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Impact of land clearing methods and cropping systems on labile soil C and N pools in the humid zone Forest of Nigeria

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Abstract

Labile soil C and N play vital roles in soil–plant nutrient dynamics, especially in the low input cropping system and are vulnerable to perturbation. Surface (0–0.15 m) soils from three land clearing methods (slash and burn, bulldozed non-windrowed and bulldozed windrowed) and each with two cropping systems (5-and 4-year cropping/2-year cassava fallow) were collected in the humid forest ecosystem of Nigeria.

The soils were analysed for total C and N, microbial biomass C and N (SMB C and N), particulate organic matter C and N (POM C and N), water-soluble C, potentially mineralizable N (PMN) and mineral N. The size of the labile C and N and their relative contributions to the organic C and total N differed significantly among land clearing methods, irrespective of the cropping system. Soils under slash and burn had a significantly ($p > 0.05$) higher particulate organic matter C, N (10.80 and 0.16 g kg^{-1}, respectively) and microbial biomass C and N (1.07 and 0.12 g kg^{-1}) compared to the bulldozed windrow, regardless of the cropping system. Four years cropping/2-year cassava fallow resulted in a significant higher labile C and N, relative to 5-year cropped plots across the land clearing methods. Effect of the treatments on the concentration of PMN and mineral N mirrored the SMB N and POM N. However, the quantity of most of the labile C and N pool and crop yield obtained from the slash and burn and bulldozed non-windrowed treatment did not differ significantly. Hence, bulldozed non-windrowed clearing could be a viable alternative to slash and burn in the case of large-scale farming in ensuring reduced losses of soil organic matter and nutrient during land clearing in the humid tropics.

Keywords: Soil fertility; Cropping system; Deforestation; Soil organic matter; Cassava fallow; Particulate organic matter

1. Introduction

The humid forest eco-region of southern Nigeria witnessed a rapid conversion into agricultural use in the mid 1990s, following the establishment of the National Agricultural Land Development Authority (NALDA) by the then Federal Military Government. Most of the areas were cleared mechanically and could not sustain arable crop production even for three consecutive years without severe soil loss and degradation (Agboola et al., 1998). Mechanical land clearing has an adverse effect on soil physical and chemical conditions more especially in the humid forest ecosystem (Seubert et al., 1977; Hulugalle, 1994). However, the intensity of the effect varies with the method deployed, with those involving a combination of tree pushing and the root rake being more damaging than the shear blade clearing method alone (Lal, 1986).

Traditionally, in the lowland humid tropics, the conversion of forest or fallow land into agricultural use involves felling and burning of the vegetation—manual clearing (Lal, 1986). The method ensures minimal soil disturbance and degradation (Seubert et al., 1977) and the cleared area can sustain economic crop yield for more than 4 years before being fallowed. However, the prohibitive amount of labour and time required to accomplish manual land clearing has

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made most people, especially large-scale farmers to opt for mechanized land clearing method without considering the consequences on the soil environment.

Degradation in soil quality often associated with the conversion of primary or secondary forest into low input agro-ecosystem is mainly due to decline in soil organic matter (Sikora et al., 1996; Smith et al., 2000). The rapid initial losses are mainly the mineralization of the biologically labile or active pools: microbial biomass, particulate organic matter, soil carbohydrate and enzymes and water-soluble C (Martins et al., 1991; Lugo and Brown, 1993). Decreases of more than 47 and 24% in particulate matter and microbial biomass C have been recorded in less than a year after clearing of a secondary forest (Motavalli et al., 2000). Islam and Weil (2000) reported a labile C loss of about 67–167% in soils under 5–7 years continuous cropping. Their rate of losses is among other factors affected by land use and management strategies (Zak et al., 1993; Feller and Beare, 1997).

Labile organic matter pools have a significant positive correlation with soil nutrient capital stock (Sikora et al., 1996; Haynes, 2000). Evaluation of changes in their quantity could be an early indicator of land use and management effect on the soil environment. The aim of this study was to evaluate the impact of three land clearing methods and subsequent uses on the soil labile C and N pools of the humid forest eco-region of southwestern Nigeria.

2. Materials and methods

2.1. Site description and field experiment

A field experiment was established in 1994 at the project site of the Department of Agronomy, University of Ibadan located at the Ondo State Aforestation Project in Epemakinde to compare the conventional (slash and burn) and two mechanical (bulldozed non-windrowed and bulldozed windrowed) methods of bush clearing for arable cropping in the humid forest area of Nigeria. Epemakinde (4°E, 6°N) is characterized by a tropical humid rain forest climate. The rainfall pattern is bimodal, with a long (April–July) and short August–October) rainy period separated by a short period of dryness between late July and early August (Table 1). The temperature ranges between 26 and 28 °C with a relative humidity of 65–80%.

The soil possesses a sandy loam in the upper layer over a well-drained sandy clay/clay loam sub soil (Agboola and Ogunkunle, 1993) which is classified in the USDA system as Typic Kandiudult (an ultisol). The soil textural analysis of samples from the adjacent matured high forest showed on average, 71.2 g 100 g^{-1} sand, and 26.3 g 100 g^{-1} silt and 2.5 g 100 g^{-1} clay and bulk density was 1.06 g cm^{-3} at 0–0.15 m depth. Some of the chemical and biochemical properties of the soil are shown in Table 2. The vegetation at the beginning of the experiment was a matured high forest (>100 years old) with some identifiable tree species such as *Pycnanthus microcephalus* (Beuth.), *Staudtia stipitata* (Warb.), *Marathes glabra* (Oliv.), *Sacoglottis gabonensis* (Baill), *Elaeophorbia drupifera* (Thonn.), *Eribroma oblonga* (Mast.) and *Ceiba pentandra* (Linn.) having a girth of between 0.25 and 0.30 m at 1.5 m height and the average tree density of >1000 ha^{-1}.

The experimental consist of a factorial combination of three land clearing methods (slash and burn, bulldozed non-windrowed and bulldozed windrowed) and two cropping systems (5 years maize/cassava inter crop and 4 years maize/cassava intercrop followed by 2-year cassava fallow). A randomized complete block design was used with three replicates. Each of the experimental unit measured 0.49 ha.

Table 1
Monthly mean maximum, minimum (mm) and standard deviation of rainfall at Epemakinde, between 1980 and 2000

Month	Maximum	Minimum	Mean ($n = 20$)	S.D.
January	31.2	5.3	±20.9	12.9
February	133.0	16.0	±34.5	23.0
March	223.9	8.5	±90.9	82.8
April	225.0	53.6	±153.7	80.1
May	284.1	174.4	±217.2	54.8
June	337.9	185.9	265.7	52.8
July	442.7	102.7	317.0	120.1
August	211.5	39.9	127.1	65.3
September	379.2	171.5	256.4	192.1
October	375.9	159.2	212.8	204.4
November	145.8	19.6	55.8	125.9
December	56.4	7.4	9.1	51.5

$n = 20$.

Table 2
Some of the chemical and biochemical properties of the adjacent matured high forest soil (0–0.15 m)

Chemical and biochemical properties	Value
Organic C (g kg^{-1})	49.78
Total N (g kg^{-1})	3.25
C/N ratio	18.39
pH (H_2O)	6.40
Available P (mg kg^{-1}) Bray 1	8.20
Exchangeable cations (cmol kg^{-1})	
Ca	6.43
Mg	0.12
K	0.29
Na	0.17
Total exchangeable acidity	0.20
CEC	7.21
Particulate organic matter C (g kg^{-1})	25.60
Particulate organic matter N (g kg^{-1})	1.35
Soil microbial biomass C (g kg^{-1})	5.82
Soil microbial biomass N (g kg^{-1})	1.17
Field moist water-soluble C (g kg^{-1})	0.30
Air-dried soil-soluble C (g kg^{-1})	19.15
Potentially mineralizable N (mg (kg^{-1} day^{-1}))	2.63
NO_3^- N (mg kg^{-1})	24.22
NH_4^+ N (mg kg^{-1})	55.69
POM C/C org (%)	51.42
SMB C/C org (%)	11.69