Soil & Tillage Research 150 (2015) 124–131

Contents lists available at ScienceDirect

Soil & Tillage Research

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

Assessing soil quality under different land cover types within shifting agriculture in South Cameroon

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ARTICLE INFO

Article history:
Received 8 August 2014
Received in revised form 5 December 2014
Accepted 20 January 2015

Keywords:
Land cover types
Soil quality
Fallow
Forest
Organic matter
South Cameroon

ABSTRACT

The common agricultural practice in the humid tropical forest zone of Cameroon is shifting cultivation, which leads to a landscape mosaic system characterized by a diversity of land cover types. Our objective was to evaluate soil properties and soil quality under these land cover types and to investigate on their interrelationships. Topsoil samples (0–20 cm) were collected at the same time from 8 different land cover types (bare soil with burned vegetation biomass (FR1), bare soil with unburned vegetation biomass (FR), *Chromolaena odorata* fallow (JC), bush ligneous fallow (JR), secondary forest (SF), primary forest (FC), Gilbertiodendron dewevrei forest (FG), and raffia and Uapacca forest (RA)) and analysed for routine laboratory determinations. A soil quality index (SQI) computed based on soil chemical properties, analysis of variance and multiple comparison tests were used to compare soils from different land cover types. Principal component analysis (PCA) was used to select the most appropriate indicators that control soil quality. Several soil properties showed high to very high coefficient of variation within the land cover types. Organic matter was significantly high under forested land cover types (FC, FG, RA) and under bare soil with burned vegetation (FR1). Soil quality differs significantly ($p = 0.000$) from one land cover to another and shows the following ranking: SQI_FR1 ≫ SQI_FG > SQI_RA > SQI_FR > SQI_FC > SQI_JC > SQI_FS > SQI_JR. Organic matter (OM), available P, calcium (Ca), and pHw combined, accounted for 88.5% of the variation of soil quality. The soil quality appeared to be highly influenced by ashes from burned vegetation biomass which temporally enriches soils with nutrient elements and by the organic matter supplied by forested land cover types.

1. Introduction

In the humid tropical forest zone, the common and dominant agricultural practice is shifting cultivation or slash and burn agriculture. It is the main land use system practiced by small scale farmers to ensure subsistence food and a small income. This practice leads to a landscape mosaic system (Forman, 1995 in Nounamo et al., 2002) characterized by a diversity of land cover types which correspond to a series of fallow plots of various ages, perennial plantations, and primary forests (Nyeck, 2005; Yemefack, 2005, 2006a,b; Ngo Mbogba, 2009). In this system, land cover types change constantly from one location to another and ash in general is from prescribe fire. In most literature, the effect of ash on soil properties depends on various factors such as: type of plant species, burning temperature, fuel density, type of ash (white or black) (Javier et al., 2013) part of plant combusted, time of exposure to heat, and other factors affecting combustion condition (Dlapa et al., 2013; Bodi et al., 2012; Cerdà and Doerr, 2008). Therefore, ash from slash and burn agriculture has been reported increase short-term soil chemical fertility immediately following burning and in a long-term negatively impact on soil quality (Edivaldo et al., 2014; Kanmegne, 2004; Yemefack et al., 2004). Thus, leaching of nutrient elements, reduction in soil organic matter content, modification

Abbreviations: FR1, bare soil with burned vegetation biomass; FR, bare soil with unburned vegetation biomass; JC, soil under *Chromolaena odorata* fallow; JR, soil under bush ligneous fallow; SF, soil under secondary forest; FC, soil under primary forest; FG, soil under Gilbertiodendron dewevrei forest; RA, soil under raffia and Uapacca forest; SQI (IQS), soil quality index; SQI13, soil quality index with combination of thirteen soil quality indicators; SQI4, soil quality index with combination of four soil quality indicators; SQI2, soil quality index with combination of two soil quality indicators; PCA, principal component analysis; OM (MO), organic matter.

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http://dx.doi.org/10.1016/j.still.2015.01.007
0167-1987/

of aggregate stability (Nounamo et al., 2002) and soil structure have been found. In Mediterranean ecosystem where ash is in majority from wildfire, as function to their characteristics, has been suggested in one hand to protect soil from the impact of raindrops, reducing soil water repellency (Bodi et al., 2012), soil erodibility by promoting flocculation of dispersed clays (Bodi et al., 2011), favoring high infiltration, lower erosion rate, reduced runoff (Javier et al., 2013; Cerdà and Doerr, 2008; Cerdà and Lasanta, 2005), increased soil chemical fertility following burning (Dlapa et al., 2014; Martin et al., 2012; Bodi et al., 2011; Lasanta and Artemi, 2005). This gives rise to be highly wettable soil with a high water storage capacity (Dlapa et al., 2013). On the other hand, ash contributes enormously to pore blockage resulting in increased surface runoff (Javier et al., 2013; Pérez-Cabello et al., 2012; Bodi et al., 2011; Cerdà and Doerr, 2008) and has been suggested to be water repellent (Dlapa et al., 2013). Under slash and burn agriculture, Koutika et al. (2005) have assessed the soil quality of acidic and non acidic soils by analyzing the status of particulate organic matter fractions. Knowledge on the monitoring of soil properties and soils quality under different land cover types of the humid tropical forest zone of South Cameroon are still scarce.

Vegetation is one of soil forming factor (Quideau et al., 2001) and plays an important role in controlling soil erosion (Cerdà, 1998; Cerdà et al., 2010; Zhao et al., 2013; Mandal and Sharda, 2013). However, its contribution in soil forming process varies in quantity and quality depending on the vegetation type. Thus, the conversion of forest lands into farm lands highly affects almost the whole soil functioning (organic matter content, bulk density, infiltration rate, availability of soil nutrient element, . . . ,etc.) (Gao et al., 2014; Liu et al., 2014; Elciol et al., 2014; De MÛelenaere et al., 2014; Biro et al., 2013; Leh et al., 2011; Ingo et al., 2011; Karhu et al., 2011; Cerdà and Doerr, 2007). In the case of assessment of soil quality in San Joaquin Valley's in California (USA); Andrews et al. (2003) considered as potential soil quality indicators: pH, WSA (wet aggregate stability), OM (organic matter), Olsen-P, PMN (potentially mineralizable nitrogen), EC (electrical conductivity), and SAR (sodium absorption ratio). These indicators may vary according to agricultural practices, vegetation type and determine soil productivity or soil fertility. In the Brazilian Luvisols, soil quality though mostly dependent on soil physical environment remained a function related to the vegetation types (natural vegetation or agroforestery) due to the supply of soil organic matter (Silva et al., 2011). Soil physical properties such as bulk density, texture, water content and soil penetration resistance are also important in the assessment of soil quality. Owing to the multiplicity of soil quality indicators, numerous authors (Andrews et al., 2002a,b; Seyed et al., 2006; Bastida et al., 2008; Yanbing et al., 2009) agreed on the selection of a minimum data set (MDS) responsible for at least 70% of the variation of site's soil parameters. The selection of MDS is based on expert opinion and on statistical analysis (Andrews et al., 2002a,b; Seyed et al., 2006; Yemefack et al., 2006a,b). Soil properties to be included in a MDS must be sensitive to change in soil management, soil perturbation and inputs into the soil system. Each selected property must also be easily and reproducibly measurable (Yemefack et al., 2006a,b).

This paper reports on the assessment of soil quality through soil organic matter and soil physicochemical properties under eight (08) different land cover types. This assessment will surely help farmers and researchers to understand the quality of each soil sampled under a specific land cover compared to soil under primary forest. The objectives were: (i) monitoring the variability of soil organic matter and soil chemical parameters under different land cover types, (ii) computing soil quality index (SQI) parameter under each land cover type and (iii) and comparing to control, appreciated the quality of soil sampled under other land cover types.

2. Material and methods

2.1. Study site and the research design

The experiment was conducted at the Nsimi village within the Zoétélé subdivision in South Cameroon (Fig. A1). The area is located at 120 km SSE of Yaoundé, between 3°07′–3°15′N and 11°45′–11°52′E. The annual rainfall shows a bimodal distribution pattern, leading to two rainy seasons corresponding to two cropping periods (March–June and September–November). The annual rainfall varies between 1500 and 1900 mm and the mean annual temperature is 24 °C (Santoir and Bopda, 1995). The area is an undulating landscape with altitudes ranging between 600 and 900 m (a.s.l).

Shifting cultivation is the main agricultural land use system practiced by small scale farmers, which results to a spatial landscape mosaic pattern where some portions of primary forest are replaced by annual food crop fields, perennial plantations (cocoa, oil palm or rubber) or diverse fallow cover types (Yemefack, 2005; Nyeck, 2005). Depending on the dominant plant species, homogeneous fallow types have been defined, corresponding to different regrowth ages of vegetation and the local conditions of their reuse for agricultural purpose in area. Our research design included the following land cover types: bare soil with burned vegetation biomass (FR1: 0 months), bare soil with unburned vegetation biomass (FR: 0 months), *Chromolaena odorata* fallows (JC: 3–5 years), Bush ligneous fallows (JR: 7–10 years), secondary forest (SF: 10–25 years), Gilbertiodendron dewevrei forest (FG >50 years), *raffia* and *Uapaca* forest (RA >50 years) and primary forest (FC >50 years) considered as control.

In the field, direct observations of land cover types, coupled with the identification of dominant plant species and interviews of local farmers allowed us to determine the various land cover types and their age range. Dominant soils across the area are Acrisols and Ferralsols (WRB, 2006). Few gleysoils or hydromophic soils are found in the swampy valleys. These soils are all derived from gneiss or schist and granites with pyroxene (Champetier de Ribes and Aubague, 1956).

2.2. Soil sampling and laboratory analyses

Composite soil samples were collected using an Edelman auger at 0–20 cm depth under each land cover type with three replications. These soil samples were air-dried before grinding and sieving, then, used for routine laboratory analyses. Physico-chemical determinations were done for the following parameters: pH in water ratio of 1:2.5 (pHw), exchangeable bases (Ca, Mg, K), trace elements (Fe, Mn, Cu, Zn) and available P were extracted by the Mehlich-3 procedure (Mehlich, 1984). Cations were determined by atomic adsorption spectrophotometry and, available P by bray II procedure (Motomizu et al., 1983), exchangeable Al using 1 M KCl and analyzed colorimetrically using pyrocatecol violet. Cation exchange capacity (CEC) was carried out using the ammonium acetate method at pH 7 (Summer and Miller, 1996). Total N using the Kjeldahl method for digestion and ammonium electrode determination (Bremner and Tabatabai, 1976), organic carbon (OC) using chromic acid digestion and spectrophotometric analysis (Heanes, 1984), Organic matter (OM) was obtained using conversion factors for surface horizons of 1.724 for soils under anthropogenic land cover types and 2.0 for soils under undisturbed land cover types (Nelson and Sommers, 1972).

2.3. Computation of soil quality index (SQI) parameter

According to Douglas et al. (2003) soil quality refers to the capacity of a specific kind of soil to function, within natural or