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EFFECT OF SHIFTING CULTIVATION ON AN UPLAND VOLCANIC SOIL IN NORTH-WEST CAMEROON

Effets des cultures itinérantes sur les sols d'une région volcanique d'altitude dans le Cameroun du NW

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RESUME

Les effets de la culture itinérante, ainsi que les teneurs en matière organique et en substances nutritives sont évaluées pour un sol volcanique d'altitude dans le NW du Cameroun en comparant des surfaces mises en cultures avec d'autres toutes proches laissées en jachère pendant 10 ans et protégées des feux de brousse.

La teneur en matière organique dans les horizons 0-10 et 10-30 cm est en général plus basse dans les zones cultivées que sous savane herbeuse. Ceci est dû aux effets cumulés des différentes expositions à l'air libre lors des façons de culture et du lessivage, de l'érosion et de la minéralisation des matières organiques qui se sont ensuivies. Les teneurs en Ca et en Mg échangeables sont toutefois plus élevées dans les parcelles cultivées. Celles-ci bénéficient de l'addition de cendres après brûlis.

Il n'y a aucune différence significative entre les deux types de parcelles en ce qui concerne les teneurs du sol en K échangeable.

ABSTRACT

The study evaluates the effects of shifting cultivation, the organic matter and nutrient status of an upland volcanic soil in north-west Cameroon. It compares the characterics soil under the cropping phase of shifting cultivation with those ones in an adjoining l0-year old grass savanna fallow protected from burning.

The organic matter contents of the 0-l0cm and 10-30cm layers of cultivated soil were generally lower than the levels in the grass savanna control plots. This is mainly due to the cumulative effects of soil exposure and the attendant effects of organic matter diminution resulting from leaching, erosion and rapid organic matter mineralisation in the cultivated sites over the years. The mean levels of exchangeable calcium and magnesium in cultivated soil were however higher than the levels in the corresponding layer of soil in the grass savanna control plots.This seemingly anomalous situation is presumably due to nutrient enrichment of the cultivated sites through the addition of ash derived from burnt vegetation slash, immediately prior to cropping.

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There were no significant differences between cultivated and the grass savanna soil with respect to exchangeable potassium status.

INTRODUCTION

The study of shifting cultivation is vital to the development of sustainable systems of arable farming in the humid tropics. An understanding of both the socio-economic and pedological aspects of shifting cultivation is essential for replacing the system with more intensive systems of arable farming. The socio-economic aspects of shifting cultivation have been examined by WATERS, (1971) and the F.A.O., (1984) amongst others.

As with socio-economic conditions, pedological aspects of shifting cultivation vary widely from place to place. Hence, a blanket solution cannot be applied to intensify shifting cultivation on a pantropical basis. In order to avoid dismal failures, it is important that proposed more intensive systems of arable farming for replacing shifting cultivation take full cognizance of local factors especially pedological and ecological conditions (AWETO, 1988). Studies such as that of NYE and GREENLAND, (1960) which presented a generalised account of soil dynamics during shifting cultivation should be supplemented by local detailed pedological and ecological studies in different ecological zones to provide a rational basis for intensifying shifting cultivation or replacing it with a more intensive system of agriculture. This brings to the fore the need to study shifting cultivation in different ecological zones and on different soil types.

Pedological aspects of shifting cultivation have received considerable attention from soil scientists in recent years. Most of the studies, however, focused mainly on non-volcanic soils under shifting cultivation in the lowland areas of the humid tropics (BRINKMANN & NASCIMENTO, 1973; JUO & LAL, 1977; AWETO, 1981, 1988; TOKY & RAMAKRIHNAN, 1983; JORDAN, 1987; UHL, 1987).

The present study examines an aspect of shifting cultivation on an upland volcanic soil in Ndu area, in North-West Province of Cameroon. It seeks to evaluate the effect of the cropping phase of the shifting cultivation cycle on the upland volcanic soil.

THE STUDY AREA

The present study was carried out in Ndu area in the North-West Province of Cameroon Republic. Physiographically the area is a part of the Bamenda lava plateau and has an average elevation of 1,500 to 3,200 metres above mean sea level. The study area, has an elevation of 1,800 - 2,000 metres. The topography is generally undulating and in many areas, the landscape is rugged and the ground is stony.

Owing to the high elevation of the plateau, temperatures are reduced and the annual temperature of Ndu area is 18° to 20°C. Night time temperatures are low occasionally falling below 5°C and frosts are experienced in the dry lasting from November to February. Annual rainfall is high owing to altitudinal effect and is usually about 2,000 mm. Ndu town has a mean annual rainfall of 2,114 mm. Most of the rains are concentrated in eight months of the year i.e. from March to October.

The vegetation is montane savanna, with scattered trees in which two grass genera, *Sporobolus* and *Hyparrhenia* feature prominently. Grass savanna interspersed with shrub or tree savanna is characterisc of large areas. The montane savanna presently found in Bamenda plateau of which Ndu area is a part, was originally a montane woodland but has become degraded into montane savanna due to frequent burning (HARRISON CHURCH, 1980). This obviously implies that the present savana vegetation in Ndu area is not the original climax vegetation. Given the heavy annual rainfall, it is not unlikely that the original (climax ?) vegetation of Ndu area is montane rain forest.

Relicts of the original montane forest or woodland vegetation are rare owing to the pervasive influence of man. Gallery forests, however, occur along river courses which have not been tempered with much by man for cultivation, owing to the high ground water table.

The soils of the study area have formed as a result of weathering of volcanic rocks, especially basalt and trachyte lavas. The soils are dark in colour and contain high levels of organic matter (HAWKINS & BRUNT, 1965). However, when a site is burnt prior to cultivation the dark-coloured soils become brownish in generally acidic and this is a reflection of the heavy annual rainfall experienced in the area which results in the leaching of base cations, particularly calcium from the soil.

Permanent cultivation featuring tea growing in plantation and shifting cultivation featuring the intercropping of cassava, yams, sweet potatoes, cocoyams, maize, beans and groundnuts on a subsistence basis, are the main features of the agricultural economy. Land preparation for cultivation usually begins prior to the inception of the rainy season i.e. between the months of December and March. The vegetation, usually dominated by grasses, is either burnt or cleared with machete and allowed to dry before being burnt to open up the land for cultivation. The ash released by the burnt vegetation adds nutrients into the soil thereby helping to enhance its nutrient status.Because of the fairly steep slopes characteristic of the area, the farmers practise contour farming or leave strips of fallow vegetation between cultivated plots in order to minimise the hazard of soil erosion.

METHODOLOGY

The effects of shifting cultivation on soil in the study area were inferred by comparing the properties of the soil under shifting cultivation with similar soils (occurring on similar position on the catena and having comparable profile characteristics) under ten year old savanna bush fallow vegetation. As was pointed out earlier, the original woodland climax vegetation of the study area has been degraded into savanna and hence could not be used as the control in the present study. The gallery forests referred to earlier occur near the rivers and are characterised by alluvial soils of fluvio-volcanic origin. Such soils are quite distinct from soils in the upper slope units of the topography which are derived exclusively from volcanic parent materials. Since shifting cultivation is practised mainly on the upper slope segments of the topography and the gallery forests occur in the footslope adjoining rivers, the soils in the gallery forest were considered unsuitable for use as a control.

Hence, a ten-year old savanna grass fallow vegetation in Ndu tea estate was used as a control. Only, upper slope sites in the ten-year old fallow vegetation which are comparable with the shifting cultivation sites were sampled. The fallow vegetation is the oldest in Ndu area, and presumably, it represents the most advanced stage of soil fertility restoration (after cultivation) in the study area where the fallow period is usually under five have years. Besides the fallow control plots have been protected against burning, implying that the process of soil fertility restoration has not been periodically interrupted as a result of savanna burning. However, it should be pointed out that the fallow control plots do not represent the ideal pre-cultivation status of soils in the study area as the savanna vegetation is not the original climax vegetation.

A map of the study area of Ndu and the surrounding villages was used as the sampling frame for selecting the fallow and shifting cultivation sites studied. Areas under fallow and those currently under the cropping phase of shifting cultivation were delimited and the map gridded. The grid intersections were numbered and the fallow or cultivated site nearest a randomly chosen grid intersection was selected for study. Using this procedure ten shifting cultivation sites and ten sites under old fallow vegetation were selected for study. In each site, a sample plot of 20 m by 20 m was delimited and soil samples collected from five randomly located points within the plot. The soils samplers were collected from two depths of 0-l0cm and 10-30cm. for each plot, the five soil samples for each layer were mixed together to obtain a composite soil sample The composite soil samples were air dried, passed through a 2mm sieve and analysed for particle size composition using the hydrometer method (BOUYOUCOS, 1926) and organic carbon by the method of WALKLEY and BLACK, (1934). Soil pH was determined potentiometrically in 0.01 M calcium chloride solution using a soil to solution ratio of 1 : 2 (PEECH, 1965). The soils were leached with 1 M neutral ammonium acetate and the leachate used for determining the levels of soil exchangeable cations. Exchangeable potassium was determined by flame photometry while exchangeable calcium and magnesium were determined by atomic absorption spectrophotometry.

RESULTS

Table I shows the physical and chemical properties of the 0-l0cm layer of cultivated soil and soil under fallow vegetation in the study area. The proportion of clay in both cultivated and fallow soil are comparable but fallow soil is more sandy than that under cultivation.The amount of silt in the cultivated soil is also higher than that of soil under bush fallow vegetation, The trend of variation in soil inorganic fragments is similar in both the 0-10cm layer and in the immediately underlying layer of 10-30cm.

The amount of organic matter in 0-10cm layer (topsoil) of cultivated soil is lower than that in the corresponding layer of soils under bush fallow vegetation ($P < 0.01$). The mean level of organic matter in the topsoil of cultivated soil has been reduced to 75.5 % of the level under bush fallow vegetation. In the subsoil layer, the mean level of soil organic carbon level in cultivated soil is lower than in soil under bush fallow vegetation.

Tab.I : Properties of 0-10cm and 10-30 layers of soils under shifting cultivation and bush fallow vegetation..

0-10 cm layer	10-year bush fallow vegetation*	shifting cultivation*
Sand (%)	82.1 (1.40)	69.8 (1.82)
Silt (%)	4.1 (1.18)	16.8 (1.58)
Clay (%)	13.8 (0.56)	13.4 (1.35)
Organic Carbon (%)	9.4 (1.41)	7.1 (0.55)
Exchangeable calcium (m.e./100 g of soil)	0.12 (0.32)	0.23 (0.05)
Exchangeable magnesium(m.e./100 g of soil)	1.55 (1.41)	2.11 (0.47)
Exchangeable potassium (m.e./100 g of soil)	1.13 (0.13)	1.09 (0.27)
pH	4.6 (0.06)	4.7 (0.07)
10-30 cm layer		
Sand(%)	80.5 (2.54)	65.8 (2.52)
Silt(%)	4.6 (1.02)	18.1 (1.99)
Clay(%)	14.9 (1.20)	16.1 (1.73)
Organic Carbon(%)	8.3 (0.33)	5.7 (0.22)
Exchangeable calcium (m.e./100 g of soil)	0.04 (0.02)	0.12 (0.03)
Exchangeable magnesium(m.e./100 g of soil)	0.75 (0.30)	1.57 (0.27
Exchangeable potassium (m.e./100 g of soil)	0.84 (0.11)	1.14 (0.23)
pH	4.6 (0.04)	4.5 (0.06)

*(values) are standard errors

The levels of organic carbon in soil under both the cultivation and fallow phase of shifting cultivation in Ndu area are generallv much higher than the levels reported by AWETO (1981) for rain forest soil in south-western Nigeria, soils under savanna vegetation and savanna fallow in West Africa (AREOLA *et al.*, 1982; JONES & WILD, 1975) and for both cultivated and forest soil in the monsoon forest of north-east India (TOKY & RAMAKRISHNAN, 1983) and for soils under rain forest in Venezuela (UHL & JORDAN, 1984). They are however comparable with data of HAWKINS and BRUNT (1965) for the study area and with the organic carbon data of volcanic tropical soils reported by MOHR *et al.* (1572) and KALPAGE (1974).

The level of exchangeable calcium in the 0-1 cm layer of cultivated soil in Ndu area are significantly higher than that in the corresponding layer of soils under bush fallow vegetation ($P < 0.05$) while the levels of exchangeable magnesium are only slightly higher than that of bush fallow soil. The mean levels of exchangeable potassium and pH are comparable in both the 0-l0 cm layer of cultivated and fallow soil (Table I). In the 10-30 cm layer of the soil mean levels of exchangeable calcium and magnesium are significantly higher under cultivated soil ($P < 0.05$). The differences between the levels of pH and exchangeable potassium in soils under bush fallow vegetation on the one hand and shifting cultivation sites on the other were not proven to be statistically significant.

Generally, the levels of exchangeable nutrient cations in both cultivated and fallow soil in the study area are low. They are much lower than the levels reported for forest and savanna fallows in south-western Nigeria (AWETO, 1981, AREOLA *et al.* 1982) and cultivated soil in West African savanna (JONES & WILD, 1975) and cultivated forest soil under shifting cultivation in Venezuela (JORDAN, 1987).

DISCUSSION

The lower organic matter status of cultivated soil indicates soil organic matter diminution during the cropping phase of the shifting cultivation cycle. Owing to site exposure during cropping (cultivated crops do not completely cover the ground, especially before they are in full foliage), soil erosion and leaching result in organic matter decline. Besides, site exposure during cropping increases soil temperatures and the rate of humus decomposition in the soil (NYE & GREENLAND, 1960). The mean organic matter index of cultivated soil i.e. the level of organic matter in cultivated soil expressed as a percentage of 'virgin' uncultivated soil is 75.5% for the 0-10cm layer and 68% for the 10-30cm layer. These rather high cultivation indices presumably suggest that the rate of soil organic matter decomposition is slow as to be expected in a high altitude location where temperatures are reduced. The point need be stressed however, that the old fallow vegetation used as the basis for calculating the cultivation index has been cultivated in the past. The high cultivation indices therefore, partly reflect the fact that the organic matter level in soil under the old fallow vegetation has not yet attained the level typical of the climatic climax of the study area.

Although the study area is currently under grassland vegetation, the levels of organic carbon in both cultivated and fallow soil are much higher than the levels reported for soils under savanna fallows and even under largely undisturbed rain forest ecosystems in parts of Africa and in the Amazon basin of South-America. The exceptionally high organic matter levels in soils in the study area is mainly due to two reasons. First, owing to the high altitude location of the study area, temperatures are considerahly reduced. The obvious implication of this that the rate of organic carbon decomposition in the soil is much lower than in well-drained soils in the lowland tropics. Secondly, the soils of the study area are of volcanic origin and are presumably rich in allophane which has the effect of adsorbing soil organic matter, thereby stabilising it against microbial decomposition. This latter reason explains why volcanic soils, which usually contain allophane, have high levels of organic carbon.

The levels of exchangeable calcium and magnesium in cultivated soil are higher than in soils under bush fallow. This seemingly anomalous situation is due to the residual effect of site burning prior to cultivation. The cultivated sites were sampled three to five months after burning and their soils presumably still contain part of the ash derived from the burn. This accounts for why the exchangeable calcium and magnesium status of cultivated soil is higher than that of soil under 10-year old fallow vegetation. JORDAN (1987) reported that following burning of the slash of cut forest vegetation in Venezuela, the levels of exchangeable calcium, and magnesium rose sharply in cultivated soil and surpassed the levels in pre-burn forest soil. The levels of exchangeable calcium and magnesium in the Venezuelan soil under shifting cultivation remained higher than the levels in soil in forest soil, prior to burning, even after, three consecutive years of cultivation. In JORDAN's study (1987), the levels of exchangeable calcium and magnesium in the soil increased several fold following forest burning. This is mainly because it was a mature forest with a large biomass that was burnt, thereby releasing large quantities of ash into the soil. In the study area, the savanna vegetation is less densely stocked with trees and has a much smaller biomass than the Amazon forest in Venezuela studied by JORDAN (1987). Consequently less ash is released into the soil as a result of vegetation slash burning prior to cultivation. This fact combined with the intense leaching the soils are subjected to as a result of the heavy rainfall has made the effects of soil nutrient supplementation through ash addition not to be as marked as in the Venezuelan forest soils under shifting cultivation. In fact after three to five months of site burning in the study area, the levels of exchangeable calcium and magnesium in cultivated soil are under twice the level in the soil under l0-years old bush fallow vegetation while their pH and exchangeable potassium levels are comparable.

In spite of the high soil organic matter levels, the levels of nutrient cations (especially calcium) in both cultivated and fallow soil in the study area are very low. This is partly because the soils are derived from acidic lava which is deficient in plant nutrients. The levels of exchangeable calcium and magnesium in soil under 10 years old fallow vegetation in Ndu area are less than one tenth of the levels in soil under l-year old bush fallow vegetation in south-western Nigeria (AWETO, 1981). This again largely reflects the nature of the base deficient acid lava from which the soils were derived, the intense leaching to which they have been subjected and the nature of the fallow vegetation itself. The relatively low levels of nutrients under ten-year old grass fallow vegetation in Ndu area suggests that grasses have a low efficiency of recycling nutrients back to the soil surface. It would seem that in the humid tropics, nutrients are leached beyond the rooting zone of grasses during cropping. Trees and shrubs in fallow vegetation with deep roots appear to be the main agents of recycling such nutrients back to the soil surface for cultivated plants to use during the subsequent phase of cropping. The paucity of trees in bush fallow vegetation in Ndu area implies that a substantial part of the nutrients leached beyond the top soil during cropping cannot be recycled back during the fallow period. In fact, a grass fallow is less effective than a woody one in recycling nutrients to the topsoil (NYE & GREENLAND, 1960). A way of enhancing nutrient build-up in the predominantly grassy fallow in Ndu area would be to introduce trees into the fallows. Alternatively, alley cropping which involves growing crops between rows of trees which are pruned periodically and the loppings applied to the soil as mulch (KANG *et al.*, 1984) should be introduced. The introduction of alley cropping will .not only reduce soil leaching but also enhance.and facilitate the process of nutrient recycling to the surface layer of the soil.

The low levels of exchangeable nutrient cations in cultivated soil in Ndu area, a few months after burning, suggests that the effects of soil nutrient supplementation through the addition of ash when fallow vegetation is burnt, is not very marked. This is mainly due to the small biomass of savanna grass fallows which contain only a few trees and it points to the need to apply organic or inorganic fertilizers to enhance nutrient availability during cropping of the base-deficient soils.

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