Ecological Engineering 99 (2017) 298–309

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

# Potential storages and drivers of soil organic carbon and total nitrogen across river basin landscape: The case of Mo river basin (Togo) in West Africa

Badabate Diwediga[a,e,*], Quang Bao Le[b,c], Sampson Agodzo[d], Kperkouma Wala[e]

[a] WASCAL Program on Climate Change and Land Use, Department of Civil Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
[b] CGIAR Research Program on Dryland Systems (CRP-DS), International Centre for Agricultural Research in Dry Areas (ICARDA), Amman 11195, Jordan
[c] Department of Environmental Systems Science, ETH Zurich, Switzerland
[d] Department of Agricultural Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana, Ghana
[e] Laboratory of Botany and Plant Ecology, University of Lomé, Togo

ARTICLE INFO

*Article history:*
Received 5 October 2015
Received in revised form 27 October 2016
Accepted 13 November 2016
Available online 23 November 2016

*Keywords:*
Soil organic carbon
Total nitrogen
Ecological variables
Topographic variables
Mo basin
Soil-landscape analysis
Multivariate statistical analysis
Soil restoration
Togo

ABSTRACT

Quantification of carbon and nitrogen in soils in relation to ecological, landform and management factors over river basins is essential to understand landscape ecosystem functions and efforts to manage land restoration and the reduction of greenhouse gases emissions. Therefore, this research aimed at providing distribution of the potential storage in soil organic carbon (SOC) and total nitrogen (TN) within the multifunctional landscapes of the Mo river basin in Togo. We (1) quantified the potential storages of SOC and TN under different land use/cover types, landscape positions, and land management regimes; and (2) highlighted the relationships among these soil chemical properties, *in-situ* ecological conditions, and other hypothesized controlling factors. We used soil data from 75 sample sites to determine the quantity of SOC and TN at two depths (0–10 cm and 10–30 cm). *In-situ* ecological variables were collected simultaneously during soil sampling. Spatial information on biophysical conditions of the study sites were obtained from satellite images and most updated global topographic and soil databases. The results showed that SOC and TN varied significantly according to land cover types, soil depths, topographical positions and land protection regime. Generally, forests and woodland contain highest SOC (4%) and TN (0.3%). Agricultural fields (fallowed and cultivating farms) exhibited the lowest values of SOC and TN, except in some selected farm sites where these chemicals are still high. Topsoil layer (0–10 cm) contribute up to 60% of the total nutrient contents in soils. The sequential multivariate statistical approach unpacked and quantified the effects of inter-dependent ecological, management and landform drivers on the two important soil chemical properties (SOC and TN). The findings from this study could contribute to the improvement of national programme for assessing of greenhouse gases induced by land conversions. Based on this case-based finding in contextualization with related studies, we discussed on its implications for sustainable landscape restoration and climate change mitigation.



## 1. Introduction

Except water and other biosphere components, lands (comprising soil, vegetation, landscape, climate and intrinsic ecological processes) provide multiple direct and indirect functions and services to all living organisms (Costanza et al., 1997; De Beenhouwer et al., 2013; Munoz et al., 2013). Billions of people worldwide and about 60 to 70% of people in Africa directly rely on land resources to ensure their livelihoods throughout agriculture, and the collection of timber and non-timber forest products (Akanni, 2013; Ghosal, 2011; Melaku et al., 2014; Steele et al., 2015). Additionally, land is crucial for global climate mitigation, as they store and sequester elements involved in the biogeochemical cycles and greenhouse effects (Foley et al., 2005). Unfortunately, in Sub-Saharan Africa, land management approaches induce land degradation and soil

* Corresponding author at: WASCAL Program on Climate Change and Land Use, Department of Civil Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.
*E-mail addresses:* diwedigaba@gmail.com, diwedigaba@yahoo.fr (B. Diwediga), q.le@cgiar.org, q.le@alumni.ethz.ch, blequan@uni-bonn.de (Q.B. Le), sagodzo@usa.net (S. Agodzo), kpwala75@yahoo.fr (K. Wala).

http://dx.doi.org/10.1016/j.ecoleng.2016.11.055
0925-8574/

quality loss through the poor resource allocation and use, inappropriate land-related policy development and inadequate planning and management strategies (Petter et al., 2012; Portman, 2013; Primdahl et al., 2013). Consequently, sustainable land management is facing inefficiency and failure due to the dearth of timely and accurate information.

As indicators of soil performance and productivity, soil nutrients, especially soil organic carbon (SOC) and total nitrogen (TN), provide information on land health (Vagen and Winowiecki, 2013; Wiesmeier et al., 2014a; Xiong et al., 2014; Zucca et al., 2013). Though SOC and TN are not the sole important elements for soil fertility and productivity measurement, they increasingly required interest because of their contribution to biogeochemical cycles and climate change mitigation processes. In this sense, it has been shown that soils represent one of the largest reservoirs of carbon interacting with the atmosphere, vegetation, climate and other carbon pools (Jobbágy and Jackson, 2000). Globally, soils are ranked as the third largest carbon pool after oceanic and fossil fuels, storing about 2157–2293 Pg C and 133–140 Pg N in the upper 100 cm (Batjes, 1996). However, this carbon pool is affected by numerous disturbances that affect its storage capacities. At any scale, land use/management (cropping, grazing, mining, etc.), and environmental factors (climatic, edaphic, *etc.*) have been targeted as major factors shaping soil system and its relationships with other subsystems of the biogeochemical cycle (Dorji et al., 2014; Gutiérrez-Girón et al., 2015; Vagen and Winowiecki, 2013; Villarino et al., 2014).

At any level, land management and land cover are of great importance as they play a key role in controlling soil chemical amounts and distribution (Biro et al., 2013; Houghton and Goodale, 2004). Land use land cover change that affect terrestrial ecosystems are responsive for carbon and nitrogen fluxes, in both soils and vegetation (Selassie et al., 2015; Touré et al., 2013; Wiesmeier et al., 2014c; Xue et al., 2013). Foremost of the concerns in land management is that the current traditional farming systems are fair-efficient and have been attributed the degradation of soil quality through organic matter depletion, productivity decline, and soil erosion (Sebastia et al., 2008; Touré et al., 2013; Vagen and Winowiecki, 2013). In response to climate change and human population growth, adaptation options usually tend to agricultural land expansion with acquisition and clearance of forested and other wooded vegetation stands. These practices affect land quality in terms of soil potential in carbon and nitrogen storage, its productivity, and other ecosystem service provision (Ciric et al., 2013; Kintché et al., 2010; Xue et al., 2013). In this regard, one of the research questions that should be answerless over time and space is how much SOC and TN are stored in soils undergoing perpetual and tremendous changes under the diverse options of adaptation and mitigation to climate change. The attempt in answering this question makes an insightful input in improving soil information through data update in order to reduce soil vulnerability and contribute to climate change mitigation (Conant, 2012; Wiesmeier et al., 2014a).

In Togo, published researches highlighted the adverse effects of charcoal production on soil biological properties (hypogea fauna) (Fontodji et al., 2009). At farm plot levels, studies carried out in the Northern Savannah area of Togo showed soil nutrient that long term farming induced nutrient loss while setting farm plots into fallows replenishes SOC amounts (Kintché et al., 2010; Sebastia et al., 2008). The latter authors mainly focused on the quality assessment for agricultural purposes to support farmers in building options to protect their lands. Meanwhile, available data on soils properties from The Global Assessment of Soil Degradation (GLASOD) (Oldeman et al., 1990) and Harmonized World Soil Database (HWSD) (FAO/IIASA/ISRIC/ISS-CAS/JRC, 2008) are of poor resolution, especially when dealing with small landscapes. Additionally, soil potential in agricultural and wild landscapes are still unknown to be accounted for greenhouse gases (GHG) assessment

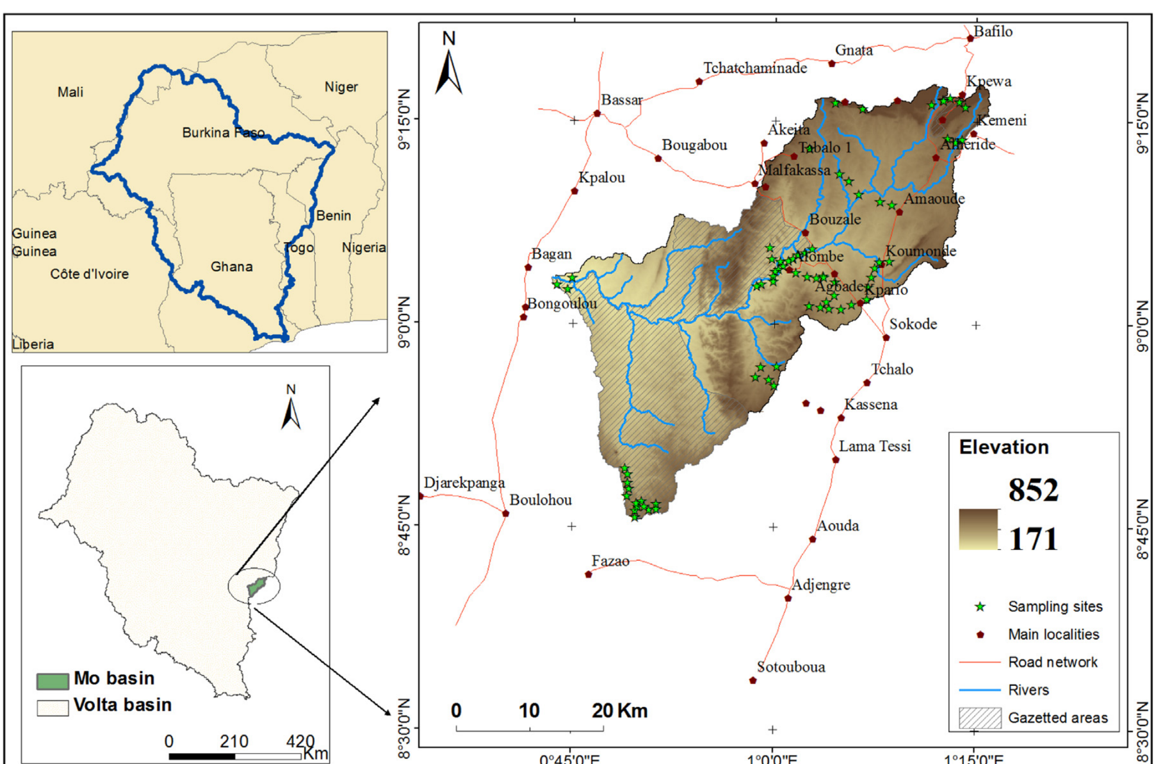


**Fig. 1.** Location of the study area with the sample sites.