Effects of Shifting Cultivation on a Tropical Rain Forest Soil in Southwestern Nigeria[1]

A O Aweto*

ABSTRACT

The chemical and physical properties of soils (Oxisols) in shifting cultivation sites in southwestern Nigeria were compared with those of soils under rain forest. The levels of organic matter, total nitrogen and exchangeable calcium, magnesium, potassium and sodium in shifting cultivation sites are lower than forest soils. The extent of organic matter and nutrient decline in shifting cultivation soil, relative to forest levels, is greater in the 0-10 cm layer than in the 10-30 cm layer. Soils in shifting cultivation sites had higher bulk densities and lower total porosities.

COMPENDIO

Las propiedades físicas y químicas de los suelos Oxisoles en sitios en donde se practica la agricultura migratoria se compararon con aquellas de suelos existentes en forestas tropicales húmedas. Los niveles de materia orgánica, nitrógeno total y calcio, magnesio, potasio y sodio intercambiables en suelos bajo cultivo migratorio son más bajos que en suelos de forestas húmedas. El nivel de disminución de la materia orgánica y de los nutrimentos en suelos bajo agricultura migratoria, en relación con los suelos forestales, es mayor en la capa 0 a 10 cm de la superficie del suelo que en la capa 10 a 30 cm. Los suelos bajo agricultura migratoria presentaron mayores densidades masales y porosidades totales más bajas.

INTRODUCTION

As with most countries in the tropics, shifting cultivation is the dominant system of arable farming in Nigeria Agronomic studies on shifting cultivation in Nigeria have focused on soil dynamics under experimental continuous cropping (1, 10); finding planted fallow substitutes to replace the natural bush fallow (8, 10); changes in the properties of soils under natural bush fallows over time (2, 3); and on the effects of land clearing on soil properties (12). These studies have made valuable contributions to an understanding of shifting cultivation and the problems of intensifying it, but have largely ignored changes in soil properties that occur during the cropping phase of the shifting cultivation cycle. Such soil changes have been documented generally for the tropics by Nye and Greenland (11). Soil and ecological condition vary considerably in the tropics. So do crops grown, nature and restorative ability of fallow vegetation, climatic conditions and length of cropping relative to fallowing. Hence, studies such as those of Nye and Greenland (11), which give an overview of the general features of shifting cultivation in the tropics, should be complemented with studies that are area-specific or soil-specific. This is necessary to ensure that blanket measures are not taken to intensify shifting cultivation in the tropics and that the measures adopted take full cognisance of the ecological and pedological conditions of the area in question.

The present study examines the effects of the cropping phase of shifting cultivation on an Oxisol in the rain forest zone of southwestern Nigeria by comparing the physical and nutrient status of soils in shifting cultivation sites at the cessation of cropping with soils in forest control sites

The study area

The present study was carried out in the Ibeju – Ode area, part of the coastal plain of southwestern Nigeria. The climate is hot, humid sub-equatorial with a double-peak rainfall regime. The mean annual rainfall is between 1 300 and 1 600 mm and the natural vegetation is tropical rain forest. Most of the original rain forest has been destroyed as a result of the prevalent practice of shifting cultivation. Remnants of the originally continuous forest cover are now confined to forest reserves and sacred groves. The rain forest is floristically diverse, with some trees over 30 m tall. Some of the major tree species include *Chlorophora excelsa, Lannea welwitchii Antiaris africana, Bosqueia angolensis* and *Pentaclethra macrophylla*.

The soils are Oxisols. They were derived from sandstone parent material and have been intensively leached. Kaolinite is the dominant clay mineral in the soils.

1 Received for publication 5 September 1987.

* Department of Geography, University of Ibadan, Ibadan, Nigeria.

Cassava and maize are the main crops grown in the study area. These are frequently intercropped with pepper, melon and yams. Farmlands are cultivated for 1-3 years and thereafter fallowed for 3-10 years depending on soil fertility and the amount of land available to the community.

MATERIALS AND METHODS

Soils in shifting cultivation sites were compared with those in sites under mature rain forest to infer the effects of shifting cultivation on soil properties. The former were sampled at the end of cropping. The shifting cultivation and forest sites were located on flat and gently slopping summits of topographical sequerences in an-area of uniform parent material (sandstone) to ensure that catenary variations in soil properties were minimal. Soil samples were collected from depths of 0-10 cm and 10-30 cm in sampling sites which measured 30 m x 30 m. Ten plots each were studied for shifting cultivation and rain forest sites. Bulk soil samples collected were air-dried, passed through a 2 mm sieve, and analysed for organic carbon by the method of Walkley and Black (15). Uncorrected organic carbon values were converted into soil organic matter by multiplying by a factor of 1 274. Total nitrogen was determined by the Kjeldahl method. Soils were leached with IM neutral ammonium acetate and the extracts used for determining soil exchangeable cations. Exchangeable calcium, potassium and sodium were determined by flame photometry and magnesium by atomic absorption spectrophotometry. Soil cation exchange capacity was determined as the sum of the exchangeable cations and exchange acidity (5). Soil particle size composition was determined using the hydrometer method. Undisturbed core samples collected from the 0-10 cm layer were analysed for bulk density using the core method (4), while total porosity values were calculated from bulk density values using an assumed particle density value of 2.65 g cm^{-3} (14). Bulk density and total porosity were analysed for only the 0-10 cm layer.

RESULTS

Table 1 shows the properties of the 0-10 cm layer of soils under rain forest and in shifting cultivation sites. The mean organic matter content of the shifting cultivation sites is low, being 46.3% of the mean forest level. Similarly, the levels of total nitrogen, exchangeable calcium, magnesium, potassium and sodium and the cation exchange capacity of the shifting cultivation sites are significantly lower than the levels in forest soils. Organic matter and nutrient levels in the 10-30 cm layer under shifting cultivation are also generally lower than the levels in the corresponding layer of forest soil. However, the extent of organic matter and nutrient diminution is greater in the 0-10 cm layer of the profiles than in the underlying 10-30 cm layer. The mean level of organic matter in the 0-10 cm layer of shifting cultivation sites was reduced to 46.3% of forest level, while that of 10-30 cm was reduced to 78.6% of the level in the corresponding layer of forest soil. The mean levels of exchangeable calcium, magnesium and potassium in 0-10 cm layer of soils under shifting cultivation were reduced to between 36% and 59% of forest soil levels. The same nutrients were reduced to between 75% and 85% of mean forest levels in the 10-30 cm layer. There are no significant differences between soils under shifting cultivation and rain forest with respect to the levels of total nitrogen and exchangeable calcium and sodium in the 10-30 cm layer. Again, this points to the fact that the effects of shifting cultivation on nutrient decline in the soil are more marked in the topsoil layer than in the subsoil layer.

Table 1. Properties of the 0-10 cm layer of cultivated and forest soil. Values are means ± standard error. N = 10.

Soil properties	Cultivated soil	Forest soil
Organic matter (%)	2.5 ± 0.18	5.4 ± 0.14
Total nitrogen (%)	0.19 ± 0.01	0.49 ± 0.04
Exchangeable calcium (kg/ha)	504.7 ± 37.1	1 029.6 ± 146.1
Exchangeable magnesium (kg/ha)	156.7 ± 9.7	265.4 ± 21.6
Exchangeable potassium (kg/ha)	24.2 ± 6.7	67.3 ± 20.3
Exchangeable sodium (kg/ha)	18.0 ± 7.0	46.6 ± 6.4
C E C (m.e./100 g of soil)	8.4 ± 0.6	17.7 ± 1.0
Bulk density (g/cm^3)	1.19 ± 0.03	0.98 ± 0.01
Total porosity (%)	54.4 ± 1.0	63.2 ± 0.3
Sand (%)	91.6 ± 0.4	81.6 ± 1.8
Silt (%)	3.4 ± 0.2	10.1 ± 1.0
Clay (%)	5.0 ± 0.4	8.2 ± 1.2

Table 2. Properties of the 10-30 cm layer of cultivated and forest soil. Values are means ± standard error. N = 10.

Soil properties	Cultivated soil	Forest soil
Organic matter (%)	1.1 ± 0.04	1.4 ± 0.12
Total nitrogen (%)	0.10 ± 0.01	0.11 ± 0.01
Exchangeable calcium (kg/ha)	465.1 ± 49.7	549.5 ± 108.9
Exchangeable magnesium (kg/ha)	165.6 ± 7.7	207.7 ± 21.1
Exchangeable potassium (kg/ha)	21.6 ± 1.3	28.7 ± 2.6
Exchangeable sodium (kg/ha)	42.0 ± 1.5	41.1 ± 1.3
C.E.C (m.e./100 g of soil)	4.7 ± 0.17	6.9 ± 0.49
Sand (%)	90.9 ± 1.0	74.3 ± 1.7
Silt (%)	2.2 ± 0.2	10.0 ± 1.1
Clay (%)	6.9 ± 1.0	15.7 ± 1.5

Shifting cultivation has adverse effects on soil physical status (Table 1) as compared to soils under rain forest. The mean bulk density of the 0-10 cm layer of soils in the shifting cultivation sites is significantly higher than that of forest soil, indicating that shifting cultivation results in soil compaction. Also, the mean total porosity of shifting cultivation soil is lower than that of forest soil (Table 1). This suggests that soils in the shifting cultivation sites are less porous and hence less permeable to water and air than forest soil. Soils in shifting cultivation sites are more sandy than forest soils. This is presumably due to vigorous downward eluviation of silt and clay particles during cultivation, owing to site exposure. The higher clay content of forest soils may be partly attributable to greater earthworn activity under forest.

DISCUSSION

The levels of organic matter in the shifting cultivation sites are low compared to soils under mature rain forest. This indicates that soil organic matter declines during shifting cultivation, due to site exposure, a reduction in litter quantity and the disruption of litter supply to the soil during cultivation. Site exposure results in high soil temperatures and accelerated soil organic matter oxidation (11). As with organic matter, there is a decline in the levels of total nitrogen and exchangeable calcium, magnesium, potassium and sodium in the 0-10 cm layer of soils in the shifting cultivation sites. The decline in the levels of nutrients during the cropping phase of shifting cultivation is due to nutrient removal in harvested crops, leaching and erosion (11), and also to a decline in organic matter. Organic matter is a source and store of soil nutrients and is the main contributer to the cation exchange capacity of kaolinitic tropical soils such as occur in the study area. Hence, a decline in soil organic matter will result in a reduction in soil nutrient-adsorbing capacity, which in turn will lead to increased leaching of nutrients from the soil. Organic matter and nutrient diminution is a universal feature of shifting cultivation and has been reported for various parts of the tropics by Joachim and Kandiah (9), Nye and Greenland (11), Cowgill (6) and Ramakrishnan and Toky (13). The extent of nutrient decline is controlled by several factors, including types of crops grown, length of cultivation, cultural practices, cropping intensity, climatic conditions and intrinsic soil nutrient status. Cowgill (6) observed that shifting cultivation had little effect on the exchangeable calcium status of soils derived from limestone that were cultivated for two years. This is mainly because the soils were very rich in exchangeable calcium, having formed from limestone. In contrast, the results of the present study indicate that shifting cultivation leads to a substantial decline in the levels of exchangeable calcium and other nutrients in soils cultivated for 1-2 years. Soils in the study are were derived from sandstone parent material which is deficient in mineral nutrients. Thus, the soils are of low nutrient status and are therefore prone to nutrient exhaustion during cropping if fertilizers are not applied during cultivation.

The extent of nutrient and organic matter decline in shifting cultivation soil (relative to forest level) is greater in the topsoil layer (0-10 cm) than in the subsoil layer (10-30 cm). This is to be expected for the following reasons. First, the topsoil is exposed to the direct impact of adverse weather phenomena, including intense solar radiation following site clearance resulting in thermally-induced soil organic decomposition and mineralisation. Secondly, the soil erosion that results in considerable loss of organic matter and nutrients from shifting cultivation sites is confined to the topsoil layer. Finally, there is a net loss of nutrients from the topsoil to the subsoil due to leaching.

Soil physical status deteriorated as a result of shifting cultivation. Soils in the shifting cultivation sites are more compact and less porous than forest soil, This is mainly due to site exposure prior to and during cultivation (crops such as cassava, maize and yams grown in the study area do not completely cover the ground), tillage prior to cultivation and to organic matter diminution. The implication of a reduction in porosity in cultivated sites is that permeability will decrease; hence surface runoff and soil erosion will increase appreciably, leading to further loss of soil nutrients and deterioration in soil physical status.

Site exposure appears to be the major factor accounting for deterioration in soil chemical and physical status during the cropping phase of shifting cultivation. Cunningham (7) observed that site exposure alone, following three years of forest clearance, resulted in a 57% drop in the level of organic matter in the top 5 cm of the soil profiles, while soil total nitrogen and cation exchange capacity were reduced to 47% and 35% of their respective initial levels under rain forest. The soil became more compact, while total porosity and the proportion of water-stable aggregates in the soil were substantially reduced. A way of conserving soil physical and nutrient status during the cropping phase of shifting cultivation, therefore, would be to adopt measures such as mulching, which ensures that the soil is covered as much as possible. The application of artificial mulch is beyond the technical and financial capability of farmers in the study area, who would find it easier to apply trash of cleared fallow vegetation, crop and weed residues as mulch.

ACKNOWLEDGEMENT

The author is indebted to Mr. Ezekiel Akinwumi for his considerable assistance during the field work.

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