DYNAMICS AND INTERRELATIONSHIP BETWEEN SOIL AND VEGETATION CHARACTERISTICS IN FALLOW COMMUNITIES IN THE RAINFOREST ZONE OF MID-WESTERN NIGERIA

Dynamique des interrelations entre sol et végétation dans les jachères (forêts secondaires) de la forêt dense du Centre-Ouest du Nigéria

A. OGIDIOLOU*

RESUME

L'évolution du sol et de la végétation au cours de période de jachère ont été analysées, dans leur interrelation, en utilisant la statistique inférentielle, à partir des observations faites dans des placeaux à différents stades de développement (de 1 à 10 ans) et en comparaison avec la forêt naturelle. En 10 ans de jachère, le recru atteint les 2/3 de cette dernière. En ce qui concerne le sol, le changement affecte surtout la teneur en matières organiques et la capacité au champ et cela, essentiellement au cours des trois premières années. Pour la région considérée, une jachère de trois ans est donc suffisante. Il se produit par ailleurs des interactions entre sol et végétation: si matières organiques et capacité au champ ont une influence sur la hauteur et la densité des arbres ainsi que sur la biomasse de la litière, les plantes, à leur tour, jouent un rôle dans l'évolution de certains caractères du sol.

ABSTRACT

Changes in soil and vegetation characteristics during bush fallowing was examined using inferential approach. Except grass density, all other vegetation characteristics studied increased with the age of fallow communities. Vegetation recovery in 10-year fallow is about two-third of those in the natural forest plots. No significant change occurs in soil texture over the entire fallow period but the water holding capacity increased from 37.3% in 1-year fallow to 54.4% in 10-year fallow. Organic matter content of the soil increased over the fallow period but about 69% of this occurred in the first three years of fallow.

Three years fallow period is considered adequate for this region. Results of the different correlation models show that significant interrelationships exist between soil

* Department of Geography and Regional Planning, University of Benin, Benin City, Nigeria

and vegetation during fallow period and this is dynamic. While soil properties such as water holding capacity, soil organic nutrients exert significant influence on plant characteristics namely tree height, tree density and litter biomass, these plant characteristics also influence soil properties significantly.

INTRODUCTION

In most parts of the tropics especially tropical Africa, the natural vegetation has been replaced by mosaic of secondary vegetation and so today fallow vegetation of different ages forms the main vegetation in many areas.

Although a large number of ecological studies have been carried out on fallow in different areas, most of the earlier studies were either focused on vegetation development alone or changes in soil alone. Both soil and vegetation are multivariate phenomena which are interwovenly related. These two components of the landscape exert reciprocal influence on each other hence a study of one to the neglect of the other, is inadequate approach (TRUDGILL, 1978).

Bush fallowing is a major land management technique in tropical Africa as it enhances the restoration of soil fertility during abandonment of cultivated plots. The dynamics and interrelationship of vegetation and soil characteristics during fallowing has been relatively neglected compared to other topical issues on fallow communities such as vegetation development, structure and floristic composition (CLAYTON, 1958; AHO, 1958; JAIYEBO & MOORE, 1964; AWETO, 1981) and process of soil and vegetation recovery (restoration) (AWETO, 1981a,b,c; TOKY & RAMAKRISHNAN, 1983; ADEJUWON & ADESINA, 1988; ADEJUWON *et al.*, 1989).

To enhance our understanding of interactions between soil and vegetation during bush fallowing, this paper examines changes in soil properties under bush fallow and the interrelationship between some characteristics of fallow vegetation and soil properties with a view to identifying those characteristics of fallow vegetation which are crucial in the processes of soil fertility recovery. Two hypotheses are tested in this paper:

(i) the there is no change in soil properties under bush fallow of different ages, and

(ii) that there is no clearly defined pattern of soil-plant relationships during bush fallowing.

THE STUDY AREA AND SITES

This study was carried out in Ekpoma and Irrua districts which are in part of the Midwestern plain of Nigeria. This area lies roughly between latitude 6° 30' and 6° 55' N, 6°00' and 6° 55' E.

The mean annual rainfall is between 1500mm and 2000mm and temperatures high throughout the year with an annual mean of about 25.6°C and a range of 3°C. The original vegetation of this area is the tropical rainforest (ILEOJE, 1965). This has been destroyed and replaced by fallow vegetation (which are physiognomically forest at various stages of development), and by farms (ADEJUWON *et al.*, 1989). The soils of the area are ferrallitic soils (D'HOORE, 1964) derived mainly from Tertiary shales (REYMENT, 1965). The dominant clay mineral of the soil is kaolinite giving rise to soils with low to moderate nutrient status (FANIRAN & AREOLA, 1978).

Fallow communities of 1, 3, 7 and 10 years were chosen and a mature rainforest as control plot. Fallow in the early stages (i.e. 1 and 3. years) are typically herbaceous dominated mainly by forbs especially *Chromolaena odorata* and to a lesser extent by grasses species such as *Pennisetum* spp. With increasing age of the fallow, tree species become increasingly more apparent, thus the 7 and 10 years fallow were expectedly dominated by trees such as *Sterculia tragacantha*, *Phyllantus discodeus*, etc. The dominant tree crops in the area include *Theobroma cacao*, *Hevea brasiliensis*, *Elaeis guineensis* while the foodcrops include *Manihot esculenta* (cassava) *Xanthosoma sagittifolium* (cocoyam), *Zea mays* (maize) and *Oryza sativa* (rice). The mature rainforest is a highly diversified community with tall trees such as *Terminalia* spp., *Milicia excelsa*, *Chorophora excelsa*, *Entandrophragma angolense*, *Triplochiton scleroxylon* as dominant species.

METHODOLOGY

To investigate the dynamics of soil and vegetation components of bush fallow, it is desirable to determine the nutrient status of the soil prior to fallowing. Thereafter the characteristics of soil and vegetation are monitored at regular intervals and compared with the initial condition in order to determine the trend of change in soil and vegetation characteristics during fallowing (AWETO, 1985). An alternative approach involves analysing fallow at varying ages and comparing them with mature forest plots. This approach is known as inferential approach and was advocated by AWETO (1985). In this study this alternative approach was adopted.

Bush fallow of ages 1, 3, 7 and 10 years were selected from an area that is uniform with respect to soil types, parent material, macroclimate, slope positions and landuse practices. Therefore in this study inferences about change in soil and vegetation properties are made by comparing the mean values of soil and vegetation characteristics under fallows with those of the mature rainforest in the same locality. Although this is recognised as major limitation in the study, the approach will enable us to analyse the trend of change in soil and vegetation parameters over time. Thus since fallow vegetation is in successional development that will revert to mature forest if left undisturbed, it is justifiable to regard the soil and vegetation characteristics in mature rainforest as the ultimate.

For detailed sampling, the map of the study area was divided into 2 kilometre squared grids and serially numbered. With the aids of the table of random numbers, 10 of them were select for study. In each of 4 km² on the ground, 4 fallow age categories were identified. Ten sample plots of 40m x 25m were demarcated covering the centre of the fallow. This sample plot size falls within the range of quadrat sizes suggested by WESTHOF & MAAREL (1978) for ecological studies in the tropics. The age of the fallow were determined by interviews with local farmers who last cultivated each of the chosen plots. Altogether 60 plots comprising 50 fallow plots and 10 mature forest plots were selected. In each plot, soil samples were collected from a randomly selected point from the top 0-15cm subsequently referred to as topsoil in this paper.

Sampling were limited to the first few centimetres of the soil profile where significant effect of fallow succession on soil properties are usually concentrated (NYE & GREENLAND, 1960; AWETO, 1981a,b; ADEJUWON *et al.*, 1989). The soil samples were air-dried, sieved with a 2mm sieve and analysed for particle size composition by the hydrometer method (BOUYOUCOS, 1926); soil pH determined potentiometrically in 0.01M $CaCl_2$ solution using a soil to solution ratio of 1:2; organic matter content by Walker-Black's method (1934); nitrogen determined by adding 2,4 phenoldisulfonic acid on the prepared sample solution. Available phosphorus was determined by the method of Bray and Kurtz (1945). Exchangeable magnesium was determined by atomic absorption spectrophotometry, while levels of exchangeable calcium, potassium and sodium were determined by flame photometry. Water holding capacity was determined by saturating soil samples with water then allowing them to drain for twenty four hours before being oven dried.

In each sample plot, the following characteristics of fallow vegetation were measured: the tree height, determined using the trigonometric relationship after determining the slope with Abney level. The final tree height was determined using the Pythagoras equation : $\tan \theta = x/n$. Diameter at breast height was measured by normal steel tape and the value divided by π (CHIJIOKE, 1991), and expressed in centimetre. Tree density was determined by counting. Tree frequency was determined by multiplying the density by one hundred (percent). In this study a tree was defined as a woody plant with a diameter at breast height (D.B.H.) greater than or equal to 2cm (KERSHAW, 1963). Litter biomass (leaf litter that fall up to 2cm depth within the plot) was taken to the laboratory and weighted after oven drying at 105° for 72 hours. Grass density was also determined by counting (ASHBY, 1969).

DATA ANALYSIS

The patterns of soil and vegetation parameters under bush fallow were examined using descriptive statistics. Simple bivariate correlation was used to assess the strength of relationship between the vegetation and the soil properties. Canonical correlation analysis was also used to relate vegetation and soil properties of the fallow communities. Thus while the simple bivariate correlation analysis relates the individual soil properties with the vegetation characteristics, canonical correlation analysis simultaneously relates all the soil properties with the vegetation gradients.

RESULTS AND DISCUSSION

VEGETATION AND SOIL CHARACTERISTICS.

Table I shows the summary data on the vegetation parameters of the fallow communities. It was observed that all vegetation parameter examined except grass density increase with the age of the fallow. Tree height and diameter at breast height both show marked increased between ages 7 and 10 years. Observations in some other parts of Nigeria show that tree height exhibits an initial rapid growth during the first 7 years but remains nearly constant thereafter (AWETO, 1981a)

Tab.I. - Summary of descriptive statistics for the vegetation parameters of the fallow communities.

Vegetation parameter	1-year		3-year		7-year		10-year	
	Mean	*C.V.*	Mean	*C.V.*	Mean	*C.V.*	Mean	*C.V.*
Tree height (m)	2.96	*16.0*	6.0	*13.0*	6.96	*28.4*	10.56	*12.0*
D. B. H. (cm)	2.72	*10.1*	3.47	*13.5*	5.80	*14.0*	8.37	*19.5*
Tree density (ha^{-1})	1160	*14.4*	288	*12.2*	2320	*14.4*	2460	*12.2*
Grass density (ha^{-1})	1128	*30.0*	796	*20.1*	526	*18.7*	262	*26.2*
Litter biomass (g)	13.4	*31.4*	23.4	*9.4*	27.0	*28.9*	28.2	*5.2*

C.V. = coefficient of variation
D.B.H.= Diameter at breast height (cm)

The results of this study in contradistinction from others indicate a slow height growth followed by a more rapid increase during fallow period. The differences in the results of this study and others observed elsewhere may be because of differences in species composition of the forest studied and the environmental conditions especially rainfall condition. While the present study area is wetter, the area studied by AWETO (1981) is a more dry deciduous forest. Also, soil types rainfall distribution and farming systems differ between the two study areas. In fact the mean height values obtained in this study are higher than those reported by AWETO (1981). The increase in the mean values of most vegetation parameters with the age of the fallow is expected because as HALL & OKALI (1979) observed bush fallowing is a regenerative and restorative system and all fallow stages are progressing towards the final climax community. When compared to mature forest in the same environment, the mean values of vegetation parameters in fallow communities represent between 22.2% - 35/8% for 1 year fallow plots, to 62% - 76.3% for 10 year fallow plots. Unlike observations for some other regions (AWETO, 1978; HALL & OKALI, 1979), the 10 year fallow plots in this study represents only half to two-third of the condition under the mature natural forest, therefore with respect to vegetation it may take 20-30 years of fallow to revert to conditions under the natural forest (assuming no disturbances).

Tab.II. - Summary of descriptive statistics of soil characteristics under the different fallow communities

Soil property	1-year		3-year		7-year		10-year		Mature forest	
	Mean	C.V.	Mean	C.V.	Mean	C.V.	Mean	C.V.	Mean	C.V.
Sand (%)	72.16	*1.17*	74.64	*4.14*	77.08	*4.25*	84.72	*2.39*	86.84	*41.9*
Silt (%)	6.30	*13.4*	9.66	*14.4*	8.62	*26.6*	3.18	*4.69*	4.66	*20.5*
Clay (%)	21.54	*71.9*	15.7	*19.5*	14.30	*23.9*	12.1	*8.09*	8.50	*8.21*
WHC (%)	37.30	*7.71*	45.56	*8.76*	51.96	*7.71*	54.48	*8.76*	61.57	*4.96*
pH	6.48	*5.93*	6.20		6.20	*5.93*	5.80	*4.40*	5.60	*5.50*
O.M. (%)	1.76	*17.9*	2.68	*21.3*	2.82	*13.1*	3.14	*18.1*	3.88	*9.18*
Total N (%)	0.11	*18.2*	0.15	*20.1*	0.17	*13.2*	0.17	*22.3*	0.24	*11.5*
*Exch. Na^+	0.17	*23.3*	0.31	*9.85*	0.43	*9.72*	0.57	*14.4*	0.68	*26.0*
*Exch. K^+	0.21	*9.69*	0.28	*25.1*	0.40	*13.6*	0.47	*18.5*	0.62	*20.7*
*Exch Ca^{++}	0.37	*10.3*	0.39	*12.4*	0.49	*21.1*	1.07	*22.6*	1.32	*6.34*
*Exch. Mg^{++}	0.96	*9.19*	1.09	*3.96*	1.21	*7.95*	1.47	*27.8*	1.93	*23.5*
Available P	1.50	*10.1*	1.96	*18.7*	2.42	*9.94*	3.14	*16.2*	3.64	*8.85*

* en $mmol.kg^{-1}$
O.M. = Organic Matter

Table II shows the pattern of soil characteristics under the different fallow age categories. Generally topsoil in this area is sandy with sand fraction of the inorganic fragments accounting for over 70% in all plots. A comparison of the soil textural properties among the different fallows shows that there are some differences in the mean values of these parameters, the difference were however not significant.

The water holding capacity (WHC) increased gradually from 31.3% under 1-year fallow plot to 54.4% under the 10-year hold plot. In general with the exception of water holding capacity soil physical properties under the different fallow ages does not show significant changes over time.

The significant improvement in water holding capacity of the soil can be attributed to the increase in the concentration of organic matter over time. In fact in the 10 year fallow plot a correlation coefficient of 0.95 was obtained between organic matter and water holding capacity. Organic matter is hydroscopic, so it contributes to the water holding capacity in tropical soils (OLAITAN & LOMBIN, 1988). Organic matter level in soil increased progressively from a mean value of 1.76% under the 1-year fallow plot to 3.14% under the 10-year fallow plot. Similar progressive increase with age of fallow plot were recorded for nitrogen and available phosphorus. The increase in these organic nutrients are similar to that of organic matter. There are many reasons for the progressive accumulation of organic matter in soil during fallow in this area. First, the gradual increase in vegetation cover especially by types and composition. Over the years, one plant community is replaced by another with greater capacity to protect the soil against accelerated organic matter destruction (AWETO, 1981b). Secondly, with increasing age of the fallow, the amount of litter added to the soil increased. Whereas in 1 year fallow plots forbs predominate in the older fallow plots, trees are more dominant and generate more litter.

A comparison of the mean value of these organic nutrients including organic matter using the analysis of variance (ANOVA) shows that there are significant differences between the different fallow ages. This comparison also gives an idea of the rate of change in these soil properties. For instance, the results show a rapid increase in organic matter during the first three years of fallow followed by a slow rate of increase. Going by the mean level under the forest plots which is regarded as the bench mark level organic matter in the 3-year fallow represent about 69%, thus we can infer that lightest accumulation of organic matter during the fallow period occurs during the first three years. Therefore with minimal input from other sources a 3-year fallow may be considered adequate resting period for farmlands in this region. This observation may further suggest that leaving land fallow for much longer than 3 years may not result in appreciable addition of organic matter in this area. Therefore unlike the observation made by AWETO (1981a) of 10 years fallow period in more drier environment 3-year fallow will be adequate in this wetter region. The difference in the result of this study and that of AWETO (1981b) was obviously because of difference in climate conditions in the two study sites, the present study area being in a wetter latitude hence, more luxuriant and vegetative growth and greater rate of organic matter decomposition and accumulation are expected.

Exchangeable cations show a gradual increase with the age of the fallow. The general increase in the level of most soil chemical properties with the age of the fallow plots is an indication of the improvement of the chemical fertility status during fallowing in this area.

SOIL AND VEGETATION INTERRELATIONSHIPS

Simple Pearson bivariate correlation and canonical correlation coefficients were computed to determine the nature and extent of relationships between soil and vegetation characteristics. While simple bivariate correlation analysis gives the patterns of the interrelationships, canonical correlation analyses gives the underlying relationship i.e. the main ways in which the properties of the soil are related to those of vegetation.

Table III shows the correlation coefficient between soils and vegetation properties in different fallow communities. In the 1-year fallow, significant relative correlations exist between tree height and water holding capacity ($r = 0.81$): tree height and exchangeable potassium ($r = 0.72$); and between litter biomass and organic matter ($r = 0.95$). Soil textural characteristics especially sand exhibit negative correlation with tree height, diameter at breast height and tree density. The patterns of relationships in the 3-year fallow are similar to those of 1-year old. In the older plots (7 and 10 years fallow) organic matter exhibits higher significant correlations with most vegetation parameters e.g. organic matter and tree height ($r = 0.80$); with diameter at breast height ($r = 0.63$); and with density ($r = 0.85$). These observations suggest that organic matter content of the soil is highly related to increases in these fallow vegetation characteristics.

Tab.III. - Correlation between vegetation parameter and topsoil (0-15cm) properties

1-year fallow	Litter biomass	Tree height	D.B.H.	Grass density	Tree density	Tree frequency
% sand	0.60	-0.55	-0.68	-0.35	-0.07	-0.07
% silt	0.51	-0.88	-0.41	0.51	-0.35	-0.35
% clay	0.80	-0.18	0.77	0.07	-0.54	-0.54
W.H.C.	-0,33	0.81	-0.07	-0.92	-0.31	-0.31
pH	0.22	-0,03	0.25	-0.36	0.70	0.70
Org. matter	0.95	0.31	0.18	-0.29	0.97	0.97
Total N	0.06	0.40	0.21	-0.38	0,95	-0.95
Na^+	0.42	0.15	0.56	-0.75	0.20	0.20
K^+	0.12	0.72	0.26	0.71	-0.09	-0.09
Ca^{++}	-0.47	0.09	-0.60	-0.33	0.95	0.95
Mg^{++}	0.75	-0.73	0.70	0.03	0.31	0.31
Available P	-0.05	0.62	0.20	-0.83	-0.71	-0.71

3-year fallow	Litter biomass	Tree height	D.B.H.	Grass density	Tree density	Tree frequency
% sand	0.56	-0.52	-0.51	-0.63	0.52	0.52
% silt	-0.60	0.07	-0.40	0.91	-0.40	-0.40
% clay	-0.04	-0.66	-0.50	-0.98	-0.18	-0.18
W.H.C.	0.57	0.49	0.53	0.44	0.55	0.55
pH	0.67	0.42	0.45	0.82	0.20	0.21
Org. matter	0,73	-0.27	-0.53	0.03	0.43	0.43
Total N	0,07	-0.27	-0.53	0.04	0.42	0.42
Na^+	-0.89	-0.15	-0.45	-0.34	0.12	0.12
K^+	-0.54	0.75	0.45	0.23	0.95	0.95
Ca^{++}	0.90	-0,13	-0.13	0.03	-0.07	-0.07
Mg^{++}	-0.30	-0.83	-0.83	-0.82	-0.43	-0.43
Available P	0.22	-0.30	-0.53	0.10	0.35	0.35

7-year fallow	Litter biomass	Tree height	D.B.H.	Grass density	Tree density	Tree frequency
% sand	0.62	-0.63	-0.87	-0.50	-0.25	-0.25
% silt	-0.53	-0.13	-0.47	0.49	0.80	-0.80
% clay	0.76	-0.25	0.31	0.20	-0.66	-0.66
W.H.C.	-0.11	0.47	-0.35	-0.91	-0.47	-0.47
pH	-0.12	-0.32	0.39	0.37	0.41	0.41
Org. matter	0.98	0.80	0.63	0.85	0.50	0.50
Total N	0.07	-0.79	0.63	0.87	0.49	0.47
Na^+	0.15	0.03	-0.09	0.43	-0.47	-0.47
K^+	-0.32	-0.44	0.30	0.56	0.70	0.70
Ca^{++}	-0.08	-0.69	0.63	0.15	0.20	0.20
Mg^{++}	-0.21	-0.80	0.44	0.72	0.65	0.65
Available P	-0.15	0.37	0.16	0.84	0.68	0.68

10-year fallow	Litter biomass	Tree height	D.B.H.	Grass density	Tree density	Tree frequency
% sand	-0.49	0.44	-0.77	-0.10	0.53	0.53
% silt	0.50	0.29	-0.16	0.17	0.73	0.73
% clay	-0.08	0.14	0.48	-0.16	-0.80	-0.80
W.H.C.	-0.87	-0.13	-0.54	-0.24	-0.14	-0.14
pH	0.66	0.00	0.56	-0.21	-0.19	-0.19
Org. matter	-0.87	-0.04	-0.75	-0.22	0.15	0.15
Total N	-0.76	0.22	0.88	-0.09	0.46	0.46
Na^{+}	0.16	0.73	-0.39	-0.18	0.60	0.60
K^{+}	0.04	0.52	-0.57	0.13	0.83	0.83
Ca^{++}	0.23	-0.57	0.40	0.84	-0.10	-0.10
Mg^{++}	0.65	0.77	-0.14	-0.39	-0.68	-0.68
Available P	-0.16	0.60	-0.62	-0.70	0.50	0.50

The pattern of the interrelationships between soil properties and vegetation characteristics as revealed by the results of the simple correlation analysis suggest that there is no one major or dominant pattern, as the patterns of relationship vary from one age category to another. Hence the canonical correlation analysis was performed on the same set of raw data.

Canonical correlation examines the way in which two multivariate phenomena are related and the strength and nature of these relationships (VELDMAN, 1967; RAY & LOHNES, 1973). From each of the sets of multivariate phenomena, a linear combination is derived in such a way that the correlation between them is maximum. These pairs of maximally correlated combination are called canonical variates (COOLEY & LOHNES, 1971)

The result of the canonical analysis for the fallow communities is summarised in table IV. Two canonical variates were extracted for each age category and each is identified by soil and vegetation components.

In the 1-year fallow plot while the canonical variate indicates a strong positive relationship of available phosphorus with tree height and litter biomass, the second variate indicates a strong positive relationship of total nitrogen and water holding capacity with diameter at breast height. In the 3-year fallow, the first canonical variate indicates a strong negative relation of soil pH and tree height meanwhile the second variate indicates strong positive relationship of organic matter and available phosphorus with litter biomass.

In the 7-year fallow community, the first variate indicates a strong positive relationship of water holding capacity and litter biomass; the second variate indicates a strong negative relationship of clay content with grass density. In the 10-year fallow plot, the first canonical variate indicates a strong negative relationship of sand content with diameter at breast height and the second variate indicates a strong positive relationship of exchangeable calcium and organic matter with grass density.

Tab.IV. - Canonical factor structure matrix of topsoil properties and vegetation parameters of fallow plots. Canonical loading

	1-year fallow		3-year fallow		7-year fallow		10-year fallow	
Canonical variate	I	II	I	II	I	II	I	II
SOIL PROPERTIES								
% sand	0.29	0.07	0.16	0.55	0.87	-0.60	-0.97	0.28
% silt	0.84	-0.72	0.29	0.24	0.28	0.02	-0.13	0.00
% clay	0.86	0.53	-0.40	0.98	-0.30	0.96	0.27	0.01
W.H.C.	0.68	0.75	0.79	0.70	0.98	0.21	0.05	0.05
pH	0.44	0.47	-0.99	0,30	-0.50	0.34	0.23	0.12
organic matter	0.39	-0.60	0.53	0.88	0.30	-0.61	-0.87	0.74
total N	0.55	0.85	0.86	0.53	0.15	0.50	0.03	-0.52
Na^+	0.93	0.40	0.40	-0.93	0.29	0.22	0.02	0.14
K^+	-0.04	0.00	0.04	0.01	0.17	-0.33	0.01	0.11
Ca^{++}	0.99	-0.43	0.37	0.93	0.88	-0.95	0.00	0.97
Mg^{++}	0.79	0.75	0.91	-0.42	0.17	0.28	0.11	0.14
available P	0.99	-0.43	0.37	0.93	0.88	-0.95	0.46	0.05
VEGETATION PROPERTIES								
litter biomass	0.10	0.52	0.74	0.73	0.94	0.54	0.10	-0.11
tree height	0.05	-0.61	-0.89	-0.52	-0.11	-0.07	0.37	0.04
D.B.H.	0.42	0.93	0.15	-0.18	0.35	0.12	-0.50	-0.98
tree density	-0.80	0.67	0.43	0.07	0.77	-0.88	0.09	-0.99
grass density	0.00	0.10	0.00	0.10	0.100	0.00	0,00	0.00
frequency	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
Canonical corr.	0.94	0.90	0.93	0.90	0.79	0.77	0.94	0.87
Wilk's λ coef.	0.05	0.16	0.14	0.14	0.30	0.35	0.11	0.19

The above pattern of relationships is presented in table V. The canonical correlation coefficient which are significant (between 0,77 and 0,98) indicates that relationships are very strong.

The pattern of relationships identified using canonical correlation analysis show that soil is related to vegetation characteristics in different ways during different fallow stages. Therefore, the canonical correlation analysis carried out in this study clearly reveals that soil-vegetation relationships during fallowing is dynamic rather than static.

The observation is important for tropical agriculture in the sense that restoration of soil properties during the course of bush fallowing depends on certain characteristics of the vegetation which appear to be very crucial at that stage.

Tab.V. - Canonical variates and canonical correlation coefficient of soil-vegetation parameters in the fallow communities.

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Period	Canonical variate	Soil parameter	Vegetation parameter	Canon; correlat.
1-year fallow	I	available phosphorus	litter biomass, tree height	0,94
	II	total nitrogen, W.H.C.	D.B.H.	0,90
3-year fallow	I	sand, K^+, soil pH	tree height	0,93
	II	organic matter	litter biomass	0,79
7-year fallow	I	o. matter, nitrogen, K^+	litter biomass	0,79
	II	clay	grass density	0,77
10-year fallow	I	sand	tree density, D.B.H.	0,94
	II	Ca^{++}, organic matter	tree height, density	0,87

Tab. VI.- Canonical variance extracted and redundancy for soil and vegetation parameters.

1-year fallow					
Canonical variates	Sq. can. Cor.	Topsoil properties		Vegetation parameters	
		Var.expected	redundancy	Var.expected	redundancy
I	0.88	0.37	0.32	0.19	0.17
II	0.82	0.55	0.45	0.58	0.48
Total variance		0.018		0.77	
Total redundancy			0.77		0.65

3-year fallow					
Canonical variates	Sq. can. Cor.	Topsoil properties		Vegetation parameters	
		Var.expected	redundancy	Var.expected	redundancy
I	0.86	0.55	0.47	0.32	0.27
II	0.81	0.30	0.24	0.38	0.31
Total variance		0.85		0.70	
Total redundancy			0.71		0.58

7-year fallow					
Canonical variates	Sq. can. Cor.	Topsoil properties		Vegetation parameters	
		Var.expected	redundancy	Var.expected	redundancy
I	0.62	0.30	0.18	0.38	0.24
II	0.59	0.17	0.10	0.30	0.18
Total variance				0.68	
Total redundancy			0.28		0.42

10-year fallow					
Canonical variates	Sq. can. Cor.	Topsoil properties		Vegetation parameters	
		Var.expected	redundancy	Var.expected	redundancy
I	0.88	0.41	0.37	0.40	0.35
II	0.76	0.31	0.24	0.58	0.44
Total variance		0.73		0.97	
Total redundancy			0.65		0.79

However most of the pattern of interrelationship revealed in table V are excepted. For instance the strong positive relationship between organic nutrient observed in 1-year old fallow plots and also the strong negative relationship between sand and diameter at breast height in the 10-year old plot. This observation suggests a decline in diameter growth of trees with increase in sand content of the topsoil in this region.

One other major observation revealed by the canonical correlation analysis is the strong negative relationship of soil pH with the height in the 3-year old fallow. This observation points to the effect of soil acidity on tree growth which in this case is negative because with increase in soil acidity, availability of soil nutrients is reduced and consequently the tree growth is reduced.

Generally, it is revealed that in all stage categories of the fallow communities investigated, there are two basic pattern of underlying relationships (2 canonical variates) which as earlier pointed out changes over time blurring fallow period. For greater expository treatment of the extent of the interrelationships between the soil and vegetation components of a fallow system, the canonical redundancy values were computed. RAY & LOHNES (1973) specifically pointed out the importance of redundancy value with throwing more light on the strength of interrelationship between two measurement domains. It expresses the substitutability of one measurement domain for the other (EBISEMIJU, 1976).

Table VI shows the variance extracted and the redundancy values. In 1-year old fallow, of the total variance of 0,92 extracted by two canonical variates, 0,77 is redundant; this implies that the soil factor (available phosphorus, total nitrogen, and water holding capacity) accounts for 22,6% of the variance extracted for vegetation characteristics (tree height and diameter at breast height). For the other ages the identified soil factors (table V) accounts for 28,6%, 71,3% and 35% of the vegetation characteristics in the 3, 7 and 10 years fallow respectively.

The results of the canonical redundancy values also reveal that there are significant interrelationship between vegetation characteristics and soils under the fallow communities. The variance extracted and redundancy values show for instance that vegetation characteristics in the 3-year fallow (tree height and litter biomass) account for 41,5% of the variation in organic matter content and acidity of the soil.

The result of both Pearson correlation and canonical correlation indicate that significant relationship exists between soil-vegetation components in a fallow system and that soil properties such as organic matter, available phosphorus and water holding capacity exert great influence on vegetation characteristics such as tree height, growth and tree density. Also certain characteristics of fallow vegetation namely litter biomass, the density significant influence on soil properties especially its organic matter contents.

Hence, the results of this study suggest that in fallow communities soil and vegetation component are related in some specific ways which vary during the fallow period.

CONCLUSION

The analysis of soil-vegetation interrelationships in this paper shows that significant soil-plant relationship exists in fallow communities; and the relationship is reciprocal with soil influencing specific changes in the characteristics of fallow vegetation and vice-versa. Soil and vegetation characteristics witness varying degree of changes during fallowing the extent of these changes depends *inter alia* on cropping history, nature of climate and soil types (AREOLA *et al.*, 1982). Therefore the period needed for fallow regeneration accordingly depends on these factors (ADEJUWON & EKANADE, 1988).

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