Contributions of selected animal manure and common farming and soil fertility management practices to soil organic carbon status and greenhouse gas mitigation in Ogbomoso, southwestern Nigeria: In: Unraveling the contributions of the Nigerian Livestock and other more prominent sectors in mitigation of global greenhouse gases.

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Abstract

Agricultural activities is a major anthropological driver for greenhouse gas emissions in the world of which crop and livestock production account for more than half of the total emissions. Agricultural activities can significantly contribute to and/or mitigate soil organic carbon depletion and greenhouse gas emissions depending on how sustainable the prevailing farming practices are. This review revealed indiscriminate use of agro-chemicals dominantly chemical fertilizers and herbicides to be major drivers for soil organic carbon depletion and greenhouse emissions in Nigerian soils. Poultry manure application could be a blessing and woe to our soils depending on its mode of application into the soils. Its application in almost raw form significantly contributed to enhanced CO_2 emissions, nutrient leaching and environmental pollution. Modifications of poultry manure through aerobic decomposition into compost and thermo-chemical conversion into biochar are sustainable means to putting poultry manure to use to the advantage of the environment.

Introduction

The major environmental challenge the world battles today is overcoming global warming emanating from climate change effects. These global degenerating effects on the ozone layer are products of continuous exertion of unsustainable activities on the ecosystem. These effects are indicated locally by increased atmospheric temperatures, incessant drought spells, drying up of streams that serve as alternative water sources during dry season, outbreak of new weeds, pests and diseases, disappearance of beneficial micro and macro-organisms in the soils and decreasing crop yield worsened by incessant crop failures following drought spells.

Global agricultural system is a major anthropogenic contributor to global greenhouse gas (GHG) emissions (FAO, 2020; Venterea *et al.*, 2016). It is reported to be responsible for about 9.3 GT CO_2 eqv. of which crop and livestock production activities contributed more than half (5.3 GT CO_2 eqv.) of these emissions majorly CH_4 and N_2O while two-third of this

(2.1 GT CO_2 eqv.) was generated from livestock farm alone in 2018 (FAO, 2020). Carbon dioxide and N_2O are the two most implicated GHGs contributing significantly to global warming (Nguyen *et al.,* 2014; IPCC 2007) and their emissions have increased geometrically from pre-industrial time from 11 to 17.7 Tg N_2O-Nyr^{-1} in 1994 and 280 to 392 ppm in early 21^{st} century respectively (IPCC, 2007). CO_2, CH4 and N2O contribute about 75, 16 and 6 % of the total global GHG emissions (Lenka *et al.*, 2015). CO_2 emission from soils is influenced by soil types, soil reactions and processes, plant root and soil microbial respiration, environmental conditions, chemical and organic fertilizer applications. Unguided intensive cultivation of arable land characterized by exhaustive crop production through indiscriminate usage of agrochemical (especially chemical fertilizers and herbicides) has contributed immensely to annual soil and environmental degradation. Information on GHG emissions especially CO_2 emissions from soils in Nigeria are scarce despite yearly, high and indiscriminate chemical fertilizer applications into the soils. It is saddening that there is no agency in Nigeria that monitors and documents greenhouse gas emissions from arable and livestock farms. This failure has further strengthens among farmers continuous indiscriminate use of agrochemicals (especially chemical fertilizers and herbicides), reckless disposal of large tonnage of manure generated from various farm animal houses and unguided application of these animal manure in almost their raw state on soils. These coupled with poor farming activities are potential drivers to enhanced GHG emissions in Nigeria.

Livestock industry in Nigeria and its associated environmental challenges

Livestock production involves economic rearing of farm animals for their meat, milk, egg, leather and other products. Livestock industry in Nigeria is the leading livestock producer in central and West Africa with annual production strength of about 180, 76, 43, 18 and 8 million poultry birds, goats, sheep, cattle and pig respectively (FMARD, 2017). The industry is said to worth over N30 trillion (Premium Times, 2019; The Guardian, 2021) and is a major source of animal protein for human diet and employment in Nigeria. The industry is explored as local source of raw materials to leather, confectionary, cosmetics and pharmaceutical industries in Nigeria. This industry however has not come without its challenges of which environmental pollution is dominant. Livestock farms are associated with air, water and soil pollutions especially when environmental regulatory bodies and policies are lacking. This of course is the situation in Nigeria where livestock farms are situated anywhere in the community and wastes from the farms especially the dung are released into the community without caution. This results in environmental pollution causing multiple direct and indirect health issues on plants, animals, aquatic lives, air and water quality, human wellbeing and eventual imbalance in the ecosystem which is ultimate to climate change.

Poor soil management from crop production farms

Most farmers in Nigeria are resource poor and their crop production activities depend largely on chemical fertilizers (especially as urea and NPK 15:15:15) provided at subsidized rates by the government for soil fertility management. A few of these farmers keep poultry as coping mechanism against crop failure from unprecedented weather conditions. The recent campaign for adoption of organic agriculture has introduced application of animal manure especially poultry manure on farmlands by few of the local farmers. Impatience and poor planning attitude of these farmers had contributed immensely to field application of these poultry manure in their almost raw forms which poses serious threat to the environment. Soils receiving similar applications of sole fresh animal manure and/or its co-application with chemical fertilizer were found to emit 123 (Mäder *et al.,* 2002) and 84 kg $ha^{-1}yr^{-1}$ (Flieβbach *et al.,* 2007) carbon into the atmosphere.

Soil organic carbon: an important soil parameter for mitigating greenhouse gas emissions from soils

Soil organic carbon (SOC) is generally referred to as a major indicator of soil health. It directly affects physical, chemical and biological characteristics of the soil. Enhanced organic carbon in the soil has been reported to improve structure, water and nutrient holding capacities of soils. In fact, balanced SOC sequestration has been well documented as a significant way out to mitigating GHG emissions especially in tropical soils (Li et al., 2019; Fungo *et al.,* 2017; Adesodun *et al.,* 2015; Brar *et al.,* 2013; Kimetu and Lehmann 2010). Channels to achieve efficient carbon sequestration in tropical soils could include: afforestation, controlled use of agrochemicals, in-situ return of biomass into soils through biomass modification into stable soil amendments such as compost and biochar. Others could include: fallowing, erosion control and slope management.

Nigerian soils which are typically tropical in nature are generally low in SOC content due to both natural and anthropogenic factors. High sunlight radiations, temperature and rainfall intensities denoted by the prevailing tropical climatic conditions are natural drivers encouraging faster SOC decompositions. Documented anthropological factors contributing significantly to enhanced SOC depletion include: indiscriminate use of chemical fertilizers, herbicides, continuous cropping without sustainable nutrient replacement, poor tillage practices and absence of conscious application of cured organic materials into the soils. In this report, contributions of filed application of raw and modified dung from livestock (pig dung and poultry manure) and different cropping and soil fertility management practices (e.g. continuous cropping, indiscriminate use of agrochemicals, fallowing, poor erosion control e.t.c.) on SOC and CO_2 emissions were summarized from our various research works.

Summarized results from incubation and field trials

Assessment of two intensively and continuously cropped soils in Ogbomoso, southwestern Nigeria revealed that organic carbon dynamics in the soils are significantly affected by adopted farming practices. All the continuously cropped farmlands studied were deficient in organic carbon contents with values far below the 3% considered as critical for productive soils (FFD, 2012). These soils therefore will serve as poor adsorbents to trap GHGs, toxic metals and mitigate nutrient leaching into surface and subsurface waters.

Soil organic carbon deletion was highest in the continuously cropped soils at the two locations managed by indiscriminate use of chemical fertilizers and herbicides, poor slope and erosion control. This preliminary evaluation showed reduction of SOC by more than 400% in soil annually receiving chemical fertilizers (especially NPK 15:15:15 and urea) and herbicides under continuous cropping compared to similar soil managed by organic fertilizers at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso. Poor slope and erosion control further reduce SOC by 204 and 367% respectively in the continuously cropped soil managed by indiscriminate use of chemical fertilizers. Our preliminary evaluation of effects of short (1-2 years) and long (> 5years) term fallow showed fallowing potentials to increase organic carbon in soils from Ogbomoso by 10 and 18% respectively compared to continuously cropped soil without fallow.

Soil organic carbon contents were higher at sites under long term (>5 years)*Tithonia diversifolia* fallow (3.54%), teak woodlot (2.58%), managed by animal (pig) dung (2.57%) and under short term (1-2 years) fallow period (1.93%). Conversely, SOC contents ranged from 0.22 and 0.55% in continuously cropped soil managed by indiscriminate chemical fertilizers exposed to water erosion and foot trafficking. Emissions of CO_2 from the soil were found to significantly vary among the different farming practices. Continuously cropped soils managed by indiscriminate chemical fertilizers and intense foot trafficking accounted for higher CO_2 emissions ranging from 337.7 – 341.1 kg CO_2/ha. On the other hand CO_2 emissions were lower in valley bottom soils (191.4 kg CO_2/ha), pasture plot (276.8 kg CO_2/ha) and soils under teak woodlot (296.8 kg CO_2/ha).

At another location, Agricultural Settlement Ogbomoso, SOC were higher at sites with evidence of termite mound activities (2.91%), presence of cashew woodlot (2.86%) and poultry manure application (2.13 – 2.31%). Farmlands under continuous cropping combined with indiscriminate usage of chemical fertilizers and herbicides (with mean SOC values of 1.43 and 1.83% respectively) and vehicular exhaust deposition (1.42%) were dominant drivers for SOC depletions in the area. The organic carbon contents of soils at this location accounted for about 44% in the variations of cation exchange capacity (CEC) of the soils. The CEC of soils are indicators of soils potentials to hold water, nutrients and serve as adsorbent to mitigate nutrient leaching and GHG emissions. Sites with higher SOC (2.13 -2.91%) consistently had higher CEC values (5.86 – 9.40 cmol /kg) while soils with lower SOC values (1.42 – 1.83%) had the least CEC range of 4.31 – 5.37 cmol/ kg .

In another trial, CO_2 emissions were monitored in soils amended with poultry manure (PM) and its two modified products. These two modified products were compost (PMC) and biochar (PMB). The PMC was produced through aerobic decomposition of PM and sawdust at ratio 3:1 in a windrow while PMB was achieved through pyrolysis of PM and sawdust at 350∘C. The PM and its modified products were applied at 1g/400g soil in a CO_2 trapped chamber. The CO_2 emission pattern of PM and its modified products under sole and co-application with chemical fertilizer (CF) composed of NPK 15:15:15 spiked with urea were compared with sole CF. Average CO_2 emitted were highest (174 mg CO_2/kg) in soil amended with sole CF followed by PMC+CF (122.1 mg CO_2/kg) > sole PM (117 mg CO_2/kg) > unamended soil (109 mg CO_2/kg) > PMB+CF (98 mg CO_2/kg) > sole PMC (84 mg CO_2/kg) and least in sole PMB (79 mg CO_2/kg). The trial concluded that management of soil with sole CF and PM in its almost raw form aggravated CO_2 fluxes from the soil studied. Thermal and biological modification of PM into biochar and compost respectively should therefore be adopted. Initial organic carbon improvement in soils following application of these PM modified products was pinpointed as the dominant mechanism for these modified products to efficiently reduce CO_2 emissions.

Preliminary evaluation of one time atrazine application into soil pretreated with sawdust based biochar was carried out in a leaching column. The biochar was prepared from sawdust with or without poultry manure at 350∘C and were applied at 5 and 10 t/ha. Soil that received only atrazine and an absolute control that received neither atrazine nor biochar were compared. One time atrazine application significantly reduced soil organic carbon, CEC and pH. In fact, sole herbicide treated soil reduced SOC and pH by 31 and 6% in just two weeks residence time of the atrazine in the soil. Soil pretreatment with sawdust based biochar prior atrazine application significantly improved SOC, CEC and pH by a range of 1.43 – 2.41% (SD+PM) and 1.78 – 2.57% (SD-PM), 5.44-8.26 cmol/kg (SD+PM) and 3.72 - 5.02 cmol/kg (SD-PM) and 6.33-6.95 (SD+PM) and 6.51-6.68 (SD-PM) respectively with enhanced performance from biochar produced at higher (400∘C) pyrolysis temperature

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