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Carbon Dioxide (CO_2) Emission on Agricultural Land Use and its Impact on food Production

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Abstract: The study assesses Carbon dioxide emissions from agricultural land use which have a great impact on food production and atmospheric weather. Emissions of CO_2 from the land use surface lead to minimum production of farm products. Global warming and climate change are the cause of great concern, demanding intensive research on CO_2 emissions from soil under some management options. The aim is to determine CO2 emission on agricultural land use with food security. An experiment was conducted using sodium hydroxide as a reagent for the emission, the results obtained demonstrated that the highest CO_2 emission was observed in maize farm which is 6.0 g CO_2 m^{-2} d^{-1} and the least was found in yam farm and forest location which are 0.5g CO_2 m^{-2} d^{-1}, at a point where the soil moisture was maximum (23.5%), the soil pH was minimum (4.84), the total organic carbon (TOC) storage in the soil was maximum (1.7%), then the CO_2 emission was low in a forest location because mineralization of soil bacteria's is not active in moist soil they are very active in a soil that lacks moisture, and bacteria contribute to the emission of carbon dioxide due to their activities in the soil.

Keywords: carbon dioxide emissions, global warming, climate change, soil bacteria, and soil moisture

I. Introduction

The distribution of CO_2 between the atmosphere and the soil is caused by the respiration of the soil and plant photosynthesis; the respiration of soil microorganisms and plant roots produces carbon dioxide emission in the soil. It is widely known that about 70% of soil CO_2 emissions are caused by soil microbial respiration [9] According to most researchers, the place of respiration of soil microorganisms on plant roots in all soil depends on hydrothermal conditions [8]. Soil respiration means the production of carbon dioxide when the soil is in an unopened mode.

In recent years, soil carbon dioxide production has been the subject of intense studies because the rate at which emissions occur depends on land use and land management systems, which include forestry, upland agriculture, paddy rice, and animal husbandry. Other factors influencing soil CO_2 production rate include atmosphere temperature, moisture, root respiration, microbial processes, soil aeration, porosity, and water [3].

Many years ago, most tropical countries, such as Ghana, considered themselves to be net anecdotal assertions based on the low level of industries in the countries. In the coming decades, a large reduction of carbon dioxide emissions will be required to mitigate climate change. The extent of emission rate lowering is needed to stabilize atmospheric carbon dioxide concentrations, and the inertia involved in rotating the world's primary energy sources from fossil fuels to other alternatives, carbon capture and storage (CCS), will likely contribute to a substantial share of the reduction in emissions in the next half-century. Previous research has made it clear that air capture is theoretically feasible in terms of thermodynamic energy requirements [10].

Temperature and precipitation are the most common and most significant factors influencing soil organic carbon (SOC) dynamics [2]. The increase in temperature may lead to an increase in plant production, therefore increasing carbon inputs to the soil which also tends to increase microbial decomposition of SOC [11]. There is strong empirical support for the idea that increasing in earth temperature will cause the net loss of soil carbon to the atmosphere. Also with climate change more common excessive rainfall and scarcity events are projected which may have greater impacts on ecosystem activity than the singular or combined effects of rising CO_2 and temperature [6]. This increase may aggravate the rate and sensitivity to quick erosion and other degradation processes leading to further carbon losses. Lastly, climatic change can affect several soil-forming factors including rainfall, vegetation, temperature, and microorganisms which badly affect the rate of soil organic carbon accumulation due to climate change. Drylands are expected to expand while SOC stock is likely to be reduced.

Carbon dioxide emissions from agricultural land use have created a low production of farm products and an increase in heat radiation. This low production of farm products occurs when the carbon dioxide that plants need for their photosynthesis escapes to the atmosphere, CO_2 escapes to the air by burning fossil fuels, felling of forestry trees (deforestation), and other human activities. Carbon dioxide (CO2) poses a significant threat to global climate change mitigation efforts [4]. Recent studies have highlighted the need for accurate quantification and understanding of the dynamics of CO2 emissions from different agricultural land uses, which is crucial for developing effective climate-smart agriculture strategies [12].

Forests are invaluable to all life on Earth and cover one-third of the total land area. It contains most of the world's terrestrial biodiversity, and 1.6 billion people look to it as their source of livelihood. According to [7], forests cover up to 4.03 billion

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hectares nearly 30 percent of the earth's surface. Mostly soil carbon is concentrated in forest land, therefore forests must be sustainably managed to reduce the act of land degradation and deforestation because large amounts of CO_2 are emitted when converting forests to agricultural land use such as maize farming, yam farming, and others. Soil management and land use can contribute to the reduction in CO_2 emissions and also lower its concentration in the air by stopping deforestation to preserve the current carbon reservoirs, and enlarge living terrestrial carbon reservoirs through reforestation [1].

Food security concerning climate change is affected in four various dimensions [3], which are: food availability, food accessibility, stability of food supply, and ability of consumers to adequately utilize the food (food safety and nutrition). There is a way to prevent this emission of CO_2 from the land by avoiding deforestation, burning fossil fuels, and other human activities that may likely lead to the emission, for a better farming system to end hunger, adapt to, achieve overall sustainable development, and control climate [5].

II. Materials and Methods

Description of the Site

The study was conducted at four locations, which were: maize farm, lied between longitudes 7^0 35' 15'' N and latitudes 5^0 17' 50'' E; yam farm, lied between longitudes 7^0 36' 7.56'' N and latitudes 5^0 17' 27.4'' E; forest area, lied between longitudes 8^0 60' 21'' N and latitudes 6^0 29' 09'' E; and cattle ranch, lied between longitudes 7^0 15' 35.4'' N and latitudes 5^0 11' 46.2'' E within the Federal Polytechnic Ado-Ekiti, Ekiti State.

Reconnaissance survey

A reconnaissance survey was carried out at each location to have an intensive knowledge of the site. The study took place at four locations which are; maize farm, yam farm, forest area, and cattle ranch area within The Federal Polytechnic Ado–Ekiti, Ekiti State.

Experimental Procedure

i. Maize farm: lies between longitudes 7^0 35' 15'' N and latitudes 5^0 17' 50'' E. The farm was subdivided into four parts (fig. 1) where the box was installed, the vegetation in this area are tall grasses.

Figure 1: Maize farm

ii. Yam farm: lies between longitudes 7^0 36' 7.56' N and latitudes 5^0 17' 27.4'' E. The farm was subdivided into four parts (fig. 2) where the box was installed, the vegetation in this area are mixture of grasses and scattered tree.

Figure 2: Yam farm

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iii. Forest area: lies between longitudes 8^0 60’ 21’’ N and latitudes 6^0 29’ 09’’ E. The area was also subdivided into four parts (fig. 3), the vegetation type in this location are tall trees and short grasses.

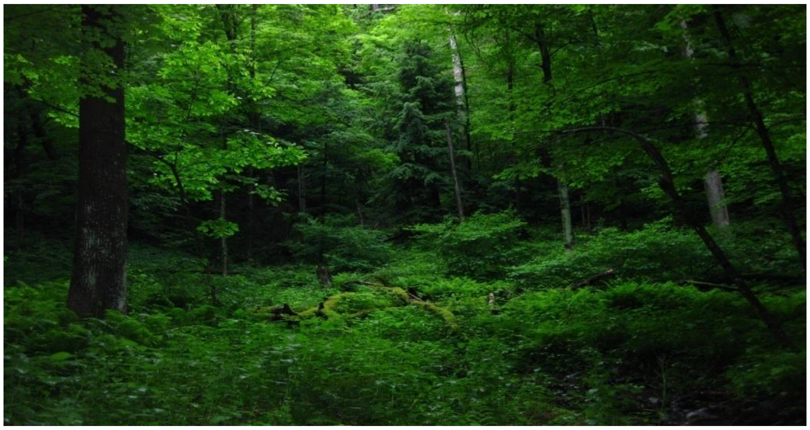

Figure 3: Forest area

iv. Cattle ranch area: lies between longitudes 7^0 15’ 35.4’’ N and latitudes 5^0 11’46.2’’ E. The location was subdivided into four parts (fig. 4) where the boxes were installed, the vegetation in this area are mixture of stubborn grass and elephant grass.

Figure 4: Cattle ranch area

Carbon Dioxide Emission Determination

Sodium hydroxide was used as a reagent. First, the empty ceramic dishes were weighed on a weighing balance and recorded to be w_1, and a specific quantity of sodium hydroxide was put into the dish and weighed to be w_2. Immediately, it was placed on the land and covered for 24 hours, with the prepared box made of plywood closed. After 24 hours, it was reweighed and recorded to be w_3. The increase in weight of the sodium hydroxide is the carbon dioxide that escaped according to this reaction:

When sodium reacts with carbon dioxide, it gives sodium hydrocarbonate.

$NaoH + Co_2 = NaHCo_3$

When reacting with water

$NaHCo_3 + NaoH \longrightarrow Na_2Co_3 + H_2o$

$2NaoH + Co_2 \longrightarrow Na_2Co_3 + H_2o$

Laboratory Analysis

Soil samples were taken from each location and labeled, then examined to remove the roots, leaves, and unwanted materials, after which they were taken to the laboratory to carry out the following analyses: bulk density, soil moisture content, soil pH, soil particle size analysis, and soil organic carbon. Two trials were achieved at each location, and the average was determined except for soil organic carbon.

Bulk density

The empty core sampler was weighed on the weighing balance and recorded to be w_1. After that, it was inserted into the soil at the location site and reweighed again to be w_2. To get the mass of the soil, w_2 was subtracted from w_1. For the volume, the height and diameter of the core sampler were measured (height of 5 cm and diameter of 4.5 cm) to calculate the volume.

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Bulk density (kg/m^3) = $\frac{\text{mass of soil}}{\text{the volume of the core sampler}}$ (1)

Moisture content

The empty moisture can was cleaned and weighed to be 0.01 g (w_1), then 100 grams of soil sample were placed into the can and reweighed to be w_2. The can with the soil sample was placed inside the oven and dried for 24 hours at a temperature of 105°C. After that, the content was removed from the oven and placed inside the desiccators to allow it to cool, and after that, it was weighed to be w_3.

Moisture content (mc %) = $\frac{W_2 - W_3}{W_3 - W_1} X\ 100$ (2)

Where: W_1 is the weight of empty moisture can

W_2 is the weight of moisture can + the wet soil sample

W_3 is the weight of moisture can + oven-dried soil sample.

Soil pH

First, the soil sample was sun-dried before being taken to the laboratory. 20 grams of soil samples from the dried soil were weighed and poured into a 250-ml beaker. 40 ml of distilled water was added to the content and stirred until well mixed, then left for 30 minutes to allow the suspension to settle. After that, the pH meter was calibrated with pH buffer solutions, and the probe of the pH meter was inserted into the content without touching the soil in the beaker. The pH value for the soil was obtained after the pH meter stopped reading.

Soil particle size analysis.

The weight of each sieve was noted and written down, including the receiver pan. All the sieves were thoroughly cleaned and carefully arranged in ascending order from the receiver pan to 0.075mm and to the highest, which is 9.5mm. A specific quantity of dried soil sample was carefully poured into the top sieve and covered. The arranged sieve stack was placed in the mechanical shaker and it was shaken for 10 minutes. After that, the stack was carefully removed from the shaker. The remaining soil inside each sieve was weighed and recorded as weight retained, and the soil in the receiver pan was weighed.

Soil organic carbon estimation

The wet oxidation method was used to estimate soil organic carbon. First, the soil sample was sun-dried for one week and it was sieved to remove unwanted debris from it, 0.5g of the sieved soil was weighed on the weighing balance and poured into a conical flask, 10ml of chromate was added and 20ml of sulphuric acid (H_2SO_4) was also added then shaken together, this was done for each sample, the blank was prepared by adding chromate and H_2SO_4 without soil, the content was left for 30minutes then 200ml of water was added to dilute the acid, 5ml of phosphoric acid and little quantity of sodium chloride (Na^+) was added to each sample including the blank, phenylanine indicator was also added to the samples, ammonium ferrous sulphate was poured into the burette then each sample was titrated until the color change and the reading was taken for the calculation.

Total Organic Carbon (TOC) = $\frac{\text{Blank} - \text{sample X 0.3 X M}}{\text{Weight of sample}}$ (3)

M = $\frac{\text{Concentration of chromate}}{\text{T blank}}$ (4)

Where M is the total mass of titration.

III. Result and Discussion

Table 1 and Figure 5 depict the average CO2 emission measured in the different land use in the study area and it was observed that maize farms emit more CO2 than other Agricultural land use while Yam and Forest have the same value (0.50 $gco2m^{-2}d^{-1}$). The lands with the highest emissions were caused by the activities of humans and animals on the land such as deforestation, overgrazing of the land, over tillage operation, bush burning and others, the land use with the lowest emission was not disturbed by such activities.

Table 1: Average CO_2 Emission in Agricultural Land Use

Land use	**Average Co_2 Emission ($gco_2m^{-2}d^{-1}$)**
Maize Farm	6.00
Cattle Ranch	4.25
Yam Farm	0.50
Forest	0.50

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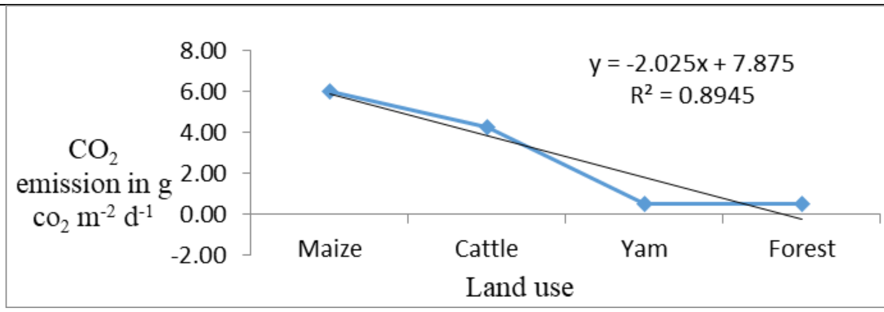

Figure 5: Graph showing the relationship between CO_2 emission and land use

Table 2 depicts Soil parameters and CO_2 emission, it was observed that soil Moisture content and Bulk density have a greater impact on CO2 emission, the higher the moisture and bulk density of the soil the lower the CO2 emission. Thus, an increase in the moisture content of the soil reduces carbon dioxide emissions.

Table 3 presents the significance of the observed correlation coefficients. Out of the total 10 correlations found between the parameters, 1 was found to have been significant at a 5% level (r = -0.965) which is between total organic carbon (TOC) and carbon emission (CE), this implies that an increase in total organic carbon lead to decrease in carbon emission, also in MC and CE at r = -0.825 an increase in moisture content lead to decrease in carbon emission.

The result for total organic carbon (TOC) in forest locations is 1.7% and yam farm is 1.5% showing that those land uses are not disturbed compared to cattle ranches and maize farms which TOC is 1.2% and 1.0%, therefore, there are clear difference in the TOC storage from each land use as shown in Table 2

Table 2: Soil Parameters and CO_2 Emission

S/N	Locations	MC (%)	TOC (%)	CO_2 (g co_2 m^{-2} d^{-1})	Soil pH	BD (kg/m^3)
1	Maize farm	15.00	1.00	6.00	5.58	1.88
2	Cattle ranch	13.00	1.20	4.25	6.90	1.71
3	Yam farm	19.00	1.50	0.50	5.76	1.83
4	Forest	23.50	1.70	0.50	4.84	1.79

Table 3: Pearson Correlation between the soil parameters and Carbon emission (CE)

	BD	MC	pH	TOC	CE
BD	1	0.199	-0.598	-0.193	0.128
MC		1	-0.860	0.895	-0.825
pH			1	-0.541	0.452
TOC				1	-0.965*
CE					1

Figure 6 shows that the higher the moisture content the lower the emission of carbon dioxide from the soil, with the relationship R^2 = 0.681 which is high and it means moisture content affects CO_2 emission.

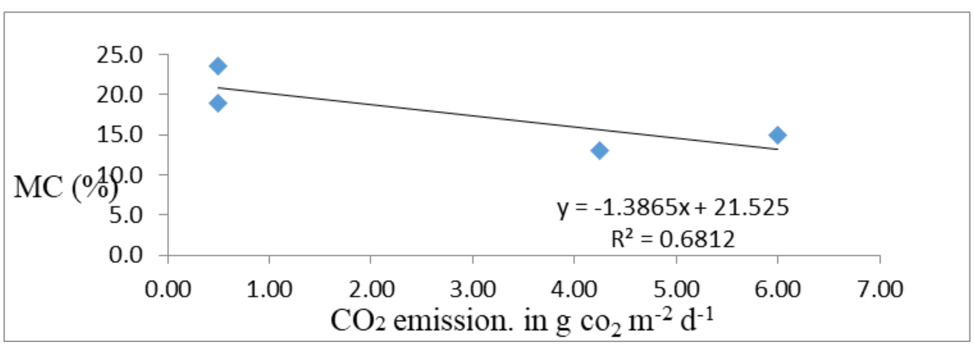

Figure 6: Graph showing the relationship between the moisture content and CO_2 emission

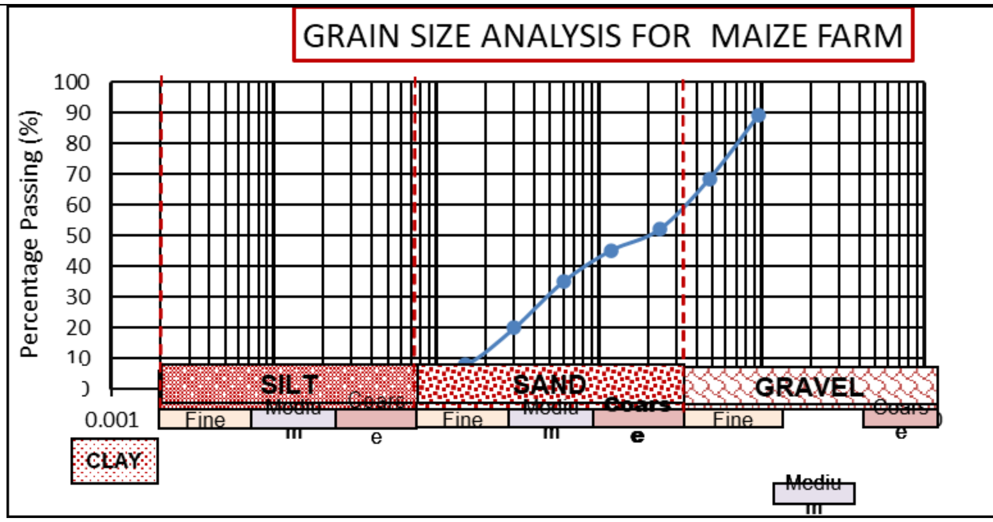

Figure 7: Grain size graph for Maize farm

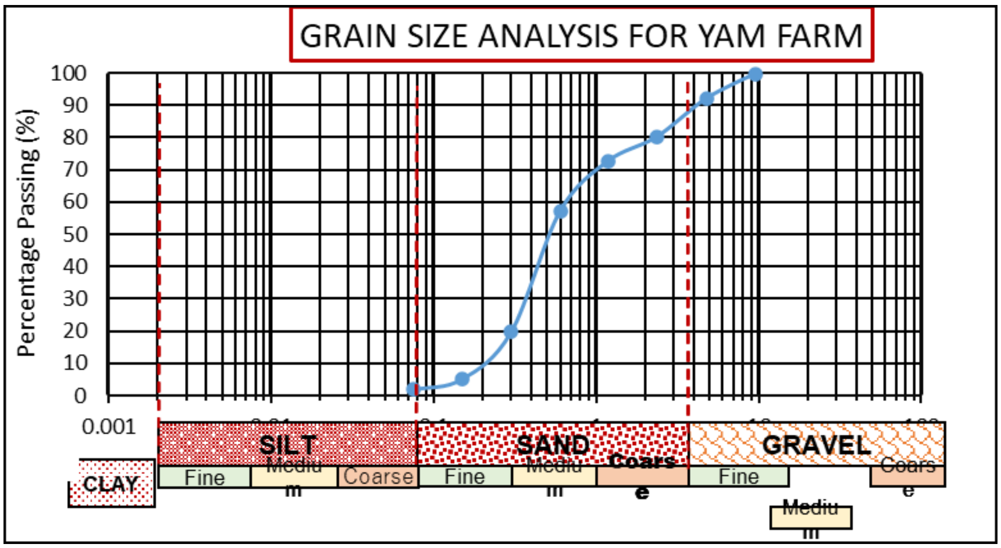

Figure 8: Grain size graph for Yam farm

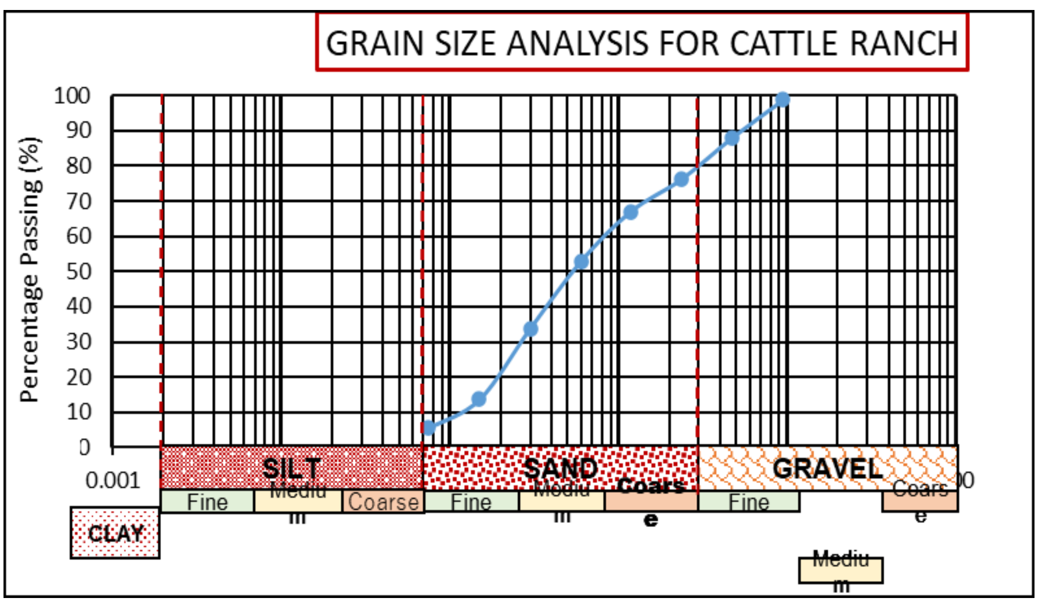

Figure 9: Grain size graph for Cattle ranch

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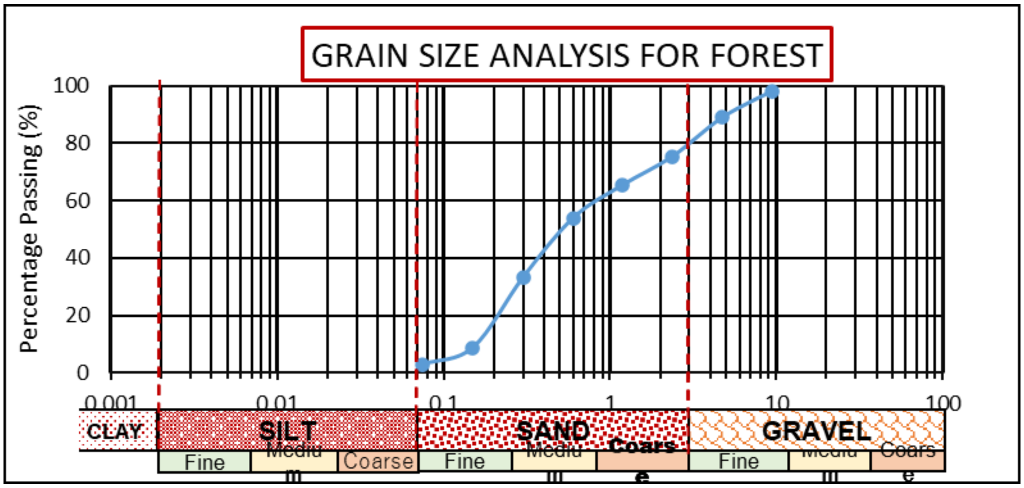

Figure 10: Grain size graph for Forest

The above Figure 7 to 10-grain size analysis graph, indicates that the graph moves from higher elevation to lower elevation based on their sieve sizes, the first three points upward are coarse soil, the second three grain sizes indicate sandy soil and the remaining two points are silt soil. This depicts the percentage of each size of grain that was contained within a soil sample of the selected locations which predicts the behavior of the soil in the locations.

IV. Conclusion

In the estimation of carbon dioxide emission on some agricultural land use, in which sodium hydroxide was used as a reagent for the emission, during the experiment the soil parameter that affects the emission is soil moisture content, the highest carbon emission was observed in maize farm which is 6g CO_2 m^{-2} d^{-1}. According to the results from each location (maize farm, yam farm, cattle ranch and forest), shown that their rate of emitting carbon dioxide is different, the physical and chemical properties of the soil also contributed to the emission in particular moisture content MC, because the higher the moisture content the lower the emission of CO_2, also total organic carbon TOC, the location that emitted higher rate of CO_2 which is maize farm has lowest storage of TOC with a rate of 1.0%.

Also, results obtained explain further that the highest TOC storage was found in forest locations with a rate of 1.7% which emitted the lowest carbon dioxide among the locations which is 0.5g CO_2 m^{-2} d^{-1} because the forest land is undisturbed, in the field of the study each land use emits different rate of CO_2 except yam and forest location. therefore, deforestation, burning of fossil fuel, land overgrazing and bush burning must be avoided then encourage afforestation and bush fallow. In terms of climate change CO_2 emission has brought rapid disorder in weather patterns which leads to changes in the hydrological pattern that make weather unpredictable which results in water scarcity and flooding of the environment.

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