EVALUATION OF SOIL ORGANIC CARBON AND NITROGEN FOR EFFECTIVE FOREST MANAGEMENT SYSTEMS

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ABSTRACT

Forest soils and the nutrients are determined by spatial activities such as agricultural systems, forest resources management and plant exploitation. SOC and N concentration were evaluated in different forest management sites at a regional scale in relation to forest site history and management regimes. This evaluation study presents SOC, SOM, N, P, K balances in different plant stand and forest history along a regional scale of tropical – subtropical climatic gradient along South China. Forest soils were collected from five different and distinct locations of regional forest and agricultural soils under 0-25 and 25-50cm profiles. Nutrient studied were Soil Organic Carbon (SOC), Soil Organic Matter (SOM), Nitrogen (N), Phosphorous (P), Potassium (K) as well as Available nutrients and TotN and TotP. Associated chemical factors including Available nutrients (AvN, AvK and AvP) and Total Nutrients (TotN and TotP) as well as SOC densities were measured in the laboratory. Soil Organic carbon evaluation showed a unique trend where Deqing (Nature reserve) - Pine and evergreen broadleaved mixed forest soil), Changtan (National nature reserve) - Secondary forest, protected and less disturbance) and Nanling forest soil (National Nature Reserves) - Secondary forest and protected) at 0-25cm depth recorded 30.00g.kg, 27.00g.kg and 27.00g.kg respectively. In the same vein, at 25-50cm depth Deqing was highest at 27.0g.kg, Nanling was 20.00g.kg and Changtan soil recorded 15.00g.kg. Available nutrients evaluated showed that Available Potassium in all forest soil recorded very high, Available Nitrogen recorded highest in Changtan (National nature reserve) - Secondary forest, protected and less disturbance) and Deqing (Nature reserve) - Pine and evergreen broadleaved mixed forest soil) respectively while Available Phosphorous consistently comparatively recorded very low in all the forest soils. The soil carbon store dominates the carbon budget at all sites and in particular at the site with a cold and wet climate where soil C constitutes 95% of the total carbon in the ecosystem. Vegetation diversity management and plant species is attributed to high SOM. This study thereby supports that soil stores and dominate the overall budget of carbon fluxes while consolidating that the changes in climate and natural forest/soil ecosystem influences C and N in soils whereby good management and less disturbance of natural ecosystems should be encouraged

Keywords: SOC, Agricultural systems, SOC, Nitrogen, regional forest management history and plant stand types.

INTRODUCTION

As climate change becomes a critical issue, the potential feedback from terrestrial ecosystems to the atmosphere through changes in carbon stocks, carbon sequestration, and general knowledge on biogeochemical cycles as well as forest soil nutrients for agricultural productivity becomes increasingly important. Biogeochemical cycles in different forest cropland ecosystems and management history as well as plant stand types have gained little attention relative to agricultural quality and forest management whereby such evaluations are required for developing and testing ecosystem models. Climate change challenges have been considered a critical issue to agricultural systems, potential feedback on forest soil nutrients and terrestrial ecosystems. This evaluation is considered very important in the general knowledge of forest soil nutrients as well as changes in carbon stocks, carbon sequestration, and agricultural productivity. This paper dealt with the evaluation of soil chemical properties (Total nitrogen, available nitrogen, available potassium, electrical conductivity, total phosphorous, cation exchange and soil organic carbon. Soil organic matter is a major attribute of soil quality (Christensen and Johnston, 1997; Carter, 2002) because it influences nutrient cycling, soil structure, water availability, and other important soil properties. Soil is the most basic of all natural resources, and its quality affects both agricultural productivity and environmental quality (Doran Prolifand Parkin, 1994; Lal, 1998). Soil quality brings about greater yield and withstands adverse climate influences. Soil C and N pools tends to produce competitive yield and a determinant of good forest soil environment. Increasing soil C is one of the basic constituent of soil organic matter and plays an important role in the sustainable use of soil resources. Also the management of organic N is very important whereby mineralization is the primary source of N in most production systems (Paul and Clark, 1996). In this investigation, we evaluated the soil chemical properties with strategic assessment of soil N and C in different forest management on a regional scale, different regimes and vegetation (forest) stand. Plant diversity and management are related to forest management history which was a considerable factor in the soil sample evaluation. Vegetation and plant biological diversity flourishes as a result of enhanced C and N properties which support crop yield and food productivity. Furthermore, diverse crop rotation and organic inputs such as fertilizers and sustainable forest/plant management enhances the concentration of soil organic C and N. This study evaluated how specific forest soil and plant stand types with organic inputs from forest management systems can enhance and manipulate soil C and N pools as well as associated chemical variables to produce greater plant yield and better plant ecological performance. This evaluation study presents SOC, SOM, N, P, K balances in different plant stand and forest history along a regional scale of tropical – subtropical climatic gradient along South China. This paper seeks to identify and evaluate the mechanisms underlying forest (history) soil chemical nutrient regional patterns and plant stand types that portrays evaluation of Total Nutrients across the forest soils recorded very high in all soils while Total Phosphorous comparatively recorded very low in all the soils in all the depths. In the same vein, SOC density evaluations across the forest soil recorded higher in Deqing soil (Nature reserve) - Pine and evergreen broadleaved mixed forest soil) (1.0 t/hm^2) and Nanling (National Nature Reserves) - Secondary forest and protected 0.8 t/hm^2 respectively. This evaluation may seek to explain the variety of mechanisms that drive Soil Organic Carbon (SOC), Soil Organic Matter (SOM), Nitrogen (N), Phosphorous (P), Potassium (K) as well as Available nutrients and TotN and TotP. However, nutrient limitation may be inferred by indirect measurements, of which the most common include: 1) nutrient availability in soil (Powers 1980); 2) plant investments in acquiring particular nutrients (Harrison and Helliwell 1974); and 3) tissue concentrations or ratios of elements (van den Driessche 1974, Koerselman and Meuleman 1996). The aim of the study was to provide a basis for assessing the range and variability of forest soil nutrients of C and N under different forest management history as well as plant stand types.

METHODOLOGY

This study was conducted in Guangdong province regional forest soils while the field laboratory analysis was conducted at the Forest Ecology laboratory of the South China

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Agricultural University Guangzhou, China. Forest soil agronomic management design was based on reduced primary tillage system and strict forest and soil encroachment regulation that were in place over the period of this study.

Vegetation forest management history

Table 1 Summary of the vegetation management history of the selected forest sites

Changtan National Nature Reserve - Large expanse of igneous rocks and other rocky status, generally classified as vegetable garden soil,	Orchard and paddy vegetation.
Deqing Sanchading Nature Reserve –	Nature reserve for forest ecosystems and wild life nature reserve, 1.100 kinds of plant under state protection, Sub – tropical evergreen broad leaved forest and mixed conifers.
Dongguan Dalingshan Forest Park –	A history of dense forest areas, monsoon evergreen broad-leaved vegetation with frequent interference as a result of population and industrial growth to destruction of original forest. Current vegetation status is mostly artificial pine, eucalyptus and bamboos.
Guangzhou Changguangshan Nature Reserve –	A protected University arboretum with forest stands of schima superba, eucalyptus plantation, pinus elliottii engelm, cyclobalanopsis glauce and other mixed forest.
Nanling National Nature Reserves –	Tropical evergreen broad – leaved forest, rare and endangered wild animals, preserved large area of forests and natural evergreen broad – leaved forest.

Sampling and Laboratory Procedures
Soil sample collections

Each forest plot site was marked out of 20 x 20 m and consisted of ten 5 x 5 m (0.025) quadrants, five of which were randomly selected for sampling. Surface (mineral) soil level was categorized under soil below O horizon and deep soil were adopted for sampling at designated at two level depth of 0 – 25 cm (surface level) and 25 – 50 cm (deep level) using a standard 2-cm diameter stainless steel sampling probe were collected at each site in 2009. A total of 10 cores were composite for each quadrant. Two 5 x 5 cm cores (strata) designated for surface and inner depth were taken per plot (forest site) sample to determine bulk density. Soil samples at both depth samples were separately finely mixed, air dried, grounded and sieved as recommended by Nelson and Sommers (1996). Organic matter concentration of each site was determined by loss on ignition (450° for 4 h). We considered the entire organic soil at surface layer and deep layer as sampled, using a 15 x 15 (225 cm^2) template for each quadrant and collected for laboratory chemical analysis.

Laboratory sample preparations

The collected soil samples were finely mixed up, bagged in a transparent bag, labelled and transported to the laboratory for analyses. The samples were air-dried over 48 hours, crushed with pestle and mortar and sieved to separate whole soil (< 2mm). Ground floor soil aggregates, plant/biomass materials (tree) components (live vegetation/roots) and stones were sieved out and separated removed. Soil bulk density (P_b) was determined by the core method (Blake and Hartge, 1986). The soil pH was measured for a 1:1 solution of whole soil sample in deionized water (USDA Natural Resources Conservation Services, 1996). Soil organic carbon was estimated by multiplying organic matter content by 0.58 (Soil Survey Staff, 1992). Organic Carbon densities (0-50 cm depth) were calculated by multiplying concentration (mg C g^{-1} soil) by the area density (g soil cm-2; Garten *et al.*, 1999). The area density of the soil was calculated as the product of the bulk density (g soil cm-3) and the depth of the sample (50 cm). We considered mineral soil organic C amounts by derivation of O layer + surface, which formed 0- 25 cm).

Forest Soil C and N Pools

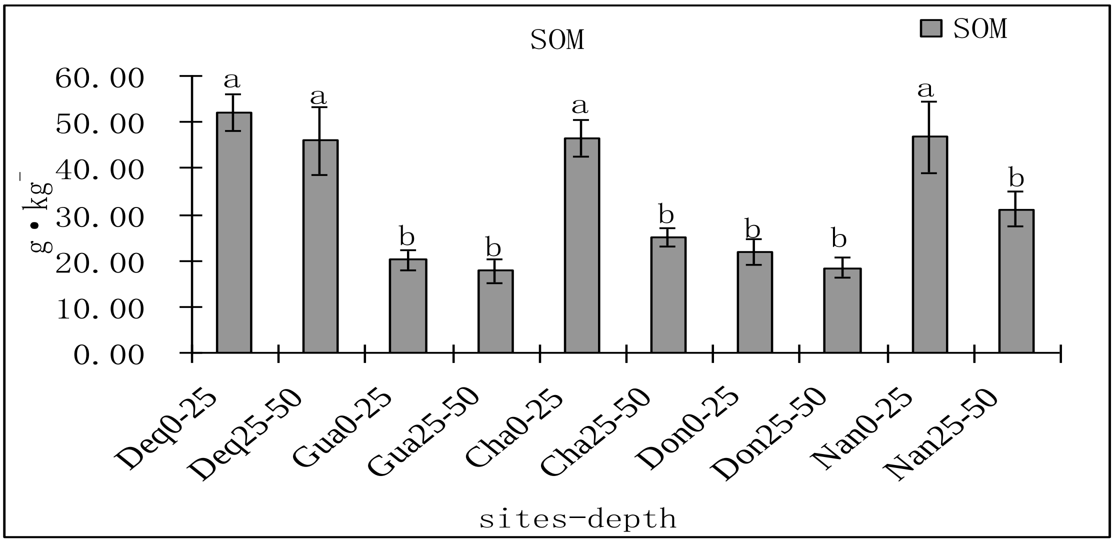
Soil C and N content was measured by collecting three soil cores from each study plot once. The soil cores were divided into the top organic soil layer (main rooting depth) and the top mineral soil or in the more layer and upper mineral soil of the forest sites. The soil was oven-dried (65_C); carbon and nitrogen content were measured considering the C and N pools estimation (Emmett *et al.*, 2004).

Data Analysis

This study involved spatial (field scale) selection and distributions of terrestrial parameters and were structured to assess the scaling and quantification of variability. Spatial forest soil and plant stand types were used in assessing and quantifying various soil chemical parameters while SPSS software to evaluate the various quantities. SOC concentration and Pearson correlation analysis (critical values 0.01 level) were used to determine the quantity of available nutrients.

RESULTS
Relative nutrient pool in different forest soil and of plant stand type
Soil Organic Matter

The evaluated chemical properties that include Soil Organic Matter (SOM) showed that Deqing forest soil at 0-25cm, Changtan forest soil at 0 – 25cm and Nanling forest soil at 0 – 25cm recorded highest (52.00g.kg, 48.00g.kg and 48.00g.kg respectively) while Deqing forest soil at 25-50cmdepth accounts 47.00g.kg and changtan forest soil at same depth accounted 28.00g.kg while Nanling forest soil recorded 36.00g.kg.



Deq – Deqing forest soil, Guan – Guangzhou forest soil, Cha – Changtan forest soil, Don – Donguan forest soil and Nan – Nanling forest site

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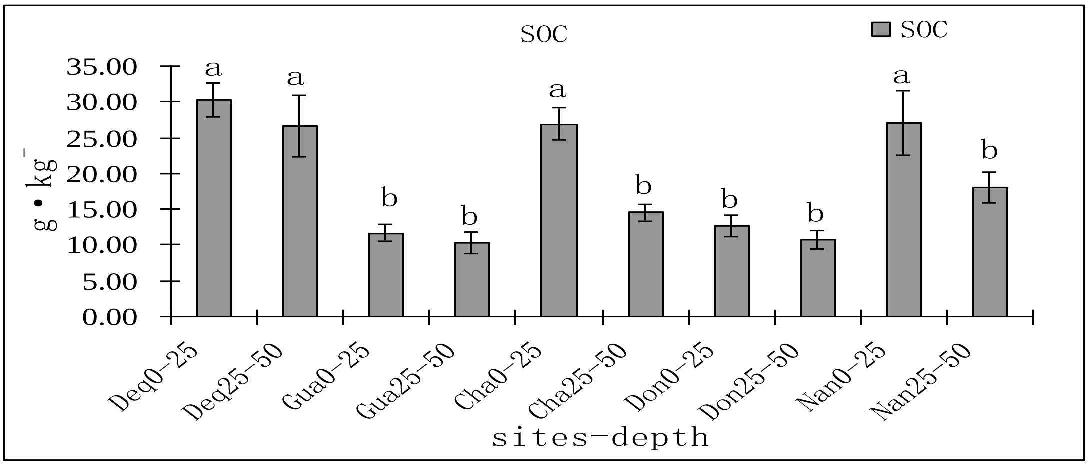
Soil Organic carbon

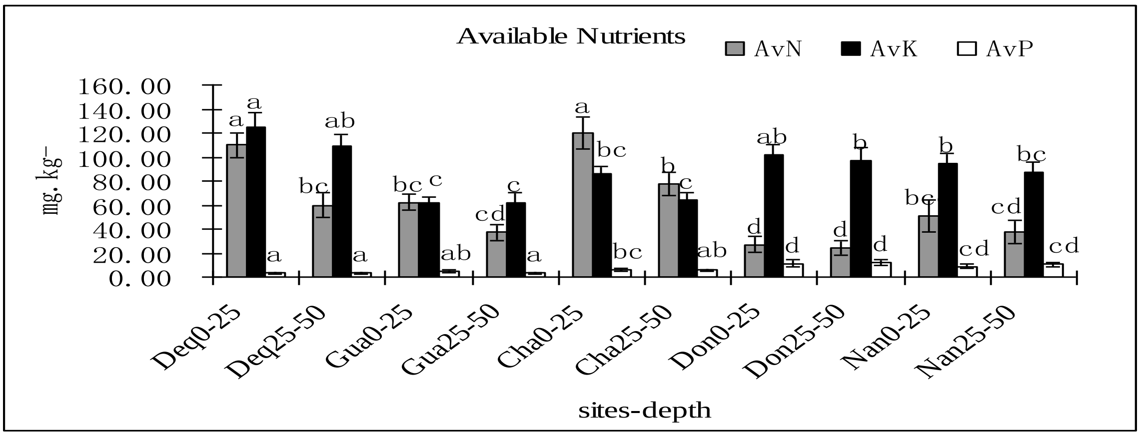
The evaluation showed a unique trend where Deqing, Changtan and Nanling forest soil at 0-25cm depth recorded 30.00g.kg, 27.00g.kg and 27.00g.kg respectively. In the vein, at 25-50cm depth Deqing was highest at 27.0g.kg, Nanling was 20.00g.kg and Changtan soil recorded 15.00g.kg.



Deq – Deqing forest soil, Guan – Guangzhou forest soil, Cha – Changtan forest soil, Don – Donguan forest soil and Nan – Nanling forest site

Available Nitrogen, Potassium and Phosphorous

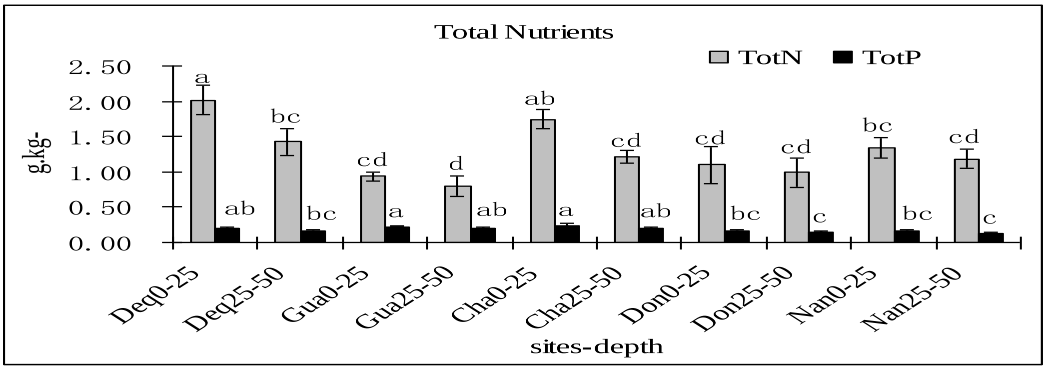
Available nutrients evaluated showed that Available Potassium in all forest soil recorded very high, Available Nitrogen recorded highest in Changtan and Deqing respectively while Available Phosphorous consistently comparatively recorded very low in all the forest soils. This trend was consistent in all the soil depth.



Deq – Deqing forest soil, Guan – Guangzhou forest soil, Cha – Changtan forest soil, Don – Donguan forest soil and Nan – Nanling forest site

Total Nitrogen and Phosphorous

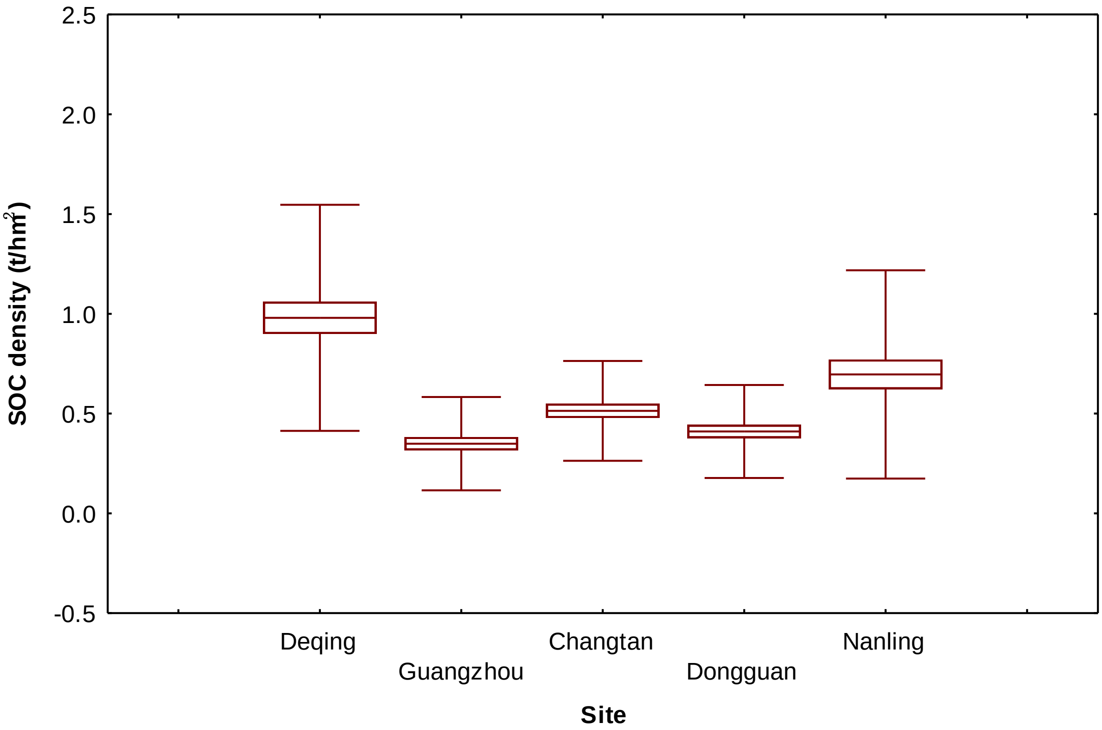
Evaluation of Total Nitrogen across the forest soils recorded very high in all soils while Total Phosphorous comparatively recorded very low in all the soils in all the depths.



Deq – Deqing forest soil, Guan – Guangzhou forest soil, Cha – Changtan forest soil, Don – Donguan forest soil and Nan – Nanling forest site

SOC density across the forest soils

Soil Organic Carbon evaluations across the forest soil recorded higher in Deqing soil (1.0 t/hm^2) and Nanling 0.8 t/hm^2 respectively.



SOC density (t/hm$^{2)}$: KW-H (4,250) = 83.8733947, p = 00.0000; F (4,245) = 21.1790895, p = 0.0000
Deq – Deqing forest soil, Guan – Guangzhou forest soil, Cha – Changtan forest soil, Don – Donguan forest soil and Nan – Nanling forest site

DISCUSSION

In agriculture, forest soil health management is very important. Across the forest soil sites the Soil Organic Matter (SOM) showed that Deqing forest soil (Nature reserve) - Pine and evergreen broadleaved mixed forest soil) at 0 - 25cm, Changtan forest soil (National nature

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reserve) - Secondary forest, protected and less disturbance) at 0 – 25cm and Nanling forest soil (National Nature Reserves) - Secondary forest and protected at 0 – 25cm recorded highest (52.00g.kg, 48.00g.kg and 48.00g.kg respectively) while Deqing forest soil at 25-50cm depth accounts 47.00g.kg and changtan forest soil at same depth accounted 28.00g.kg while Nanling forest soil recorded 36.00g.kg. Soil Organic carbon evaluation showed a unique trend where Deqing (Nature reserve) - Pine and evergreen broadleaved mixed forest soil), Changtan (National nature reserve) - Secondary forest, protected and less disturbance) and Nanling forest soil (National Nature Reserves) - Secondary forest and protected) at 0-25cm depth recorded 30.00g.kg, 27.00g.kg and 27.00g.kg respectively. In the same vein, at 25-50cm depth Deqing was highest at 27.0g.kg, Nanling was 20.00g.kg and Changtan soil recorded 15.00g.kg. Available nutrients evaluated showed that Available Potassium in all forest soil recorded very high, Available Nitrogen recorded highest in Changtan (National nature reserve) - Secondary forest, protected and less disturbance) and Deqing (Nature reserve) - Pine and evergreen broadleaved mixed forest soil) respectively while Available Phosphorous consistently comparatively recorded very low in all the forest soils. This trend was consistent in all the soil depth. Evaluation of Total Nitrogen across the forest soils recorded very high in all soils while Total Phosphorous comparatively recorded very low in all the soils in all the depths. SOC density evaluations across the forest soil recorded higher in Deqing soil (Nature reserve) - Pine and evergreen broadleaved mixed forest soil) (1.0 t/hm^2) and Nanling (National Nature Reserves) - Secondary forest and protected 0.8 t/hm^2 respectively. These are in line with the findings of Powers R.F. (1984).

It is identified that nutrient limitation to primary productivity and other biological processes is a widespread issue on food productivity. However, in terrestrial ecosystems, nitrogen (N) and phosphorus (P) is the most common limiting elements though mechanisms that limit P and interactions with N cycle. Greater conceptual frameworks for terrestrial nutrient limitation have been synthesized by Walker and Syers (1976) that implies P is derived primarily from rock weathering. It is documented that terrestrial ecosystems are largely devoid of N as they begin their development (Walker and Syers 1976). Unlike P, N is accumulated from the atmosphere rapidly via biological N fixation, where symbiotic N fixers dominate an early stage of ecosystem development, or more slowly via atmospheric deposition and dispersed sources of biological fixation (Vitousek, P.M *et. al.*, 2002, Vitousek, P. M., and H. Farrington. 1997).The sites are representative for their respective forest soil, plant stand type and as the soils differ in soil type, plant species composition, and succession stage. The nutrients as well as C and N are largely depending on disturbance while they are all subject to relatively degrees of management history. (Table 1). SOM is the dominant component of soil respiration loss rather than autotrophic respiration from roots. Considering the chemical properties are unique in this regional evaluation which SOC, P and N is of cardinal interest and where the plant growth and stand type is concentrated on pine and evergreen broadleaved mixed, secondary forest, protected and less disturbance, public forest park and formally a tree farm, non commercial purposes and non – commercial ecological forest. The results are contrary to expectations that N supply typically limits plant growth in temperate forests, grasslands and the coastal ocean while P limits freshwater ecosystems and tropical forests (Schindler 1977, Vitousek and Howarth 1991, Howarth and Marino 2006 and Vitousek, P.M *et. al.*, 1997), they found the mean effect of P (when added alone in soils) to be substantial – similar to that of N added alone - across terrestrial ecosystems. The soil carbon store dominates the carbon budget at all sites and in particular at the site with a cold and wet climate where soil C constitutes 95% of the total carbon in the ecosystem. Vegetation diversity management and plant species is attributed to high SOM.

Nutrient return and litter fall in soil under different forest stands

It is part of the study objective and we identify that different forest and vegetation stands contribute to nutrient return in forest and cropland nutrient cycling. Forest soil nutrient quality and quantity may strongly be in relation to the above-ground tree biomass. Forest ecosystem litterfall is the major pathway through which the pool of nutrient in the soil, depleted by nutrient and leaching is replenished (Morris 1991). This understanding provides more information on nutrient dynamics and cycling in different forest soil and ecosystems. Vegetation and cropland with different management history such as protected, less disturbed forest soil and public disturbed forest croplands where some plant species at periodic shed old leaves which plant species and soil properties could be the attributed factor. Generally climatic factors do strongly affect nutrient concentration and status especially the more mobile nutrients such as N, P, and K. Forest and cropland fertilization may also increase the concentration of nutrients though depending on particular plant species. Assessing the range and variability in carbon, organic matter and soil available nutrients in tropical – sub tropical forest soil and plant type in this era of climate change would be a dominating vegetation assessment. Considering poor or no forest soil and plant stand management tropical and sub-tropical vegetation as well as plants soil nutrients may deplete fast resulting to poor agricultural yield and forest environment stability. Because of the semi natural nature of the ecosystems with low or no management we hypothesized that the carbon balance at all sites would be close to steady state and that the soil carbon pool would be dominating carbon fluxes.

CONCLUSIONS

It may be concluded that the most important mechanisms causing soil nutrients variation could be as a result of forest soil disturbance and plant stand type leading to each forest soil history. These will affect the forest soil ecosystem-level balance of SOC, N and available mobile elements. The study shows that in the future a good forest soil management and cropland driven land cover between different plant stand type in tropical and sub-tropical regions will likely lead to increased ecosystem C, N and available nutrients enhancement. It is thereby encouraged to maintain mixed plant stand types to achieve better nutrient stability and promote good forest management overtime. However, it also emphasizes that if feedbacks on the carbon and nitrogen cycle are to be predicted, it will be critically important to quantify and understand belowground carbon allocation and processes as well as soil carbon pools, particularly on different vegetation management and types of plant species. This will rather boast plant functional nutrient interaction and stability towards better agricultural productivity. This study thereby supports that soil stores and dominate the overall budget of carbon fluxes while consolidating that the changes in climate and natural forest/soil ecosystem influences C and N in soils whereby good management and less disturbance of natural ecosystems should be encouraged.

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