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Research Article

Remediation and Management of Acid Sand Soils in Oil Palm Plantations by Carbon Sink Techniques

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Efforts to recycle and capture the ocean of green house gases emitted from the huge amount of crop removed from the earth surface and from the indiscriminate application of N fertilizers in agriculture, are of serious consideration to soil and environmental scientist world over. In the light of this, a study to investigate and evaluate the available processes that would recapture this huge quantum of green house gases (GHGs) using soil nutrient and efficient crop management, and spatial area stock of SOC techniques was embarked upon in the Nigeria Institute For Oil palm Research NIFOR, Nigeria. It is a study to optimize and exploit the enormous biodiversity created by the present institute environment of the main station in the Nigeria Institute for Oil palm Research. Which helps to create an ecosystem that sequesters SOC and reduces GHGs within the environment? The study covers three fields and a pool gene site of the Institute, where soil nutrient and environmental/agronomic management practices that exploit spatial photosynthetic energy, powered by solar system are practiced, adopted and encouraged. The Nigeria Institute for Oil palm Research, NIFOR, is a center that is geared a step forward to introducing this technology in its fields and plantations. The nutrient and crop management practice is an intensive spatial photo-energy reserve techniques in plants (carbon sink) that holds down carbon in store in both soil and plants in blocks or fields planted to palms in the institute. It's by reducing to the minimum the constant and continuous opening of the vegetation through removal of the earth covers. The institute allows standing crops (Palms) to their maximum productive age, to optimize their productive life yielding highest outputs per stand year-1 and getting to diminishing return before felling. The application of the right amount of N-targeted fertilizers to meet the required needs of the palms is administered after a fertilizer trial result is established. This has reduced the lost of N-fertilizer through N2O de-nitrification either in form of N2O to the atmosphere, or NO3- ions through soil saturation and erosion. Thereby reducing the effects of green house gases emitted in the institute area spanning about 1,700hactares of palm plantations, The extension department of the institute recommends these practices to farmers in the industry to create in the nearest future a clement and proficient environment that hold unquantifiable volume of CO2 in soils and in the plants.

INTRODUCTION/BACKGROUND

Integration of some agrononomic and soil nutrient management practices in our various oil palm plantations is growing by the day, due to the fast developing agrarian environment the society has found itself. Soil and vegetation forms the major instrument of the environment in agrarian setting that will ever remain in history of the earth if well managed. Nature provides measures to cleansing the atmospheric pollutant from within itself, created by Man's indiscriminate exploitation of the environment. Janssen et al, (2001) reported that atmospheric CO2 is constantly being fixed during photosynthesis balancing the volume of it by transferring it to the soil as Organic carbon. They added, that this ultimately returns back to the atmosphere as CO2 produced during mineralization of soil organic carbon. It has been established that 40 to 60% of the world's land mass is used for agriculture with about 150 pentagram or Giga- tones of carbon dioxide (CO2) being emitted annually from this source only, an amount to the tune of 150 x1015grams of GHG emission of CO2.. The emission of carbon dioxide is the most apparent GHG emission while others such as N2O and CH4 are respectively the most potent and are effluents from manures and N fertilizer application to the soil. The processes of bacteriological and de-nitrification of N fertilizers in the soil produces these green house gases including the constant or continuous removal of plant life. All these activities culminate in GHGs emission that depletes soil carbon reserves (SCR), which could have be adequately managed by recapturing over 60% of the GHGs emitted annually. Hasnol et al, (2011) reported on efforts to recycle and capture the ocean of green house gases emitted from the huge amount of crop removed from the earth surface and from the indiscriminate application of N fertilizers in agriculture. While Okpamen et al, (2012) added also that tropical soils which supports vast volume of vegetation on the earth surface are mainly developed on soils derived from three sources namely; sedimentary rocks, marine alluvium pits and basement complex sources. Stating that, these soils are open to physico-chemical weathering and natural metamorphosis advancing into various soil types such as acid sand; coastal plain sand or flood plain, alluvium and basement complex soils.(Brady and Weil, 1999). These are formed under rainforest and savannahs in the tropics and equatorial zones of the world which includes Nigeria's soils. Nigeria soils and soils of acid sand of southern Nigeria had been classified by Ogunkunle (1983) as soil formed from basically sedimentary and igneous related parent materials. They are soils that defined the nations agricultural landscape and geo-climatic vegetation wherein the wealth and economy of Nigeria is currently been sustained. Acid sand soils of Nigeria are formed basically under four parent materials namely; coastal plain sand, alluvium, shale and basement complex (Ogunkunle, 1983, Fagbemi, 1985). And they are found in the South Midwestern and Eastern Nigeria. These soils are soils that are characteristically having greater than 85 percent sand fraction with a ph of ≤ 6.4 and having exchangeable acidity of greater than 1.0c molkg^{-1} and are usually found underneath rainforest vegetation (Ogunkunle, 1983). The term remediation as used by Odeyemi (1991) was used in relation to Bioremediation of oil spills or derelict lands which refers to correction or making right a crude oil polluted soil to a cultivatable level; such that could support crop growth and development by application of bio-fertilizers (flora and faunas) to stabilize soil performance for crop growth and development. Carbon sink as captioned in the title is a term used in relation to green house gas emissions GHGs; it is defined as processes that remove greenhouse gases (GHGs) from the atmosphere and stores same in a long term reserve (Janathan et al, 2010). Carbon dioxide is the commonest GHG but may not be the most potent; it is known to contain almost half the weight by mass of the compound. Hutchinson (2007) reported that carbon remain the major parent atom in most GHGs while it is needed in the process of de-nitrification of nitrogen compounds that are GHGs (N_2O and NO_2). Russell et al, (2009) however added that Soil carbon reserve is constantly being depleted by man and its activities stating that soil is a dynamic biological system that stores GHGs abundantly. They reiterated that any soil factor(s) that could influence soil management would invariably affect net amount of CO_2 or Carbon sink in soils. There are notable agro-practices that are capable of stemming the increase flight of carbon from the soil by driving more organic matter into the soil when introduced (Carbon sequestration). The processes will decrease the volume of CO_2 emission and increase carbon sink by allowing more emergent of plants and other biological entities that can trap carbon into the soil. IPCC, (2007) added the use of perennial forages in crop rotation system, stating that it is appropriated to reducing GHG emission and increasing carbon storage (sequestration) in soils to about 2-3tonnes of CO_2 ha^{-1}yr $^{-1}$. It was also discovered that the establishment of leguminous covers on soils encourages the fixing of N from the atmosphere, a process that indirectly reduces the green house gas emission by increasing N-fertilizer to the soil. Janathan et al, (2010) concluded by adding that cultural and soil nutrient practices that are aimed at curbing nutrient losses and promoting prolonged stay of vegetative life on the soil will enhance soil carbon sequestration.

MATERIALS AND METHODS

This research was carried out in NIFOR main station located on lat.060 .33'N and Long 050 .37'E and on altitude 149.4metres. The institute cultivated land area presently spans over 1700hactares and are predominantly occupied by oil palm stands of varying ages. The soils in the area have been classified by FAO/UNESCO (1994) as rhodic paleudults, having sand loam on topsoil and clay loam to silt clay at depths. (Okpamen et al, 2012) Four profile pits were dug and assessed morphologically and physico-chemically (Table 1) with preliminary work established and set up from sampled block/fields (3-1, 13-1 and 14-1) Table 2 and 3 from the cultivated areas of the institute (1700ha). While the profile pits were dug at pool gene 1, the stock of soil organic carbon SOC in the area was evaluated within the depths of (0-150cm) Table 1, of profiles examined. The total estimate of soil area stock of soil organic carbon SOC was given by Organic C% X 1.724 while the estimated Carbon dioxide CO2 emission was calculated from Hooijer et al (2009).The volume of biomasses removed from sampled fields were estimated using 20m x 20m dimension from sample fields to calculate a block/field respectively. Eight compost pits (1-8) Table 3, were also dug to ferment/decompose the biomasses removed for further evaluation, and estimation of gas effluents which was allowed to pass through sealed glass funnels with alkaline parogallol inside (absorbance agent). The weight of the alkaline agent was initiated by an initial reading and the difference in weights of the alkaline reagents were used in the calculation of CO2 emission using Hooijer et al (2009) multiplying factor of 0.91where soil spatial compaction is a constant of 1.0 and water table (WT) was approximated as 1.0. and field percentage error estimation was ≤ 15 % . CO2 emission (ton) ha-1 = (0.91 x1.0 x weight of effluent absorbed) (Hooijer et al 2009). Tons ha-1yr-1 were converted to Giga tons of CO2 by dividing by 1015 gram x 1000 = Mg C (Jonathan et al, 2010).

Statistical Analysis of Data; the quantities of biomasses and the volume of carbon dioxide were compared with each other to draw any seeming relationship between the GHGs and the masses of vegetation being removed annually per year ha-1 from the fields. This was done using regression analysis, in SPSS statistical package version 16. Test of significance used were 1 and 5% respectively.

RESULTS AND DISCUSSION

Table 1: Physico-chemical Properties in Soils of Rhodic paleudults, Soils of NIFOR.

P.M	Depth Cm	Silt gkg^{-1}	Clay gkg^{-1}	O.M gkg^{-1}	C;N	K;ECEC	ECE c $molkg^{-1}$	Soil Ph(H_20)	Exch. Kc $molkg^{-1}$	Tot. N %	Org. C gkg^{-1}
	0-3	40	110	21.2	20.8	0.017	5.91	5.34	0.10	0.59	12.3
	3-16	30	140	12.8	20.1	0.011	6.43	5.43	0.07	0.37	7.45
CPS	16-45	10	190	4.57	6.46	0.009	6.80	5.23	0.06	0.41	2.65
	45-75	20	250	4.07	5.76	0.009	6.58	5.16	0.06	0.41	2.36
	75-90	18	332	0.00	0.00	0.007	5.63	4.93	0.04	0.25	0.00
	90-150	10	350	0.00	0.00	0.010	4.69	5.32	0.05	0.05	0.00

$C0_2$ Carbon(iv)dioxide CPS;coastal plain sand , cm; centimeters; c;n carbon;nitrogen;o.m; organic matter,ecec; effective cation exchange capacity;

From table 1, column of O.M, organic matter across the profile indicates that the stock of soil Organic carbon in the Institute soil is concentrated in 0-75cm depths, and there are no carbon reserves in the lower depths. And the pool of nutrients indicates higher volume of nutrient reserves in the aforementioned depths compare to 75-150cm depths of the soils in the institute. The implication of this is that the pool of nutrients across the soil spatial consideration in the institute is depth related rather than nutrient pool distribution. Now since the stock of soil organic carbon SOC is within 0-75cm it can then be deduced that the present nutrient pool of most elements in the institute soil is soil organic carbon related (Table 1). This is in line with the report on Jonathan et al (2010) on impact of SOC on pasture soil in Australia. Table 2 presented the results of the CO_2 emission with relation to the quantity of biomasses removed from the institute sampled fields/blocks that were subjected to induced decomposition and open-field conditions. The time for their degradation and decay were recorded and the rate of decay calculated from the time taken, this was divided by weight of biomasses. The eventual results from each pit revealed that the effluents gave satisfactory weight increases, to the alkaline reagents and was used to compute the carbon dioxide emitted.

Adoptable Methodologies To Creating Agro-Environmental Safety in Nigeria Institute for Oil palm Research Plantations.

A study on the review of the influence created by the natural vegetation on soils which forms a major factor in soil-water reserves and nutrient pool management was x-rayed with important agronomic practices inherent in agriculture. Practices that conserve nutrients such as SOC and mitigate CO_2 are recognized modulations to agro-climatic safety. Under this technique the impacts of natural application of biological and chemical inputs such as fertilizer applications through leaf falls, prolong sustainability of crop stands, microbial stimulation by bush fallow methods and bio-fertilization are exploited. The emphasis on the use of inorganic fertilizers is de-emphasized to a reasonable extent for environmental safety. The influence created by prolong accommodation of oil palm stands in a micro-scale is evaluated and exploited as advantages that have direct positive nutritive impart to the soil and the larger atmospheric environment. A long term studied of oil palm fields in the institute (18-30yrs) revealed that the various vegetation and plantations in the area are responsible for the near serene atmospheric condition being observed. Presently the totality of efforts expended by local field laborers in Fields and plantations planted to both oil palm and coconut per man day in the Institute are evaluated with regards to the volume of biomasses constantly being removed to estimate the amount of CO_2 removed. This is use as case study to quantify the volume of biomass removed as crop removal during slashing, and is compared with estimated volume of nutrient pool conserved. See table 1 and 2. The extent of agro-practices; nutrient management practices employed is the measure of nutrient management application to the soil; this is quoted as being factor to management of agro –environmental safety. The sum total impact of these technologies to the soil also has bearings on the atmosphere around and in the areas of green house gases on soil nutrient and the environment. Table 2 shows the role of soil nutrient management in sequestering carbon in palm fields or plantations as the SOC calculated from the Org.C% directly is tied to the 0-75cm depths only across area examined. This however is currently being used as factor in estimating the total soil area stock of SOC of the institute soils. This study therefore is a current literary survey of methodologies that are capable of changing the present degrading climatic environment of most agrarian ecology if adopted in the fields. Though the correlation of biomass quantity with volume of CO_2 emission was fairly significant (r=0.587, ∞ =0.05), it only statistically proves the fact that the volume and stock of SOC and carbon reserved in the plants forms more than half the quantities in the atmosphere giving absolute credence to this research work. And also synergized efforts to stem the depleting soil carbon reserve and reduces the GHGs in the oil palm fields in the Nigeria Institute for Oil palm Research. Pragmatic synchronization study of oil palm environment and other palms growing ecologies by scientists would in the long run provide the needed solution to environmental safety. Soil carbon sequestration is however a current global issue that dominate that the agro-oil and coconut palm and off course a scientific well managed research farm would have solution to with all the integrated agronomic practices adopted in the institute.

Nutrient Management in Oil palm fields/Plantations

The use of inorganic and Organic fertilizers is the usual routine in most oil palm fields and it is what is done in the various fields of the institute. N-fertilizer from commercial and organic sources were applied to the soil/fields and were noted to have increased the volume of growth of biomass in a long run but resulted in the volume of green house gas emitted per year ha^{-1} from the soil of the field in a short run. The finding of this result was corroborated by Russell et al, (2009) who gave a procedural breakdown of nitrogen loss by de-nitrification process and stated that fraction of GHG (nitrogen (1) Oxide = N_2O) is emitted. They further added that when commercial inorganic fertilizers that gives N to the soil are added to the soil, they are converted to the nitrate by soil reaction carrying oxygen while the more potent methane (CH_4) and nitrogen (1) Oxide (N_2O) are also introduced into the atmosphere when organic manure is added to the soil during bacteriological decay. The results in table 3 corroborates the equation of reaction indicating Organic materials containing N-fertilizer constituents being acted on by micro-organism/ nitrobacteria forming products of NO_3^- and N_2O including an alkyl complex (R-H). humic compound from residue decomposed (Table 2 and 3). The chemical process uses oxygen from the soil water and leaves the soil with N_2O (Nitrogen (1) Oxide) which is lost under intense sunshine and process of de-nitrification of the nitrogenous compounds. This result in shortage of oxygen and the increase in N_2O and CO_2 that results in green house effects, this process are constantly occurring in soils faced with constant N-fertilization. This result and finding corroborates Mckeon et al, (2009) who stated that in management of nitrate in soil only a fraction of the applied nitrogen is absorbed and greater volume are lost through processes of organic decay and de-nitrification. The institute soil is constantly experiencing fallowing from over grown weeds and palms, this is however a safe measure to conserving carbon dioxide and Build up organic reserves that hold back enough carbon in our various oil palm fields, though may be adverse to increase production in the short run as the weeds may constitute impediments to effective nutrient supply and uptake by the palms.

Table 2: Comparison of Volume of Biomass with Estimated Amount of CO_2 Calculated With Numbers of Man days $ha^{-1}yr^{-1}$ In three Fields/Plantations in NIFOR

Ages of palms varied from 18-30yrs on fields.

Fields/Plantations	Number of Man Days ha^{-1} yr^{-1}	Quantity of biomass removed $Kgha^{-1}yr^{-1}$	Estimated amount of CO_2 removed Mg C	SOC Lost Mitigation Sources
13-1	110	177.75	0.430	Sustaining oil palm stands on plots for longer ages. Reduction in the rates of clean weeding of fields. Application of N-targeted fertilizers crops
14-1	127	89.97	0.194	
3	34	112.50	0.243	

Table 3: Volume of Biomass with Time and Rate of Decay of Composted Samples

Pit No.	Decay Time/ days Open field.	Quantity of biomass Open Field (kg/ha)	Rate of Decay in Open field Kg/day	Rate of Decay in Compost Kg/day	Quantity of Biomass Composted (Kg/ha)	Decay Time/ days in Compost (days)
1	15	122	0.123	0.057	122	7.0
2	14	84	0.167	0.095	84	8.0
3	18	194	0.093	0.052	194	10.0
4	14	128	0.110	0.078	128	10.0
5	14	119	0.110	0.076	119	9.0
6	15	129	0.116	0.078	129	10.0
7	13	123	0.105	0.063	123	8.0
8	14	143	0.097	0.063	143	9.0
Total	117	942	0.921	0.562	942	71.0

Nutrient Utility and Fertilizer Efficiency in the Fields and Plantations

Nutrient utility and fertilizer efficiency is the determination of how much and to what extent a crop requires a nutrient and would respond to it when used (Tennakoon, 2003). In the light of this, it is always important to know the N-rates required by the soil and the crop. It is also needful to know how much N-available in the soil to know whether an additional N-requirement would bring about the required output. All these are achieved with proper soil testing and application for this will adequately take care of the problem. When the right amount of N-targeted to meet the required need of the plant is administered it will reduce the loss of N-fertilizer through N_2O de-nitrification either in form of N_2O to the atmosphere. NO_3 through soil saturation and erosion. When there is proper N rating for the crop and applied appropriately will optimize crop response, reduce lodging and nitrate leaching in soils (Hulugelle et al, 2009). Most areas of the soils in the institute main station are well drained, while the institute substations located in the riverine and Delta/coastal areas such as Otego substation in Bayelsa state are subject to anaerobic condition most parts of the year. Soils in the areas are hydromorphic and could be classed as anaerobic soils, microbes in such soils uses the nitrates and nitrous oxides in the soils in the absence of oxygen to carry out life activities. They de-nitrify and convert most organic nitrogenous compounds to nitrogen and nitrous gases leaking out these potent gases to the atmosphere adding to GHGs emission. Grace et al (2006) said that adoption of good agricultural practices that would improve and maintain fertilizer efficiency will help to reduce GHG emission and encourage carbon sink. They emphasized that these must include; recognition of type of fertilizer, the rate of application, timing of application and methods of application. In the case of flood prone fields the most important consideration is the type of fertilizer, method of it's application, before the rate it could be applied, this is because there is water in most areas of the plantation virtually across the year. Rates of biomass conversion is slower in anaerobic soils as organic decay and mineralization is at it's lowest ebb. Thus the most potent means of fertilizing soil of this nature is through direct fertilization of the palms. The term manure is defined as a heterogeneous mixture of nutrient organic matter and water applied to soil for crop wellbeing and added that manure should be applied at the rate that perfectly meets the crop nutrient requirement. In a similar experiment done by environmentalist in Canada it was stressed that the constant removal of plants in annual basis is becoming the most expressive medium of carbon flight from the soil. IPCC, (2007) added that it has remained the most potent medium of GHGs quantification and emission. In Nigeria currently, the relationship between soil and plants in terms of daily to weekly activities apart from agricultural institutes that centers on crop management can best be associated to local indigenous Nigerian farmers whose means of income depends on agriculture. The volume of vegetation removed from soil surfaces across the nation's geo ecosystem can only be quantified when a thorough statistics of the numbers of local and commercial farmers who on daily basis are engaged in farming is managed. Other means of removal of vegetation on daily basis is in the construction and expansion of cities and infrastructures in Nigeria. These medium accounts for the world's total carbon drift and increased GHGs emission; it was asserted by Sanderman and Baldock, (2010) that native land for agriculture takes between 40 to 60% of the global land and amount for the greatest loss in soil carbon. The process produces a large volume of the atmospheric CO_2 > 150pg of the gas annually released to add to the sea of GHGs already in the atmosphere. The decomposition of organic matter produces carbon dioxides, methane, ammonia, water and organic solids, the putrefaction of plants and animal remains lead to the recycling of several nutrient elements back to the soil. Processes leading to lost of carbon dioxide in soils are related to respiration and energy breakdown of photosynthesized matters of both liquid and Solid waste of the organic remains which comprise humic acid and nutrient elements. Bio-gas is a form of natural gas from this process, it is the mixture of methane , ethane and ammonia gases with traces of impurities such as Sulphur which in furtherance of series of naturally occurring chemical reactions in the soil culminates into soil nutrients for plant benefits.

CONCLUSION

From this experiment, it has been established that the likelihood of storage of soil carbon by efficient soil nutrient and crop management technique is a more potent agency than any other established processes. As processes leading to loss of carbon dioxide in soils are related to respiration and energy breakdown of photosynthesized matters of both liquid and Solid waste of the organic remains which comprise humic acid and nutrient elements that constitute the composted material used in this work. The controversy among school of thoughts in this respect has not proven otherwise either. It was discovered that about 0.2 to 0.3Mg C ha-1 yr-1 of carbon dioxide is conserved from improved management of crop and good cultural practice (Janathan et al, 2010). The local indigenous farming system has always been the greatest and most rapid medium of lost of soil carbon in Nigeria than in scientifically managed agricultural settings like the institute. The Institute fields have formed the basis of comparison with reviewed literatures that was sited in this work. These various fields were investigated and evaluated for soil nutrient and crop management practices that sequester atmospheric carbon. Various agro-practices were itemized to sequester Carbon among which were transiting from established cropping system and maximizing water and nutrient- use efficiencies to increased productivity, irrigation fertilization, Stubble management that help to eliminate burning and grazing. Others are reduced tillage, direct drilling, and shift to perennial species that can utilize water throughout year, even below ground allocation. The movement to different farming system such as from the native system to organic farming system is likely having more SOC available than most conventionally established agro-practices. This however is depending on the specifics of the organic system (i.e. manuring, cover crops, etc…) it includes cropping to pasture system, this has been accepted as generally giving greater C return to soils.

RECOMENDATION

The findings of this work have prompted the following as recommendations firstly that, there is the likelihood of mitigating C in the atmosphere rather than sequestering CO2 in most environments such as this. The institute is a highly vegetative environment with a clement climate that favors multi-generation of crop varieties with oil palm and coconut as the most common. Therefore these palms should traditionally be maintained to endue environmental safety with consistent application of leguminous perennials and other vegetative surface covers that could synchronize plant growth with atmospheric cleansing of carbon rather than embarking on continuous use of N fertilizers, bush burning, deforestation and constant opening of the earth surfaces.

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