International Journal of Animal Biology
Vol. 1, No. 5, 2015, pp. 158-164
http://www.aiscience.org/journal/ijab

Impact of Soil Microbial Respiration on Atmospheric Carbon Under Different Land Use in Part of Kano State, Northern Nigeria

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Abstract

This study has investigated the organic carbon content in two land use types in view of the increasing attention being paid to the sensitivity of organic carbon to global change drivers because of its importance in the global carbon cycle. The data for the study was derived from the analysis of twenty soil samples collected using composite sampling method. The samples were collected from two different land use types, forestland and cropland. Two sites of each land use type were used. Five samples were collected from each of the two land use types (Forestland and Cropland) from the two study areas that were purposively selected, Goda and Yanbawa. The samples were collected within 0 – 20 cm depth because it is the zone of maximum biological and chemical activities in soil. The organic carbon was analysed by Walkley-Black method and pH using pH meters. The result shows that the two forestland, Goda and Yanbawa recorded higher mean organic carbon of 1.09 and 0.89 C/100g soil and pH 6.8 and 6.5 respectively than their cropland site Goda and Yanbawa with 0.13 and 0.4 C/100g soil and pH 5.2 and 5.6 respectively. This shows that there is variation in soil organic carbon from forestland and cropland, this is probably attributable to the fact that forestland receives high amount of plant litters and other biomass from the forest communities thereby influencing the rate of soil respiration in that ecosystem and influencing other factors that control the amount and the rate of soil respiration such as temperature, moisture, nutrient content and level of oxygen in the soil. The percentage organic carbon in forestland is significantly different from that of cropland which indicated that forest communities have a great impact in the release of soil organic carbon to the atmosphere through soil respiration.

Keywords

Organic Carbon, Soil, Atmosphere, Soil Respiration

Received: May 25, 2015 / Accepted: June 13, 2015 / Published online: July 16, 2015

1. Introduction

Soil organic carbon is an important component of the global carbon circle since it represents twice the amount of carbon found in the atmosphere and about 75% of the total terrestrial organic carbon pool . The sensitivity of decomposition of soil organic carbon to global changes drivers is receiving increasing attention because of its importance in the global carbon circle and potential feedback to climate change (Davidson and Jansense, 2006). Carbon stored in soils represents the largest carbon pool in nearly all terrestrial biomes (Bolin *et al.*, 2001) and thus it has a huge potential for either sequestering or releasing carbon into the atmosphere. Consequently, the knowledge of the dynamics of soil carbon is essential for a better understanding of the terrestrial carbon balance.

Soil organic carbon content in soils has been of interest for several reasons. Carbon can be transferred from the soil to the atmosphere as a result of agricultural processes. These emissions have contributed approximately 55 Pg (Petagram) to anthropogenic increases in atmospheric carbon dioxide and changes in the global carbon balance (Amundson 2001;

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Post, *et al.,* 2004). Net carbon flux budgets for agriculture that incorporates a full accounting of emissions and sequestration are beginning to show that modern agricultural land can function either as a net source or a sink of carbon, and it is important to clarify these budgets further (Coder, 1996). Additionally, soil organic carbon is an important component of soil quality, and it regulates soil moisture and structure, nutrient supply rates, and microbial activity.

When organic remains in addition to microbial bodies decay in soil, a portion of the carbon stabilizes into the soil (soil carbon sequestration or humification), the remainder is released mainly as CO_2 and H_2O (mineralization). In environmental situations where the above balance shifts to humification, a progressive increase in soil carbon concentration will be produced through time. This contributes to alleviating the greenhouse effect, global warming and hence climatic change (Batjes, 1996 and Lutze *et al.*, 2000).

The magnitude of these mechanisms in different soils provides a framework for determining the rates of loss and accumulation of soil organic carbon through different agricultural practices.

1.1. Natural Sources of Atmospheric Carbon

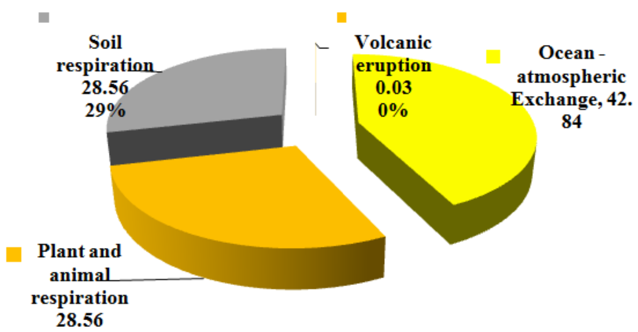

Figure 1. Sources of carbon dioxide.

Source: Adopted from IPCC, (2007)

Apart from being created by human activities, carbon is also released into the atmosphere by natural processes in form of carbon dioxide. Soil respiration and decomposition are important natural source of atmospheric carbon which account for 28.5% of the natural emission. Other sources are oceans – atmosphere exchange 42.84%, plants and animals respiration 28.56% and volcanoes 0.03%. (IPCC, 2006). Many organisms that live in the Earth's soil use respiration to produce energy. Amongst them are decomposers that break down dead organic materials which are the main concern of this research. Both of these processes release carbon dioxide as a byproduct. Annually these soil organisms create about 220 billion tonnes of carbon dioxide emissions (IPCC, 2006). Any respiration that occurs below-ground is considered soil respiration. Plant roots, bacteria, fungi and soil animals use respiration to create the energy they need to survive but this process also produces carbon dioxide.

1.2. The Role of Soils in the Kyoto Protocol

The world's soils contain approximately 1500 Petagram (Pg) (1 Pg =1Gt = 1015 g) of organic carbon (Batjes, 1996), roughly three times the amount of carbon in vegetation and twice the amount in the atmosphere (IPCC, 2001; Denman *et al.*, 2007). The annual fluxes of CO_2 from atmosphere to land (global net primary productivity, NPP) and land to atmosphere (respiration in particular) are of the order of 60 Pg C y−1 (IPCC, 2000b). The amount of carbon stored in soils globally is therefore large compared to gross and net annual fluxes of carbon to and from the terrestrial biosphere, and the pools of carbon in the atmosphere and vegetation. Because of this, increasing the size of the global soil carbon pool by even a small proportion has the potential to sequester large amounts of carbon, and thus soils have an important role to play in mitigating climate change.

Soil carbon sequestration can be achieved by increasing the net flux of carbon from the atmosphere to the terrestrial biosphere by increasing global NPP (thus increasing carbon inputs to the soil), by storing a larger proportion of the carbon from NPP in the longer term carbon pools in the soil, by adding additional carbon-containing materials to the soil (such as manures or cereal straw) or by slowing decomposition. For soil carbon sinks, the best options are therefore to increase carbon stocks in soils that have been depleted in carbon, i.e. agricultural soils and degraded soils (Lal, 2004; Smith, 2004a), since the capacity for increasing carbon storage is greatest in these soils. It is also important to minimize further losses of soil carbon stocks by more judicious land management, for example avoiding land degradation and the drainage of peatlands (Bellamy *et al.*, 2005).

The Kyoto Protocol lists the Quantified Emission Limitation or Reduction Commitments for 39 of the parties that ratified the United Nations Framework Convention. on Climate Change (UNFCCC). The Kyoto Protocol allows carbon emissions to be offset by demonstrable removal of carbon from the atmosphere. Thus, land-use/land-management change and forestry activities that are shown to reduce atmospheric carbon dioxide levels can be included in the Kyoto emission reduction targets. These activities include afforestation and reforestation and may include the improved management of agricultural soils, grazing, land management, forest management and revegetation (IPCC, 2007).

On the other hand, additional carbon emissions caused by land-use change (e.g. due to deforestation) have also to be accounted for. These carbon emissions as well as the offset by carbon sequestration have to be reported as part of national greenhouse gas inventories. The respective guidelines (IPCC, 2006) define precise rules for preparing annual greenhouse gas inventories in the Agriculture, Forestry and Other Land Use sectors (AFOLU).

1.3. Soil Carbon Relations: A Basic Concept

In terrestrial ecosystems the source of soil organic carbon input is from photosynthesis or net primary productivity. Assimilates can be transferred directly to the roots via the phloem or can be converted to biomass that might be transferred to the soil via litter. The 'assimilate-fed' and the 'litter-fed' pathways have also been named 'autotrophic' and 'heterotrophic' components of soil respiration in many studies. For many concepts and methods related to soil carbon dynamics it is a prerequisite to distinguish between these components of soil respiration because they depend on very different mechanisms determining their response to environmental conditions. The autotrophic component can be further separated into respiration of the roots *sensu stricto* and their mycorrhizal symbionts and the microbiota of the rhizosphere, which depend directly or indirectly on carbohydrate sources from roots or mycorrhiza.

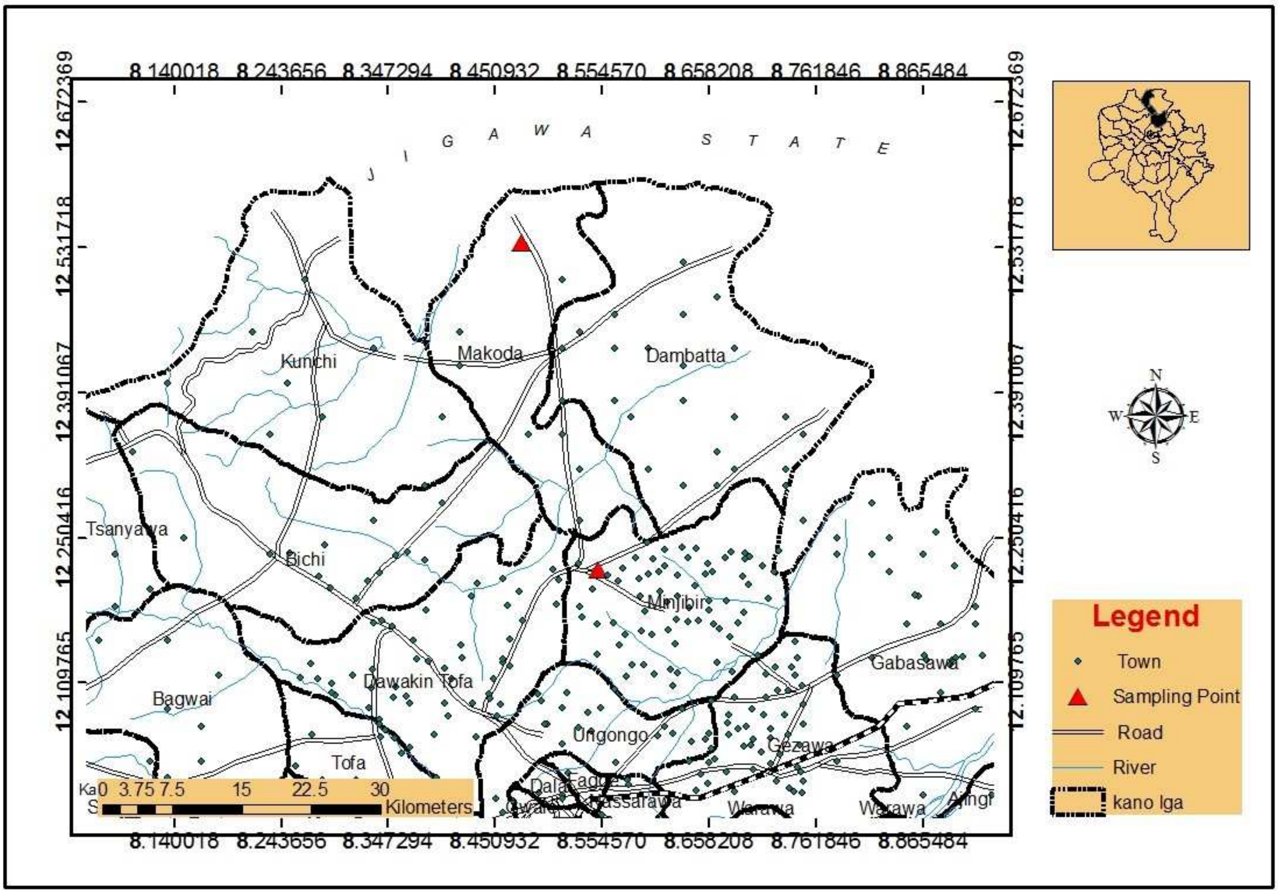

Figure 2. Study Area.

Source: Cartography Lab, Geo. Dept., BUK

In many conceptual (i.e. modelling) approaches three pools of organic matter are distinguished. The easily decomposable active soil organic matter and the more stable slow and passive humic substances, also often called the recalcitrant pool. These pools receive fresh organic matter via litter input but also from microbial turnover and other events such as fire (Werner, *et al.,* 2009, Ekschmitt *et al.*, 2008 and Krull *et al.*, 2003). Litter and the resulting humic substances are decomposed mainly by the bulk soil micro-organisms that comprise bacteria, fungi and the soil meso- and macro-fauna, resulting in respiration and subsequent soil CO_2 efflux and changes in the chemical composition of soil organic matter. This biological activity is the driving force for the conversion of litter into stable humus and is also related to bioturbation (e.g. earthworm activity). This research is based on the litter-fed pathway (heterotrophic) rather than 'assimilate fed' autotrophic.

2. Material and Method

2.1. The Study Area

Two forestland sites and two croplands (adjacent to each of the forestland) were purposively selected based on the assumption that all the factors influencing soil organic carbon such as temperature are all most homogeneous. Goda forestland and cropland is located along Minjibir road about three kilometers away from Kunya town while the Yanbawa forestland and cropland are located along Dambatta-Kazaure road and situated in Makoda Local Government Area of Kano state (figure 2).

The climate of the region is the tropical wet and dry type coded as Aw by W. Koppen and influenced by the movement of two air masses, the maritime air mass originating from Atlantic Ocean and the dry desiccating tropical continental air mass emanating from the Sahara desert. These air masses meet at the zone called Inter Tropical Convergence Zone and it is the seasonal movement of this front that determines the climate of the area.

2.2. Methodology

A composite sampling technique is used in which various samples were collected from different point, mixed vigorously and then a sub-sample is taken from the bulk sample. The samples were collected from 0 – 20 cm depth because it is a zone where chemical and biological activities are dominant in the soil. Five samples were collected from the four study points, (Goda forestland, Goda cropland, Yanbawa forestland and Yanbawa cropland) making twenty samples for the whole analysis.

The samples were taken to the laboratory for analysis where soil organic carbon was determined using Walkley Black method and soil pH was determined using pH meter. pH is analyzed because pH is regarded as master variable that affects all physical, chemical and biological property of the soil. The organic carbon was calculated using the formulae (Brady, 1999)

$$\%OC = \frac{Blank\ value - Titre\ value\ x\ 0.3xMxF}{Weight\ of\ dry\ soil(g)}$$

Where: M – Concentration of $FeSO_4$ (0.5N), F – Correction factor (1.33)

The percentage organic carbon was converted to carbon per hundred gram of soil (C/100g of soil) as recommended by Micheal and Beverly, 2005.

The values of organic carbon were subjected to geostatistical analyses; using variables such as mean for the analysis of mean, mean pH, standard deviation and variance. Analysis of variance and logarithmatic correlation were also used to assess the difference in organic carbon and the relationship between organic carbon and organic matter under different land uses respectively.

2.3. Hypothesis Formulation

The hypotheses to guide the investigation are

i. There is no significant difference in the mean values of organic carbon under different land uses.

ii. There is no significant relationship between the mean value of organic carbon and organic matter under the different land uses.

To test the hypothesis, the Analysis of variance t and Logarithmatic correlation were used and at 0.05 (5%) level of significant different.

The aim of this paper is to assess the impact of soil respiration on the atmospheric carbon in different land use types and the specific objectives are to assess the level of soil carbon generated from forestland and cropland site, assess the impact of land use type on the quantity of soil organic carbon, examine the relationship between soil organic carbon and soil organic matter under different land use types of the area and make recommendations, based on the outcome of the analysis.

2.4. Justification and Scope of the Study

The sensitivity of the decomposition of soil organic carbon to global change drivers is receiving increasing attention because of its importance in global carbon cycle and potential feedback to climate change (Davison and Janssen, 2006). However, soil respiration is an important component of soil quality, soil moisture and structure, nutrient supply rate and microbial activities.

Several studies on soil respiration have been carried out such as Davidson, *et al.,* 2006, Smith, *et al.*, 2005a, Miller*, et al.,* 2004 and Amundson, 2001. However, most of these studies were carried out outsite Sudano Sahelion region, even then, the studies are limited in scope as they focus on only one land use type. It is very pertinent to conduct an empirical investigation for different land uses in this area and on a continuous basis.

2.5. Scope of the Study

Soil respiration refers to the production of when soil organisms respire. This includes

a. Autotrophic soil respiration (R_A) which is the respiration activity of root, mycorrhizal and associated rhizosphere. This represents the respiration of carbon recently accumulated by plant.

b. Heterotrophic soil respiration (R_H) is the soil organic matter decomposition by soil microbes and the release of carbon that may have residence times in the soil reaching millennia (Trumbore, 2000).

This research focuses only on heterotrophic respiration because it is directly related to soil microbes that decompose plant and animal residues in the area.

However, various ways are used to determine organic carbon release in respiration process such as Walkley – Black method (Brady, 1999), Lundegardh's respiration bell method and elemental analyser (Jukka, *et al.,* 2009). This work adopted the Walkley-Black method because of the accessibility and availability of the resources at the time of this work.

3. Result and Discussion

Table 1 Illustrates geostatistical parameters of soil properties investigated in this study by land use type and by location.

Table 1. Geoststistical parameters of soil properties under investigation.

STUDY SITES	C/100G SOIL	SD	VARIANCE	MEAN OM	PH(MEAN)	BULK DENSITY
GF	1.09	0.77	0.06	1.08	6.8	0.76
GC	0.13	0.13	0.01	0.01	5.2	0.88
YF	0.8	0.12	0.01	0.01	6.6	0.67
YC	0.42	0.19	0.03	0.03	5.4	0.99
SOURCE: LABORATORY, 2014						

Note: GF Goda forestland, GC Goda cropland, YF Yanbawa forestland and YC yanbawa cropland.

The mean carbon per hundred gram of soil (C/100g soil) of four study sites under the two different land use shows that the two forest land sites (Goda and Yanbawa) have higher mean carbon per hundred gram of soil (C/100g soil) than their counter part cropland (Table 1). The distribution of soil organic carbon (Figure 2) shows that Goda forestland recorded highest mean values of 1.09C/100g soil followed by Yanbawa Foresland (0.80C100gsoil) while the two cropland sites Goda and Yanbawa recorded lowest mean carbon per hundred gram of soil (C/100g soil) 0.13 and 0.42 respectively (Figure 2).

The variation of mean carbon per hundred gram of soil (C/100g soil) under different land use is probably attributed to the fact that all the factors that enhance soil respiration such as organic matter, plant litters, nutrient supply and soil moisture were highly favored in the forestland than the cropland, due to vegetation cover.

The low mean carbon per hundred gram of soil (C/100g soil) in cropland is attributed to the fact that inadequate plant cover on cropland can expose the soil to various forms of erosion, and inadequate plant litters as well as the removal of annual crops biomass through harvest and removal of crops residue for animal fodder and other domestic uses. This is adduced by Smith, *et al.*, (2003) and Tiessen and Stewart, (1983), that there are several mechanisms of agricultural reduction of soil organic carbon due to alteration of carbon inputs to and output from soil such as removal of crops biomass, tillage and erosion. This is further contended by Brady, 1999 that the pH and organic matter content and composition influence soil respiratory activities of numerous species of soil organisms and thereby increase organic carbon release through soil respiration. This probably accounts for the higher value of mean organic carbon in forestland which has higher pH and soil organic matter content (Table 1).

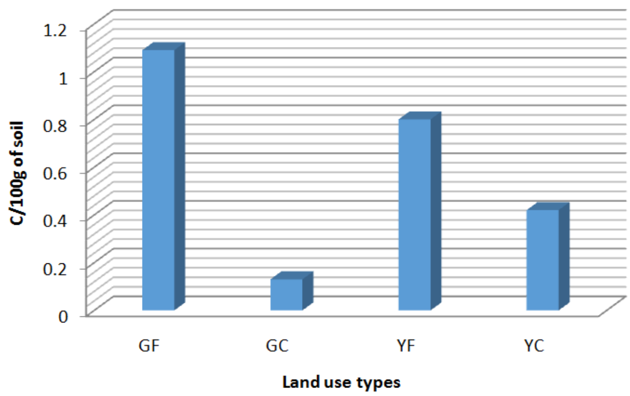

Figure 3. Mean percentage of organic carbon under different landuse.

Based on the analysis of variance, there is significant difference in the mean value of organic carbon between forestland and cropland at *p= 0.05* level of significant difference however, this shows that forestland releases more carbon to atmosphere than cropland. This is adduced by USEPA (2012) that forestland serves as carbon sink because atmospheric carbon dioxide is reduced by plants through photosynthesis. However, on other hand, forestland also serves as a source of carbon to atmosphere due to the presence of plant litters which enhance soil pH and organic matter and therefore influence soil structure, water holding capacity, which enhances the activities of soil organisms resulting in increases in the rate of soil respiration which would lead to the release of organic carbon.

The analysis also shows that land use type have significant impact on soil respiration because the amount of soil respiration that occurs in an ecosystem is controlled by several factors such as temperature, moisture, nutrient content, soil erosion tillage, pH and level of oxygen in the soil, all these factors were active in forestland use than cropland.

The logarithmatic correlation Figure 4, shows that there is a strong relationship between percentage organic matter and soil respiration in the study area. This indicates that organic matter is strongly related to organic carbon to about 84% as shown in Figure 4 where R^2 = 0.841. The hypothesis in this case was rejected at 0.05 level of significant which shows that there is positive correlation between organic carbon and soil organic matter in the study area and therefore organic carbon is dependent on organic matter. Thus, land use have great impact on the activity of soil microbes thereby influencing the rate and amount of soil respiration and therefore the amount of organic carbon released to the atmosphere.

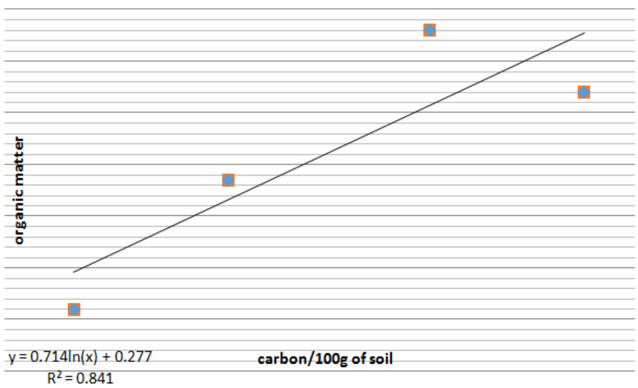

Figure 4. Logarithmatic correlation between %organic carbon and organic matter.

4. Conclusion

Soil respiration is strongly linked to plant metabolism and recent production of plant litters. This conclusion indicates that forestlands have positive and negative impact on the release of organic carbon to the atmosphere because on one hand they help to sink the atmospheric carbon through green plant photosynthesis while on the other hand they produce carbon to the atmosphere through soil microbial respiration. However, the balance situation suggests that plants serve more as carbon sinks than as carbon releasers.

Recommendation

It is recommend that cutting down of trees should be reduced because they serve as carbon sink and when cut down, the soil may be disturbed (like erosion and poor structural stability) and increase the rate of soil respiration through adding more litters from their remnant both create more carbon dioxide emission to the atmosphere.

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