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Removal and Emission of Carbon Dioxide from Wetlands Soil UnderFluctuating Hydrology: a Case Study from Sudan, Africa

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Abstract

The role of hydrology in carbon sequestration in wetlands soil is unmistaken, wetlands are keenly tuned to the hydrology of their climate, their watersheds, and, in some cases, their coastlines. In this study a forested riverine wetlands (Bankieu wetlands), was examined. In summer season, 15 soil samples were taken from 3 profiles. In the winter season, where the wetland suppose to endure flooding and it does not, 3 profiles were made to compare the carbon stock with the summer season in. Carbon concentration in the soil samples collected was determined by Walkly- black method. The carbon turnover times to determine the residence time of carbon in the soil were measured by the Accelerator Mass Spectrometry (AMS) i.e. C14 dating. The data was statistically analyzed using SAS package and the means were separated using Student T-test. In the first season, carbon concentrations in the wetland was 62. gC/cm2 in. In the second season the carbon concentrations was 43.8 gC/cm2. The results were significantly different ($p<0.05$) in both seasons. The turnover time was -634.57 years, indicating, with the reduction in carbon concentration, that Bankieu is emitting carbon. This means that in the second season Bankieu wetland acted as a source of carbon due to unsuccessful flooding. This study revealed that the hydrology is an important controlling factor as well as the temperature and its pattern has been affected by the climate change.

I. Introduction

One of the most intense changes in the global system resulting from human activity is the rising greenhouse gases. The increase in greenhouse gases is recognized to be the basis of the current and future climate change.The organic carbon stocks of wetland soilare determined by the climate, hydrology, topography, age, vegetation,type of wetland soil and land utilization condition,thus, itis important to establish the relationships between the geographicaldistribution of soil carbon and climate, hydrology,human development and other factors as a basis for assessingthe influence of changes in any of these factors on thewetland carbon cycle,[4].

When climate changes, wetlands are among the first ecosystems to undergo the impact. If rainfall does not come in time, if droughtspersists by watershed changes, or if water tables drop, wetlands will dry out and sequestered carbon is sent back to the atmosphere by oxidation—either biological processes or sudden fires, [9].Photosynthesis, decomposition, and respiration rates are determined comparatively by climatic factors, most importantly soil temperature and moisture levels. For example, in the cold wet climates of the northern latitudes, rates of photosynthesis exceed decomposition resulting in high levels of SOC. Arid regions have low levels of SOC mostly due to low primary production, while the tropics often have intermediate SOC levels due to high rates of both primary productivity and decomposition from warm temperatures and abundant rainfall,[7].The main goal of this study is to highlight the role the hydrology plays in organic carbon sequestration and emission process.

Climate change could affect tropical wetlands in fourdistinctive ways: changes of hydrologic pulses fromupstream; changes in local precipitation patterns;changes in temperature/humidity and subsequentevapotranspiration patterns; and sea level and coastalstorm influences for coastal wetlands, [9].

II. Method

A- Study Area

The Blue Nile coming from the Ethiopian Highlands contribute between 80 and 90 per cent of the Nile's flow, but is highly seasonal and carry high sediment loads.Bankieuwetland, (called locally Mayaa)is a forested wetland falls within Bankieu Forest on the Blue Nile, the main plant community is *Acacia Nilotica* trees, it occupys an area of 580.7085 acre, (244 hectare), the mayaa is located between N: 14.50141 E: 33.46840, N: 14.50042 E: 33.47301, N: 14.50936 E: 33.47057, N: 14.50713 E: 33.47392 (Figure 1).

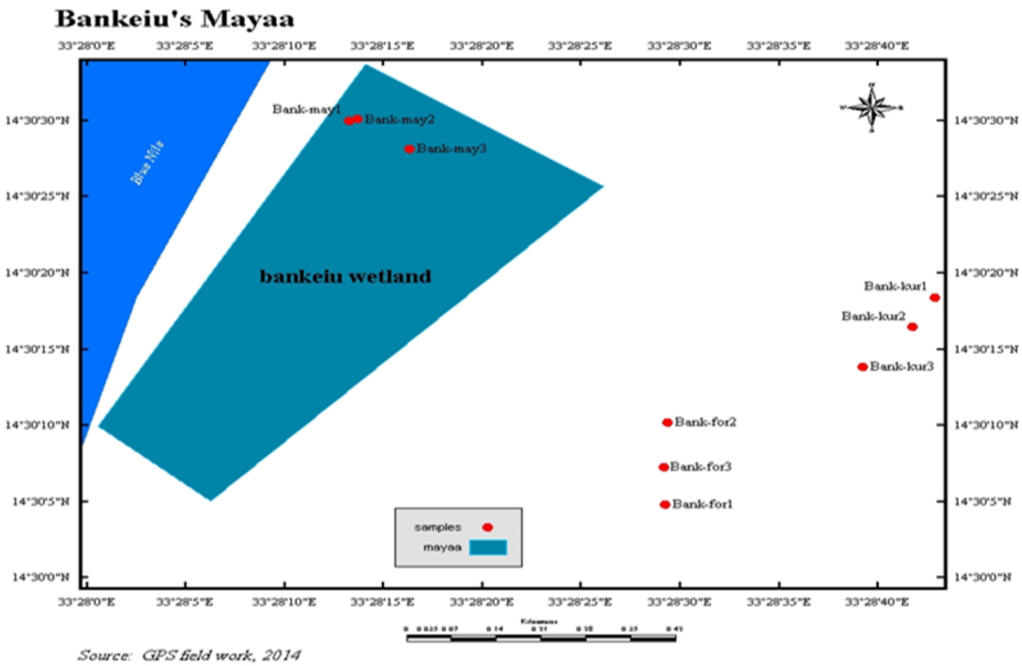

Figure (1)

The management practice in the Mayaa include thinning periodically and felling every 15-16 years, and grazing of goats is all year around. The average rainfall in the rainy season is 600 mm-1000mm. and the average temperature during 2013 summer extending from May to July was 41.4°C, the average relative humidity was 26.7% Bankieu. The NNW wind speed was 4.75 Knots.

The Mayaa was flooded in the first season.In the second season, the Mayaa should go through flooding and endure winter time, as such the stock is expected to increase, but the flooding in Bankieu was not successful and the rain was very low that the Mayaa was dry over the wet season (from July through September).

The soil type in Sunut and Bankieu is Entisols. The soil have recently being formed and they also occur along the water ways, seasonal streams and rivers and along the River Nile on its flood plains, (Adam, 2012).

B- Sampling strategy and analysis

In Bankieu Wetlands; samples for the hot dry season were taken on 16th May 2014. The average temperature was 32.5ºC, the relative humidity 19% , and the north north west wind speed was 12 knots. Thelocations of Maya profiles were at: N: 14.50834 E: 33.47036, N: 14.50836 E: 33.47078, N: 14.50782 E: 33.47121.

In the winter season soilsamples were taken on 19th of March. Thetemperature was 31ºC,samples were analyzed according to Walkly-black Method.

Sampling for Turnover

Samples for measuring the carbon turnover in the soil were taken in season two on 19th of March. Samples were taken from 30 cm depth. Analysis was made using Accelerator Mass Spectrometry (AMS) as described lately.

Sampling Strategy: Soil samples were extracted, taken from profiles up to 150 cm depth at an interval of 30 cm i.e. 5 samples from each profile in the two seasons.

Samples' Analysis

2.2.1- Carbon Concentration

It is the gm carbon/100 gm soil, measured using the Walkly-black Method.

2.2.2- Bulk Density:

The bulk density of a soil sample of known volume is the mass (or weight) of that sample divided by the bulk volume.

C- Turnover Time

The following equation of the analytical solution is used to calculate the turnover:

$$\tau = (A_{abs} - A)/A\lambda$$

where :

τ : the turnover time

A_{abs} : the activity of the input at steady state level of pre-bomb atmospheric activity equals 226 Bq/Kg C.

A : the specific activity of the sample equals to A_{SN} corrected with $\delta^{13}C$.

λ : the decay rate constant of ^{14}C equals (1/8267) yr^{-1}

Description of Analytical Processes Used in Testing the Samples

Pretreatments

After macroscopic contaminants and granules were removed using tweezers, the sample was ground and treated as bulk. The sample was soaked in HCl (1M) in order to eliminate carbonates, then, neutralized with ultra pure water, and dried. It is described as "HCl" in the table. The sample was oxidized by heating to produce CO2 gas. The produced CO2 gas was purified in a vacuum line. The purified CO2 gas sample was reduced to graphite by hydrogen using iron as a catalyst. The produced graphite was pressed into a target holder with a hole of 1 mm diameter for the AMS 14C dating, using a hand-press machine.

Measurement

The graphite sample was measured against a standard of Oxalic acid (HOxII) provided by the National Institute of Standards and Technology (USA), using a 14C-AMS (accelerator mass spectrometry) system based on the tandem accelerator. A blank for the background check was also measured.

Calculation of Age

The Libby half-life of 5568 years was used for the calculation of 14C age (Stuiver and Polach 1977). 14C age (conventional ^{14}C age: yrBP) refers to an age going back from the year 1950 (= 0 yrBP), assuming a constant ^{14}C concentration in the past atmosphere. The value was corrected for its isotopic fractionation using the δ13C value. ^{14}C age and error are rounded off to tens place. The error range is expressed by one σ, meaning that the ^{14}C age lies within $\pm 1\sigma$ range in probability of 68.2%. The $\delta^{13}C$ value refers to a difference of the ^{13}C concentration ($^{13}C/^{12}C$) of a sample from that of a standard. The value is expressed by ‰ for the difference from the standard value. The ratios are measured using an accelerator mass spectrometer, and it is noted as (AMS) in the table. pMC (percent Modern Carbon) refers to a ratio of the ^{14}C concentration in the sample relative to that of the year 1950. Calibrated calendar age is a range of age corresponding to ^{14}C age via a calibration curve, which was produced from the ^{14}C concentration of samples of known age. It is expressed by one σ error range (68.2% probability) or two σ error range (95.4% probability). The ^{14}C age without rounding off was used for calibration. Calibration curve and calibration program can be updated by the database revision, and therefore, the calibrated age may vary depending on the program used. The calibration in this report was conducted by OxCal v.4.2 (Bronk Ramsey 2009) based on IntCal13 database (Reimer et al. 2013).

D- Statistical Analysis

The data was analyzed using SAS and the means were separated using Student T-test and analysis of variance (ANOVA).

III. Results

A- carbon concentration and bulk density

Organic carbon density is greater at the upper layer and diminishes down ward with the greater density (62.48 g C/cm2) at the top to (26.616 g C/cm2) at the bottom.In general the OC concentration range from 0.58 to 1.31% in the first season to 0.55 to 1.011% in the second season and it varies through all the profiles in the locations examined with the mean equals to 0.5067%.The difference in OC concentration and density is insignificant ($p > 0.05\%$), table (1). In the second season a drop in density occurred in, so the stock changeby dropping by (-6765.73 t/h).

Table (1): Carbon Concentration and Bulk Density

In Bankieu Wetland (1st and 2ndseaons)

First season				Second Season		
Average depth (cm)	Carbon content (C%)	Bulk density (g/cm^3)	Carbon density g C/cm^2 at 30 cm depth	Carbon content C%	Bulk density (g/cm^3)	Carbon density g C/cm^2 at 30 cm depth
0-30	1.31	1.59	62.48	1.011	1.443	43.766
30-60	0.91	1.57		0.913	1.490	
60-90	0.85	1.5		0.781	1.513	
90-120	0.74	1.43		0.368	1.587	
120-150	0.58	1.48		0.552	1.513	

B- Turnover Time

Calculating turnover time which is called also the Mean Residence Time, (MRT) is not straight forward, some parameters were measured using Accelerator Mass Spectrometry, (AMS), i.e. $\Delta^{14}C$, and from them MRT was calculated. In this study the following equation was used to calculate A_{SN} to be used in the analytical solution:

$\Delta^{14}C=(A_{SN}/A_{abs}-1)X1000‰$ [2] With $\delta^{13}C$ correction.

Where:

$\Delta^{14}C$: is the ^{14}C isotopic ratio, ($^{14}C/^{12}C$), of a material relative to the modern standard after correction for fractionation to $d^{13}C$ = -25 o/oo. $\Delta^{14}C$ is only reported if a date of collection or other date to apply the decay correction to is provided, since otherwise it is a meaningless value.

A_{SN}: Measured $^{14}C/^{12}C$ value of the sample, which was corrected with $\delta^{13}C$.

A_{abs}: the activity of the input at steady state level of pre-bomb atmospheric activity equals 226 Bq/Kg C.

Assuming that A in our original equation is equals to A_{SN}, from it the turnover time was calculated using the analytical solution equation mentioned in the methodology.

The measurements were done for bulk soil due to the difficulty and unavailability of accurate method to separate organic carbon from organic matters. The century to millennial time scale results of the mean resident time showed the organic carbon found in the 0-30 cm layer of the three wetlands is passive carbon and not labile carbon as expected, i.e. it cycles with the atmosphere in centuries to millennial years, (Table 2). The turnover time found to be (-634.57 yrs) at Bankieu, the age is Modern. See discussion for explanation.

Table (2): Turnover Time, $\Delta^{14}C$ (‰), turnover rate and Age of the Wetland

Parameter	Bankieu Wetland
Turnover time (year)	-634.57
$\Delta^{14}C$ (‰)	83.16+/-2.92
Turnover rate (atom/yrs)	10.66
Age (yrs BP)	Modern

IV. Discussion

Bankieu forested riverine wetland is fed by river water, and thus the change in its hydrology will depend on how climate change alters the river flow. In the second season Bankieu had no flooding water due to the failure of the rainy season in the catchment of the Blue Nile which feed the river therefore there was no inundation which reduce the carbon stock greatly by the dry conditions lead to oxidized the organic carbon.High rates of primary production are an important contributing factor to carbon sequestration in wetland soils. The typical wetland soil is anoxic (i.e., contains no O_2) except for thin layers at the soil surface and in close proximity to plant roots. These anaerobic soils affect root metabolism, cell growth, and nutrient acquisition. Fluctuating hydrology (e.g., seasonal wet vs. dry periods) can cause temporal changes in water availability, soil O_2 concentrations, and nutrient availability, although these stresses, in tidal wetlands, and other systems, primary productivity is maximized under a pulsed flow regime, pulsing also allows for periods of soil drying, increasing subsurface O_2 concentrations and leading to higher nutrient availability. These factors increase plant productivity, [8]. This proves that the hydrology is one of the important factors that affect the OC accumulation and the anaerobic conditions really enhance the accumulation and hinder the decomposition of the organic materials, so Bankieu acted as a source by emitting C in large quantity amounts to (6765.73 t/h). This finding is in line with the finding of [1], who stated “the presence of continuous anaerobic conditions is more powerful in enhancing carbon storage in wetland soils than the presence of greater organic inputs into the soil”.

Soil carbon stocks vary with soil drainage class, with the largest C stocks occurring in poorly drained sites. It is quite clear now that more of the carbon stored in wetlands will be released if wetlands continue to be drained. Upon drainage, fungi and bacteria which thrive in the newly aerated conditions will oxidize much of the carbon stored previously, and return it to the atmosphere, [6].

In Bankieu wetland the positive value of $\Delta^{14}C$ supported by the Modern age of this wetland mean that it is still been cycling with the atmosphere for decades only. Accordingly the negative sign of the turnover times of Bankieu would mean it is still accumulating carbon and sequestering, and the emission of carbon only in the 2nd season due to unsuccessful flooding, and needs 634.57 year to fill the soil with carbon if it continues to act as a sink and no emission episodes is encountered. Here comes the importance of the hydrology which is linked directly to the climate change and here appears where exactly the climate change will affect the carbon content of these wetlands.

Using this Δ notation, positive values indicate incorporation of recent atmospheric CO_2 enriched in ^{14}C produced by nuclear weapons testing, and a high positive value of $\Delta^{14}C$ indicates decadal-scale- cycling versus a very negative value indicating millennial-scale cycling [3]. This is very applied to Bankieu wetland. Although the depression in the stock in the 2nd season but its Δ notation, (positive value), indicates it is recently deposited carbon.

When the turnover rate is calculated i.e. the number of carbon atoms leaving the reservoir per year, Bankieu ranked at higher rate (10.66/yr). The age is one of the factors that determine whether the wetland is a source or sink as elaborated in the introduction, [5].The Modern, young, wetland soil cycles actively with the atmosphere and has the tendency to sequester more carbon.

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