	18/02/23	24.2	132.3	124.4	7.90	100.20	**7.88**
4	18/02/24	25.6	135.9	124.8	11.10	99.20	**11.19**
4	18/02/25	25.6	130.2	116.1	14.10	90.50	**15.58**

M1=mass of can. M2=mass of can+wet soil. M3=mass of can+dry sample

Table 3.2 shows the soil moisture content for the soil sample collected at depth 50 cm below the soil surface, with moisture contents of 6.5%, 13.84%, 11.29% and 26.64% for week 1, week 2, week 3 and week 4 respectively. The variation in Soil Moisture Content within these weeks with an increase between the third (11.29%) and fourth week (26.64%) indicates lesser water uptake when compared with the soil layer at 10 cm and that's because effect of evaporation rate is felt more on the soil layer closer to the surface and of course soil at depth 50 cm will experience hydraulic lift from soil at upper layers.

Soil Moisture Content data at 100 cm

Soil moisture content of the soil sample collected at depth 100 cm as shown in Table 3.3 for the first four (4) weeks and the remaining twenty (20) weeks are presented in the Appendix C4.2

Table 3.3 Soil Moisture Content data at 100 cm

WEEK	DATE	M1 (g)	M2 (g)	M3 (g)	M2 - M3 (g)	M3 - M1 (g)	M.C (%)
1	18/01/29	24.5	62.6	59.9	2.70	35.40	**7.63**
1	18/01/30	24.8	62.5	61.9	0.60	37.10	**1.62**
1	18/01/31	27.3	61.8	61.2	0.60	33.90	**1.77**
1	18/02/01	24.3	62.7	58.9	3.80	34.60	**10.98**
1	18/02/02	23.1	64.6	60	4.60	36.90	**12.47**
1	18/02/03	24.8	62.3	60.2	2.10	35.40	**5.93**
1	18/02/04	23.5	64.2	62.3	1.90	38.80	**4.90**
2	18/02/05	24.7	70.2	66.5	3.7	41.8	**8.85**
2	18/02/06	22.6	74.2	71.6	2.6	49	**5.31**
2	18/02/07	24.5	75.5	68.9	6.6	44.4	**14.86**
2	18/02/08	23.5	75	68.9	6.1	45.4	**13.44**
2	18/02/09	26.1	70.3	66	4.3	39.9	**10.78**
2	18/02/10	20.3	76.2	72.6	3.6	52.3	**6.88**
2	18/02/11	27.6	76	72.8	3.2	45.2	**7.08**
3	18/02/12	24.1	90.4	87.5	2.90	63.40	**4.57**
3	18/02/13	24.6	88.3	84.3	4.00	59.70	**6.70**
3	18/02/14	23.7	94.2	87.7	6.50	64.00	**10.16**
3	18/02/15	26	93.5	90.1	3.40	64.10	**5.30**
3	18/02/16	24.1	93.4	87.9	5.50	63.80	**8.62**
3	18/02/17	24.6	99.4	93.1	6.30	68.50	**9.20**

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

3	18/02/18	25.2	99.4	94.3	5.10	69.10	**7.38**
4	18/02/19	23.3	105.2	99.1	6.10	75.80	**8.05**
4	18/02/20	26.7	115.4	104.3	11.10	77.60	**14.30**
4	18/02/21	23.9	177.6	141.9	35.70	118.00	**30.25**
4	18/02/22	24.3	104.8	94.8	10.00	70.50	**14.18**
4	18/02/23	23.3	155.3	139.2	16.10	115.90	**13.89**
4	18/02/24	25.2	154.3	132.6	21.70	107.40	**20.20**
4	18/02/25	23.7	123.7	108.5	15.20	84.80	**17.92**

M1=mass of can. M2=mass of can+wet soil. M3=mass of can+dry sample

Table 3.3 shows the soil moisture content for the soil sample collected at depth 100 cm below the soil surface, with moisture contents of 12.47%, 14.86%, 10.16% and 30.25% for week 1, week 2, week 3 and week 4 respectively. The variation in Soil Moisture Content within these weeks with an increase between the first (12.47%), the second (14.86%) and fourth week (30.25%) indicates lesser water uptake when compared with the soil layer at 10 cm and that's because effect of evaporation rate is felt more on the soil layer closer to the surface and of course soil at depth 100 cm will experience hydraulic lift from soil at upper layers.

4.1.2 Meteorological Data

The Rainfall data used in this research work was obtained from the Nigeria Meteorological Agency (NiMET), Abuja Nigeria. The rainfall data measured in millimetres covering from the last week of January 2018 to the last week of July 2018. Rainfall date for the first three (3) weeks are shown in Table 3.4 and the remaining twenty (20) weeks presented in the appendix c.4.3.

TABLE 3.4: Rainfall data

S/N	YEAR	MONTH	DAY	RAINFALL (cm)
1	2018	JANUARY	29	0.00
2	2018	JANUARY	30	0.00
3	2018	JANUARY	31	0.00
4	2018	FEBRUARY	1	0.00
5	2018	FEBRUARY	2	0.00
6	2018	FEBRUARY	3	0.00
7	2018	FEBRUARY	4	0.00
8	2018	FEBRUARY	5	0.00
9	2018	FEBRUARY	6	0.00
10	2018	FEBRUARY	7	0.00
11	2018	FEBRUARY	8	0.00
12	2018	FEBRUARY	9	0.00
13	2018	FEBRUARY	10	0.00
14	2018	FEBRUARY	11	0.00
15	2018	FEBRUARY	12	0.00
16	2018	FEBRUARY	13	0.00
17	2018	FEBRUARY	14	0.00
18	2018	FEBRUARY	15	0.00
19	2018	FEBRUARY	16	0.00
20	2018	FEBRUARY	17	0.00
21	2018	FEBRUARY	18	15.00
22	2018	FEBRUARY	19	0.00
23	2018	FEBRUARY	20	0.00

cm represents centimetres. S/N = serial number.

Table 3.4 shows the Rainfall data for the first four weeks of measurement of which no Rainfall was experienced indicating a period of dryness and it`s within this period that hydraulic lift between upper soil layer and lower soil layer is high and to cease when the raining season starts.

Table 3.5 Evapotranspiration data

YEAR	MONTH	DAY	T_{MAX} (^oC)	T_{MIN} (^oC)	T_{MEAN} (^oC)	Ra_{MEAN}	ET_O
2018	1	29	30.6	18.4	24.5	16.48	**5.60**
2018	1	30	31.8	19.2	25.5	16.48	**5.83**
2018	1	31	32.7	20.5	26.6	16.48	**5.88**
2018	2	1	34	20.6	27.3	17.32	**6.58**
2018	2	2	35.7	20.7	28.2	17.32	**7.10**
2018	2	3	36.8	22.3	29.55	17.32	**7.18**
2018	2	4	37	21.5	29.25	17.32	**7.38**
2018	2	5	37.3	21	29.15	17.32	**7.55**
2018	2	6	38	22.5	30.25	17.32	**7.54**
2018	2	7	36.8	23	29.9	17.32	**7.06**
2018	2	8	36.5	22.9	29.7	17.32	**6.98**
2018	2	9	35.7	22	28.85	17.32	**6.88**
2018	2	10	36	23	29.5	17.32	**6.79**
2018	2	11	36	23.7	29.85	17.32	**6.66**
2018	2	12	36	23	29.5	17.32	**6.79**
2018	2	13	35	21.8	28.4	17.32	**6.69**
2018	2	14	35.4	22.1	28.75	17.32	**6.76**
2018	2	15	33.9	23.5	28.7	17.32	**5.97**
2018	2	16	35.5	21.8	28.65	17.32	**6.85**
2018	2	17	35.2	20.6	27.9	17.32	**6.96**
2018	2	18	35.8	22.2	29	17.32	**6.88**
2018	2	19	35.5	23	29.25	17.32	**6.63**
2018	2	20	33.6	21.8	27.7	17.32	**6.23**
2018	2	21	33.4	20.8	27.1	17.32	**6.35**
2018	2	22	35	21.5	28.25	17.32	**6.74**
2018	2	23	35.9	23.4	29.65	17.32	**6.68**
2018	2	24	38.5	23.5	31	17.32	**7.53**
2018	2	25	36.5	22.9	29.7	17.32	**6.98**
2018	2	26	37	25.1	31.05	17.32	**6.71**
2018	2	27	37.5	17.3	27.4	17.32	**8.09**
2018	2	28	38	17.8	27.9	17.32	**8.18**
2018	3	1	37.4	23.5	30.45	18.32	**7.58**
2018	3	2	39	25.5	32.25	18.32	**7.75**
2018	3	3	39.6	24.3	31.95	18.32	**8.20**
2018	3	4	41.4	25.9	33.65	18.32	**8.54**
2018	3	5	39.8	24.4	32.1	18.32	**8.25**
2018	3	6	38.2	26.4	32.3	18.32	**7.25**
2018	3	7	38	26.4	32.2	18.32	**7.18**
2018	3	8	37.3	24.6	30.95	18.32	**7.32**
2018	3	9	38.3	25.8	32.05	18.32	**7.43**
2018	3	10	36.8	24.5	30.65	18.32	**7.16**
2018	3	11	36.8	25.9	31.35	18.32	**6.84**
2018	3	12	37.1	26	31.55	18.32	**6.93**
2018	3	13	39	24.7	31.85	18.32	**7.91**
2018	3	14	38	22.5	30.25	18.32	**7.97**
2018	3	15	38.9	27	32.95	18.32	**7.38**
2018	3	16	38.5	26.8	32.65	18.32	**7.27**
2018	3	17	37.8	23.5	30.65	18.32	**7.72**
2018	3	18	39	24.4	31.7	18.32	**7.97**
2018	3	19	38.5	25.5	32	18.32	**7.57**
2018	3	20	38	25.6	31.8	18.32	**7.36**
2018	3	21	38	26.8	32.4	18.32	**7.08**

2018	3	22	37.7	26.3	32	18.32	**7.08**
2018	3	23	37.5	26.7	32.1	18.32	**6.91**
2018	3	24	38.9	26.8	32.85	18.32	**7.42**
2018	3	25	38.5	27.5	33	18.32	**7.10**
2018	3	26	39.6	25.3	32.45	18.32	**8.01**
2018	3	27	38.7	27.3	33	18.32	**7.23**
2018	3	28	38.5	26.5	32.5	18.32	**7.34**
2018	3	29	38.9	27	32.95	18.32	**7.38**
2018	3	30	38.5	26.6	32.55	18.32	**7.32**
2018	3	31	39.4	26.9	33.15	18.32	**7.59**
2018	4	1	38.5	27.6	33.05	18.28	**7.06**
2018	4	2	35.4	28	31.7	18.28	**5.66**
2018	4	3	37	27	32	18.28	**6.62**
2018	4	4	35	28	31.5	18.28	**5.48**
2018	4	5	35	21.9	28.45	18.28	**7.04**
2018	4	6	36.8	26.3	31.55	18.28	**6.72**
2018	4	7	36	22.7	29.35	18.28	**7.23**
2018	4	8	38	24	31	18.28	**7.68**
2018	4	9	37.5	24.6	31.05	18.28	**7.38**
2018	4	10	38	26.9	32.45	18.28	**7.04**
2018	4	11	39.4	25	32.2	18.28	**7.98**
2018	4	12	38.1	26.4	32.25	18.28	**7.20**
2018	4	13	39	26	32.5	18.28	**7.63**
2018	4	14	36.5	26.4	31.45	18.28	**6.58**
2018	4	15	38.2	25.8	32	18.28	**7.37**
2018	4	16	38.7	26.4	32.55	18.28	**7.42**
2018	4	17	37	27.2	32.1	18.28	**6.57**
2018	4	18	31.5	22	26.75	18.28	**5.77**
2018	4	19	35.6	23	29.3	18.28	**7.03**
2018	4	20	36.3	25.7	31	18.28	**6.68**
2018	4	21	38	26.4	32.2	18.28	**7.16**
2018	4	22	38	27	32.5	18.28	**7.01**
2018	4	23	35.5	26	30.75	18.28	**6.29**
2018	4	24	35.8	26.5	31.15	18.28	**6.28**
2018	4	25	35.3	20.1	27.7	18.28	**7.46**
2018	4	26	34.1	25.1	29.6	18.28	**5.98**
2018	4	27	30.5	22.5	26.5	18.28	**5.27**
2018	4	28	32.8	24.5	28.65	18.28	**5.63**
2018	4	29	36.4	26.5	31.45	18.28	**6.52**
2018	4	30	36.8	26.4	31.6	18.28	**6.70**

IV. DISCUSSION

4.1 Discussion

4.1.1 Soil Moisture content and Rainfall

The relationship between the Soil Moisture Content at 10 cm and 50 cm and Rainfall data is significant to this research work as it shows the inter-relationship between Soil Moisture Content, water uptake (hydraulic lift) and Rainfall and the variation in Soil Moisture Content with depth within the Dry period and Wet period. The results of the Soil Moisture Content (10 cm, 50 cm and 100 cm) and Rainfall are plotted in Figure 4.1.

Figure 4.1 shows the graph of the soil moisture content at depths 10 cm, 50 cm and 100 cm and Rainfall which gives a better comparism between soil moisture content variation with depth and rainfall.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

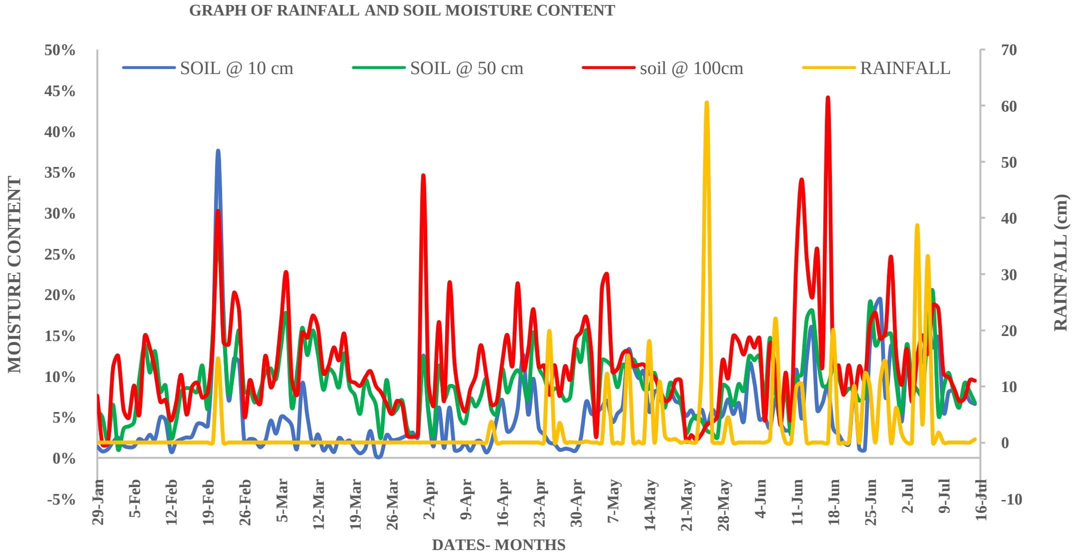

Fig 4.1RAINFALL AND SOIL MOISTURE CONTENT AT DEPTH 10 cm, 50 cm and 100 cm

Figure 4.1 shows the Soil Moisture Content and Rainfall values obtained during the dry to the wet period of twenty-four (24) weeks. It shows that between January 30th and third (3rd) week of February soil at depth 10 cm has the lowest proportion of Soil Moisture Content and that's only because there is no rainfall and the rate of evaporation is low and water uptake low as well. In this period the environment is best for construction activities (shallow foundation works), the risk of flooding or inundation is ignorable, water resource pollution is low as there is no infiltration process happening and it's the right time to carry out Irrigation practice on farmlands with crops having root depth lesser than 15 cm (rice, potatoes, beans and groundnut) in their early stage and having high field capacity and soil water requirement.

There exists in the third (3rd) week of February a sudden increase in Soil Moisture Content resulting to a moisture content of (37.79%) which was due to the occurrence of sudden Rainfall of 15cm experienced in the study area.

Figure 4.1 also shows that from the third week of April which was the beginning of the raining season there exist corresponding rise in the soil moisture content, with Rainfall starting from 20 cm depth and Soil Moisture of 1.89% on 25th of April to Rainfall of 37 cm and Soil Moisture of 19.37% on 4th of July.

Figure 4.1 shows the Soil Moisture Content and Rainfall values obtained during the dry to the wet period of twenty-four (24) weeks. It shows that between January 30th and third (3rd) week of February soil at depth 50 cm has the lowest proportion of Soil Moisture Content and that's only because there is no rainfall and the rate of evaporation is low and water uptake low as well. In this period the environment is best for construction activities (shallow foundation works), the risk of flooding or inundation is ignorable, water resource pollution is low as there is no infiltration process happening and it's the right time to carry out Irrigation practice on farmlands with crops having root depth lesser than 15 cm (rice, potatoes, beans and groundnut) in their early stage and having high field capacity and soil water requirement. There exists in the third (3rd) week of February a sudden increase in Soil Moisture Content resulting to a moisture content of (26.64%) which was due to the occurrence of sudden Rainfall of 15cm experienced in the study area.

Figure 4.1 also shows that from the third week of April which was the beginning of the raining season there exist corresponding rise in the soil moisture content, with Rainfall starting from 20 cm depth and Soil Moisture of 9.89% on 25th of April to Rainfall of 37 cm and Soil Moisture of 20.21% on 7th of July.

Figure 4.1 shows the Soil Moisture Content and Rainfall values obtained during the dry to the wet period of twenty-four (24) weeks. It shows that between January 30th and mid-week of February soil at depth 50 cm has higher Soil Moisture Content than soil at depth 10 cm and that's only because there is no rainfall but the rate

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

of evaporation is low and water uptake low as well. In this period the environment is best for construction activities (shallow foundation works), the risk of flooding or inundation is ignorable, water resource pollution is low as there is no infiltration process happening and it's the right time to carry out Irrigation practice on farmlands with crops having root depth lesser than 15 cm (rice, potatoes, beans and groundnut) in theirearly stage and having high field capacity and soil water requirement.

Soil layer at depth 10 cm experienced the highest soil moisture content percentage in the third (3^{rd}) week of February due to a sudden Rainfall of 15 cm resulting to moisture content of (37.79%). It can be said that within this period the soil layer at 10 cm has an increase in moisture compare to other periods within in the dry season but not enough to sustain crop production because it was only a flash rise in Soil Moisture Content. Between the last week of February and the end of the third (3^{rd}) week of April, water uptake by soil at 10 cm depth reduces, soil at 50 cm had more moisture than 10 cm because it marks the beginning of Rainfall causing hydraulic lift to cease between soil layers as water now goes down into soil (infiltration process). The beginning of the raining season in the third week of April reduces the level of variation and fluctuation of Soil Moisture Content between soil at 10 cm and 50 cm depth, this implies that water happen at the soil depth of 10 cm can be used to predict the condition of soil moisture at 50 cm depth.

The fourth (4^{th}) week of week recorded the highest rainfall depth of 61mm leaving the Soil Moisture Content of soil at 10 cm higher than soil at 50 cm (5.1% > 4.35%).

As of February, moisture content at 50cm increases and drop again getting to march ending. Pick up again early march and dropped gradually and pick up a little in April. There is high moisture content at 100 cm around February – march, and march to April, but the highest was between June to July which is realistic because the highest rainfall was between May and June from our graph, so it is expected that before July lots of water should have go deep down to the ground which may lead to increase in moisture content as one goes deeper so likewise at 100 cm.

From the result obtained in fig 4.1, the field capacity occurs in the month of June which is the amount of soil moisture or water content held in the soil after excess water has drained away and table 4.2 shows that the highest rainfall depth was in the month of July. While table 4.3 shows that rainfall is significant at the depth of 10cm with 0.048 and at the depth of 100cm with 0.643 which indicates that there is a moderate positive relationship between rainfall and

soil moisture at the depth of 10cm and 100cm respectively, although rainfall is more significant at the depth of 10cm compared to the depth of 100cm because from literature soil water storage gradually decreases from upper layer to the lower layer of the field soil(Xu et al., 2011) and fig 4.1 shows that the significance value < 0.05 which means that there is a statistically significant difference between soil moisture content at 10cm and 100cm respectively with soil moisture at 10cm having means of 5.51(lowest) and soil moisture at 100cmhaving mean of 11.44(highest),

In addition, since water uptake ceased (dry season ends) and Rainfall sets in, thus, the need for irrigation practice becomes unnecessary for shallow root and deep root crops, early flash flooding and inundation begins in areas with very bad soil condition, rainfall-runoff modelling and forecasting becomes effective, weather forecasting, actual yield of surface water bodies and underground wells monitoring can be determined and lastly it's the period where construction works on site becomes more challenging as the engineer has to deal not only with the planned activities but also with ground soil moisture and variation in mix design due to increase in moisture content of stored fine aggregates (sharp sand) stored on site.

The relationship between the Soil Moisture Content at 10 cm and 50 cm and 100 cm and Evapotranspiration data is significant to this research work as it shows the inter-relationship between Soil Moisture Content and the variation in Soil Moisture Content with depth within the Dry period and Wet period. The results of the Soil Moisture Content (10 cm, 50 cm and 100 cm) and Evapotranspiration are plotted in Figure4.2

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

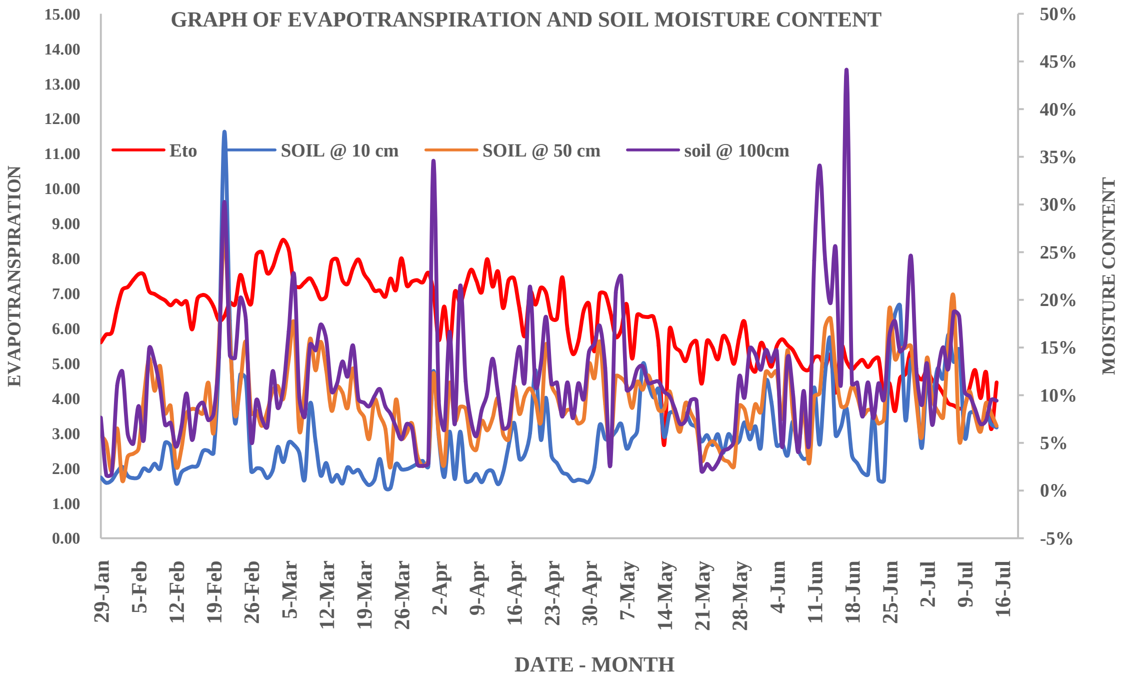

Fig 4.2: EVAPOTRANSPIRATION AND SOIL MOISTURE CONTENT AT DEPTH 10 cm, 50 cm and 100 cm

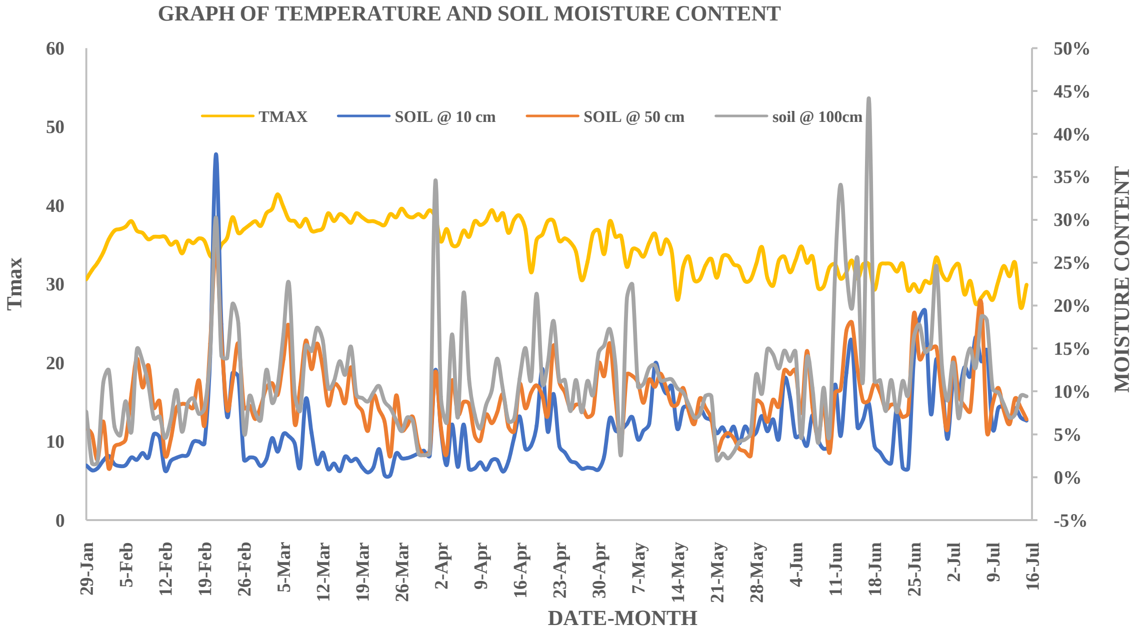

Fig 4.3: MAXIMUM TEMPERATURE AND SOIL MOISTURE AT DEPTH 10 cm, 50 cm and 100 cm

4.2.2 Correlation and Analysis of Variance (ANOVA)

For further explanation about the influence of rainfall, evapotranspiration and temperature on soil moisture content, Correlation between soil moisture at the depths 10 cm, 50 cm and 100 cm and rainfall, evapotranspiration and temperature with confidence interval of 95% and one (1) way analysis of variance (ANOVA) between and within groups on the soil samples was carried out and the results presented Table 3.6.

Rainfall

With the Confidence Interval (C.I.) level of 95%, Table 4 shows that at depth 10 cm there exist a weak correlation between rainfall and Soil Moisture content at 10 cm depth (0.166* and C.I. = 0.031<0.05) and there exist a significant relationship between rainfall and soil moisture at 10 cm, this means that changes in Rainfall also causes changes in the Soil Moisture Content at depth 10 cm. Also, at soil depth 50 cm, with correlation values (-0.004 and C.I. = 0.958), this means that there is no significant relationship between rainfall and soil moisture at 50 cm and the changes in the condition of Rainfall is different does not affect the changes in the condition of Soil Moisture Content at depth 50 cm. Table 4 also shows that the correlation between Soil Moisture Content at 10 cm and 50 cm is statistically significant with a Confidence Interval Level of Sig < 0.05, meaning that the changes in soil moisture condition at 10 cm is statically related to the soil moisture condition at 50 cm.

The Pearson correlation is used to examine the strength of the linear relationship between two continuous variables. The correlation coefficient can range in value from -1 to +1. The larger the absolute value of the coefficient, the stronger the relationship between the variables.

For the Pearson correlation, an absolute value of 1 indicates a perfect linear relationship. A correlation closes to 0 indicates no linear relationship between the variables. From the correlation table, the correlation of Moisture content at 50 cm with itself (r=1) and the number of non-missing observations for height is (n=168). Correlation of moisture content at 50 and 100 cm (r=0.642) base on (n=168) non missing value. Correlation of Rainfall with the two depth (-.11) the correlation in the same diagonal are all equal to 1 this is because variable is always perfectly correlated with itself. I am opted to 0.01 significance level that is why I am having two asterisk (**) in cell B. we can see that the Pearson correlation for moisture content at 50 and 100 cm is (.642**) which is statistically significance (p<.001 for a two tail test).Base on the result from the table, SMC at 50 and 100 cm have statistically significant linear relationship. The two depths are positively correlated.

Evapotranspiration

With the Confidence Interval (C.I.) level of 99%, Table 4.4 shows that at depth 10 cm there is a negative value of correlation between $ET_O$and Soil Moisture content at 10 cm depth but with a significance of 99% (-0.405** and C.I. = 0.00 > 0.01), this means that changes in ET_O causes changes in Soil Moisture Content at 10 cm depth. Also, with the Confidence Interval (C.I.) level of 99%, Table 4.4 shows that at depth 100 cm there is a negative value of correlation between $ET_O$and Soil Moisture content at 100 cm depth but with a significance of 99% (-.125 and C.I. = 0.107 < 0.01), this means that changes in ET_O has insignificant effect in Soil Moisture Content at 10 cm depth.

Temperature

Post hoc test comparisons using Turkey HSD test indicated that the mean score for the soil moisture content at 10cm is (M = 5.5117, SD = 4.83198) was significantly different than that of soil moisture at 100cm (M = 11.4423, SD = 6.24639) and by which the average total of the two depth makes it higher than the values obtained on soil moisture at 10cm depth.

TABLE 3.6: ANOVA

SOIL MOISTURE

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2993.385	2	1496.692	57.690	.000
Within Groups	12997.701	501	25.944		
Total	15991.085	503			

Table 3.6 shows that the one-way analysis in the values between and within the Soil Moisture Content at depths 10 cm and 100 cm, gives a degree of freedom (Df) of 1 between the groups and 334 within groups with a (sig .000) significance level F-Value = 94.746. Adding up all

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

these, the result therefore suggests that the increase or decrease in soil moisture content at 10 cm soil depth results in increase or decrease in soil moisture content at 100 cm soil depth, meaning the soil depth affects the amount of soil moisture.

Table 5 shows that the analysis of the variance (ANOVA) in the values between and within the Soil Moisture Content at depths 10 cm and 50 cm, gives a degree of freedom (Df) of 1 between groups and 334 within groups with $P < 0.05$ and significance level F-Value = 54.667. Putting all these together, the result suggests that the increase or decrease in soil moisture content at soil depth 10 cm results in increase or decrease in the soil moisture content at depth 50 cm, concisely the soil depth affects soil moisture content.

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The aim and objectives of the research work was completed and the influence of the hydrological processes investigated under the following;

Rainfall

From the result obtained at the end of this research work, it was concluded that soil moisture content is proportional to rainfall in the sense that rainfall is an important contributor to soil moisture content although the depth of the soil also determines the extent to which rainfall affects soil moisture content. And rainfall is usually experienced from late April to mid-October.

The investigation of the relationship between Rainfall and Soil Moisture Content of soil at varying depths has been carried out and has actually shown that Rainfall influences the soil moisture content with depth. From the dry to wet period soil at depth of 10 cm has Soil Moisture Content ranging from 37.79% to 19.37% and soil at depth 50 cm has Soil Moisture Content dropping from 26.64% at the third week of February to 2.5% at the last week of March due to increase in rate of evaporation and no Rainfall supply, but latter increase to 20.21% in the third 3^{rd}week of July which show a significant influence of Rainfall on soil layer. Statistically soil moisture content exhibits a significant relationship with depth and with soil at depth 10cm and rainfall resulting with a degree of freedom (Df) of 1 and 100% significance between groups (Sig. = 0.00). Thus, the influence of Rainfall on Soil Moisture Content with depth is statically significant.

From the daily analysis of soil moisture content for a period of 24weeks at 50 and 100cm depth, it was observed that the soil moisture content at a particular depth varies due to the amount of rainfall, topography of the area, and the nature of soil and locations of the area. The results on the daily basis give us insight to land and water management most especially how to control or minimize the harmful effect of flood when there is excessive rainfall. It was observed that soil moisture balance computation on a daily basis plays important role for evaluation of irrigation scheduling, crop yielding and recharged of groundwater. It was observed from analysis of variance table (ANOVA) that the two conditions satisfy the sig value $p< 0.000$ which implies there is significant difference between group and within groups which makes the results perfectly okay.

Evapotranspiration

From the data graphs, SPSS correlation and One-way ANOVA analysis, both depths are significant to themselves, because the amount of moisture that gets into the soil through its pores, goes from the surface, down beneath the ground.

There is significant effect of evapotranspiration on the soil moisture at 10 cm depth. That is, the higher the evapotranspiration, the lower the soil moisture and also the lower the evapotranspiration, the higher the soil moisture, but has insignificant effect on the soil moisture at the 100 cm depth.

The importance of Soil Moisture Content to plant and animal life and by extension to human existence cannot be over emphasized, as such all factors that influences it should be studied and their various interactions analysed. One of such factors is Evapotranspiration, therefore, this research analyses the extent to which evapotranspiration influences Soil Moisture Content.

The relationship between Evapotranspiration and Soil Moisture Content has diverse applications in the field of agriculture, engineering, environmental protection, soil engineering and environmental engineering to mention a few.

Temperature

The effect of temperature on soil moisture content cannot be over-emphasized. From the results obtained from the analytical and statistical comparison of soil moisture contents at 50cm and 100cm to maximum temperature. It was observed that soil moisture content at 50cm only affects (significantly) the soil moisture at 100cm and vice-

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 515-533 www.ijaem.net ISSN: 2395-5252

versa. Also, a slight inverse effect of temperature was observed at 50cm and relatively smaller effect at 100cm.

Thus, from the result it can be concluded that

1. Soil moisture content at higher depth(50cm) affects strongly, soil moisture at lower depth (100cm)
2. Temperature (even at maximum) does not really affect soil moisture content below root zone (50 – 100cm)

The soil moisture content collected at depth of 10cm and 100cm during the dry season and wet season period shows how much more moisture that is present at each specific period of the season and considering the effect temperature has on each soil depths.

From the analysis of the results obtained at each soil depths, it shows clearly that temperature affects the surface soil moisture to a particular depth beyond 10cm and doesn't have much effect on the soil moisture at 100cm depth. Water balance of an area depends on the meteorological factors influencing surface and sub-surface water movement, soil infiltration, percolation and water storage capacity characteristics, crop species and development stage and agricultural practices. The study of soil moisture helps to determine the months with sufficient moisture available for crop growth and those that do not have sufficient moisture.

5.2 Recommendations

With the conclusion of this research work on the investigation of the influence of Rainfall on Soil Moisture Content and their obtained correlation and ANOVA results, of no doubt the knowledge about how much important soil moisture content does shows that:

- Soil Moisture Content plays an important in the scientific world and gives more information about what goes on in the environment.
- It is important in areas with high frequent flash flooding cases, bad experience of inundation and drought scenarios.
- It can be incorporate in the study of Hydrological processes in the areas of yield monitoring, flood and drought warning and flood risk management programs.
- Civil engineers (water resources engineers) also can adopt this for easier and effective studying of ground water yield estimation and monitoring.
- International bodies like United Nations (UN), ECOWAS, UNICEF and Food and Agriculture Organization (FAO) can adopt this in their research and projects towards creating a sustainable environment in the aspect of food security, green engineering, water resources management and environmental hazards management like (flood, drought and pollution).

In the field of structural engineering and constructions, it is advisable to know the soil moisture content and soil type during the feasibility assessment, and also knowing that some natural processes such as evapotranspiration at a certain depth has insignificant effect on the soil which would in turn enable structural engineers to ascertain the following:

a. The type of soil on the site whether it is suitable for load bearing and if otherwise, it should be excavated and refilled with a better load bearing soil and then compacted.

b. To know the foundation type to be used during the design and construction.

In the field of environmental engineering and management, understanding these natural processes, soil moisture and topography of some areas would help to indicate or predict areas prone to flooding.In the field of agriculture, understanding how evapotranspiration affect the soil moisture at certain depth,Farmers would be able to know the type of crops to produce in some certain areas.

a. In certain areas with lower moisture in the soil, irrigation can be utilized to boost crop production.

b. Agriculturists would be able to produce all year round knowing the amount of water required for plant use, amount of water to be used for irrigation during drought.

It is therefore recommended that further investigation of depths below 50 cm (that is; 75 cm, 100 cm) up to 200cm should be carried out so as to give more understanding about the soil moisture condition and how this information is relevant to the engineering world.

It is advisable that more research should be carry out and making use of different model which will help most especially in the area of forecasting of weather and predicting the outcome of an event so as to know a way of tackling the problem and to guarantee safety before it occur. Furthermore, the meteorological stations should be active and take readings on a daily basis for accuracy in results.

REFERENCE

[1]. Ambast, S.K.; Keshari, A.K.; Gosain, A.K. An operational model for estimating regional evapotranspiration through surface energy partitioning (RESEP). International Journal of Remote Sensing 2002, 23(22), 4917-4930.

[2]. Ayoade J.O. (1976). Evaporation and Evapotranspiration in Nigeria. Journal of Tropical Geography. Vol. 43, pp. 9-19.

[3]. Bidlake, W.R. Evapotranspiration from selected fallowed agricultural fields on the Tule Lake Carlson, T.N. An overview of the so-called "triangle method" for estimating surface evapotranspiration and soil moisture from satellite imagery. Sensors, 2007, 7, 1612-1629.

[4]. Dr.k.R. Arora - Irrigation, Water power and Water Resources Engineering Dr.R. Suresh - Soil and Water Conservation Engineering.

[5]. FAO Irrigation and Drainage Paper 56. 1998. Crop evapotranspiration: Guidelines for computing crop water requirements. Roma: FAO.

[6]. Gao, X., Wu, P., Zhao, X., Wang, J., and Shi, Y.: Effects of land useon soil moisture variations in a semi-arid catchment: Implications for land and agricultural water management, Land Degrad.Dev., 25, 163–172, 2014.

[7]. Kite, G.W.; Droogers, P. Comparing evapotranspiration estimates from satellites, hydrological models and field data. Journal of Hydrology 2000, 229, 3-18.

[8]. National Wildlife Refuge, California, During May to October 2000. U.S. GEOLOGICAL SURVEY, Water-Resources Investigations Report 02-4055 Tacoma, Washington, 2002.

[9]. Nnamchi, H.C. (2005): Dynamics of the little Dry Season Over South-Eastern Nigeria.Unpublished M. Sc. Seminar Paper 1, University of Nigeria, Nsukka.

[10]. Oguntunde, P. G. 2004. Evapotranspiration and complimentary relations in the water balance of the Volta Basin: Field measurement and GIS-based regional estimate. PhD diss., Ecology and Development Series, No. 22: 16–91.

[11]. Parodi, G.N. AVHRR Hydrological analysis system: Algorithms and theory-version 1.0. WRES-ITC, 2000.

[12]. Thomas. V. Cech - principle of water Resources(Third Edition)

[13]. Wang, Y. F., Mo, X. G., Hao, Y. B., Guo, R. P., Huang, X. Z., & Wang, Y. F. (2008). Simulating seasonal and interannual variations of ecosystem evapotranspiration and its components in Inner Mongolia steppe with VIP model. J. Plant Ecol., 32(5), 1052-1060.

[14]. Warren Viessman, Jr.Mark, J. Hammer Elizabeth.M. Perez Poul A. Chadik - water supply and pollution control.

[15]. Arduino, G., Reggiani, P., & Todini, E. (2005). Recent advances in flood forecasting and flood risk assessment. Hydrology and Earth System Sciences, 9(4), 280–284. https://doi.org/10.5194/hess-9-280-2005

[16]. Chigbu, N., Mba, E. O., Ogbenyealu, & Anyanwu, I. (2018). Assessment Of Flood Risk Of Cross River State Using Geographic Assessment of Flood Risk of Cross River State Using Geographic Information System (GIS). (9276) Njike Chigbu , Esther Ogbonyealu Mbah and Ignatius Anyanwu (Nigeria) FIG Congress 2018 Emb, (9276).

[17]. ETH (2017). Soil moisture measurements; Climatological and hydrological field work - FS2017.Swiss: Swiss Federal Institute of Technology, Zurich.

[18]. Feng, X., Kerber, A., & Gr, G. (2012). Effect of seasonality on soil water balance and plant growth. Water Resources Research, 48(5), 935–938.

[19]. Findell, K. L., & Eltahir, E. A. B. (1997). An analysis of the soil moisture-rainfall feedback, based on direct observations from Illinois. Water Resources Research, 33(4), 725–735. https://doi.org/10.1029/96WR03756.

[20]. Guillod, Benoit P., Orlowsky, Boris Miralles, Diego G. Teuling, Adriaan J. Seneviratne, Sonia I. (2015). Reconciling spatial and temporal soil moisture effects on afternoon rainfall. Nature Communications Journal. (6).

[21]. Guarin, P. G., Westen, C., J., Montoya, L. (2004). Community-Based Flood Risk AssessmentUsing GIS for the Town of San Sebastian, Guatemala. Enschede, Netherlands.

[22]. HO, N. (2016). Groundwater and Poverty Reduction: Challenges and Opportunities for Sustainable Development in Nigeria. Journal of Waste Water Treatment & Analysis, 7(2). https://doi.org/10.4172/2157-7587.1000240

[23]. Oladokun, V. O., & Proverbs, D. (2016). Flood risk management in Nigeria: A review of the challenges and opportunities. International Journal of Safety and Security Engineering, 6(3), 485–497. https://doi.org/10.2495/SAFE-V6-N3-485-497

[24]. Raghunath, H. M. (2006). Hydrology.

[25]. Ufoegbune, G., Fadipe, O., AO., E., & AA., M. (2014). Growth and Development of Watermelon in response to Seasonal variation of Rainfall. Climatology and Weather Forecasting, 117(2).

[26]. Han, D. (2010). Concise Hydrology. Dawei Han and Ventus Publishing APS. ISBN 978-87-7681-536

[27]. Jun Yin, A. P. (2014). Interplay of climate seasonality and soil moisture-rainfall feedback. Water Resources Research, An AGU Journal.

[28]. Thilagavathi, G., Tamilenthi, S., Ramu, C., Baskaran, R. (2011). Application of GIS in Flood Hazard Zonation Studies in Panamas Taluk, Thanjavur District, Tamilnadu. India.

[29]. Usoro, U., E., (2004). Assessment and Mitigation Strategies of Flood Risk. in Akwa Ibom State. A Geographical Perspective. Enugu: London.

[30]. Valente, A., Cunha, J. V. Boaventura, Correia, J H Couto, C. (2002). Soil Moisture Measurements. Agriculture Journal. 701(7).

[31]. Xu, Q., Liu, S., Wan, X., Jiang, C., Song, X., & Wang, J. (2011). Effects of rainfall on soil moisture and water movement in a subalpine dark coniferous forest in southwestern China.https://doi.org/10.1002/hyp

[32]. Ziadat, F.M., Taimeh, A.Y., (2013). effect of rainfall intensity, slope, land use and antecedent soil moisture on soil erosion in an arid environment.Land Degradation & Development Journal. 24(6).

[33]. Zhang, Y., Liu, J., Xu, X., Tian, Y., Li, Y., & Gao, Q. (2010). The response of soil moisture content to rainfall events in semi-arid area of Inner Mongolia. Procedia Environmental Sciences, 2(5), 1970–1978. https://doi.org/10.1016/j.proenv.2010.10.211

[34]. Basara, J. B. (2001). Soil Moisture Observations for Flash Flood Research and Prediction. Coping With Flash Floods, 231–241. https://doi.org/10.1007/978-94-010-0918-8_22

[35]. Li, B., Wang, L., Kaseke, K. F., Li, L., & Seely, M. K. (2016). The impact of rainfall on soil moisture dynamics in a foggy desert. PLoS ONE, 11(10). https://doi.org/10.1371/journal.pone.0164982

[36]. Xu, Q., Liu, S., Wan, X., Jiang, C., Song, X., & Wang, J. (2011). Effects of rainfall on soil moisture and water movement in a subalpine dark coniferous forest in southwestern China. https://doi.org/10.1002/hyp

[37]. Zhang, Y., Liu, J., Xu, X., Tian, Y., Li, Y., & Gao, Q. (2010). The response of soil moisture content to rainfall events in semi-arid area of Inner Mongolia. Procedia Environmental Sciences, 2(5), 1970–1978. https://doi.org/10.1016/j.proenv.2010.10.211