Geo-Eco-Trop 1993, 17, (1-4) 121-135

SOIL - VEGETATION RELATIONSHIPS IN THE KANO PLAINS OF NORTHERN NIGERIA

Relation entre le sol et la végétation dans les plaines du Kano (Nord Nigeria)

I.E. ESU * & O.E. ASIRIBO **

RESUME

Dans une réserve forestière de la plaine de Kano (N. Nigéria), trois associations végétales de savane buissonnante ont été identifiées et caractérisées par la ou les espèce(s) dominante(s): Securinega/Combretum, Combretaceous et Acacia seyal. Chacune de ces associations se situe sur un sol de caractères différents tant du point de vue morphologique que physico-chimique. Selon la légende de la F.A.O. (1988), ces sols sont respectivement les plinthic lixisols, les eutric et dystric regosols associés à des lithic leptosols et enfin les stagni-gleyic solonetz

Les tests de χ^2 et de Kruskal-Wallis montrent une différence significative au niveau de 0,01 ou tout au plus 0,05 entre les sols sous les trois associations végétales. Une telle relation étroite peut déboucher sur plusieurs applications.

ABSTRACT

Detailed soil and vegetation surveys using the basic grid format were conduced in a long-term fallow forest reserve within the Kano Plains of northern Nigeria. The survey resulted in the delineation of three distinct shrub Savanna vegetation communities namely: Securinega/Combretum shrub savanna, Combretaceous shrub Savanna and Acacia seyal shrub savanna. Each vegetation community is supported by a distinct soil mapping unit characterized by its morphological and physicochemical properties. According to the criteria of the FAO/UNESCO soil map of the world revised legend of 1988, the soils under the Securinega/Combretum vegetation are classified as Plinthic Lixisols while the Combretaceous shrub savanna occupy Eutric & Dystric Regosols associated with Lithic Leptosols and the thorny Acacia seyal vegetation grow on Stagni-Gleyic Solonetz. Both χ^2 -test and Kruskal-Wallis test statistics have shown that significant differences exist between soil properties in the three vegetation types at

* Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria.

**Data Processing Unit, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

mosly 1 % and to a less extent at 5 % level of significance. These strong relationships between soil mapping units and vegetation communities can be successfully exploited in the accurate delineation of soil boundaries in high intensity soil surveys within areas of similar savanna ecology in the tropics.

INTRODUCTION

Since the days of DOKUCHAEV (1946 - 1903), the founder of modern pedology, it has been recognised that plants are an important factor in the genesis and classification of soils (CROCKER, 1967). Correlations between vegetation and soil types or other soil classification units have three important purposes which include (i) for better understanding of soil genesis (ii) as an aid in recognizing soil boundaries and (iii) for making predictions about the kind and growth of natural vegetation from soil maps (Soil Survey Staff, 1951).

Several workers (JENNY, 1958; CROCKER & MAJOR, 1955; FROST, 1960; CARMEAN, 1967; DYRNESS & GRIGAL, 1979; ESU & GRIGAL, 1979; POPENOE *et al.*, 1992) have used vegetation soil relationships in either soil genesis, soil mapping or in forest-site productivity evaluations.

In Nigeria, however, there are no reliable information relating soil types to specific vegetation communities. This is inspite of the important role that such established relationships can play in the current efforts to carry out a detailed mapping of the soils of the country with the aid of remote sensing techniques. The objectives of this study were, therefore, (i) to identify the major vegetation communities in a long-term fallow forest reserve typical of the Shrub Savanna vegetation in the Kano Plains of northern Nigeria, and (ii) to study the soils under each vegetation community so as to establish relationships between the soils and the vegetation types.

MATERIALS AND METHODS

Study area

The Kano Plains comprises extensive tracts (30 970 km^2) of almost level to gently sloping land with scattered hills rising 50-400 m above the surrounding land. It lies within longitudes 7°30 - 9°50 E and latitudes 10°30 - 13°20 N within the Sudan savanna ecological zone of Nigeria (KEAY, 1959) (Fig. 1).

The study was carried on in the Bagauda area (Lat. 11°40 N, Long 8°30 E) of Kano State, which is in the centre of the Kano Plains. The area is underlain by a basal complex of igneous and metamorphic rocks of mainly Pre-Cambrian to Lower Palaeozoic age. The rock types are essentially granits, gneisses, schists and quartzites. The only recent sediments are various colluvial - alluvial deposits and wind-blown drift which can be traced over the entire area (WALL, 1978).

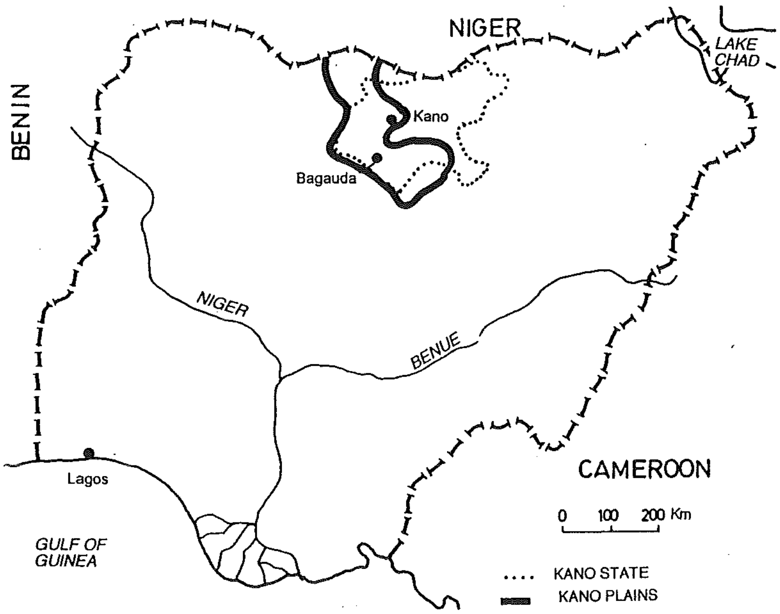

Fig.1. - Localisation map of the Kano plains in Nigeria

According to KOWAL and KNABE (1972), long-term mean annual rainfall for 50 years in the study area is 800 mm, while the mean annual potentiel evapotranspiration is 1770 mm. The mean annual air temperature varies from a minimum of 21.2°C at the peak of the Harmattan season (January) to a maximum of 30.5° C just before the onset of the rainy season in April, with an overall annual mean of 26.0° C.

Field studies

Detailed soil and vegetation surveys were carried out in a 42 ha government forest reserve which has been under fallow for at least 20 years. Both the vegetation recording and soil mapping were carried out using the basic grid format. Traverses were cut along the baseline at 100 m intervals while vegetation recording and auger observation points were pegged at 50 m intervals along the traverses.

Species composition of the arboreal cover was recorded in a four-point abundancy scale and the physiognomy was noted at each auger observation point. The classification into vegetation types was based on physiognomy and on species dominances in the tree or in the herbaceous stratum or in both.

For the purpose of soil mapping, auger borings were made to a depth of 125 cm or to any impenetrable layer, whichever came first. Morphological soil descriptions were made at 25 cm depth intervals or according to horizon sequences where possible.

Both the soil and vegetation surveys resulted in the delineation of three distinct soil mapping units, which also coincided with three distinct vegetation communities. Within each of the three mapping units, at least three soil profile pits were dug and described to characterize the soils. In each of the pits, the morphological characteristics of the soils were described following the pattern given in the "Guidelines for Soil Profile Description" (FAO, 1977). Following the description, bulk soil samples were collected in plastic bags for laboratory analysis.

Laboratory studies

Soil samples were air-dried, ground and passed through a 2 mm sieve. Selected physico-chemical properties were determined according to the standard laboratory procedures contained in "Methods of Soil Analysis" (BLACK *et al.*, 1965).

Statistical analysis

The statistical analysis was carried out with the aid of a Minitab package (RYAN *et al.*, 1985) in an Olivetti M24 microcomputer. Normal probability plots and histograms were constructed to test whether the physico-chemical properties of the soils can be assumed to come from a normal distribution.

A χ^2 test was used to test the independence between soil properties and the vegetation types; while the Kruskal-Wallis test for non parametric statistics (SNEDECOR & COCHRAN, 1980) was used for testing the differences in the physico-chemical properties by vegetation type.

RESULTS AND DISCUSSION

VEGETATION COMMUNITIES

The dominant physiognomic unit in the entire survey area is the savanna shrubland typical of the semi-arid sudan savanna region of Nigeria. The three vegetation communities which also coincided with three distinct soil mapping units are as follows :

(i) Open *Securinega/Combretum* Scrub Savanna

This vegetation community occupied a soil mapping unit with deep to moderately deep, well-drained, loamy soils. The dominant shrubs were *Securinega virosa* and *Combretum glutinosum* which occupied 60 - 80 % of the area in association with a 20 - 40 % mixture of *Daniella oliveri, Annona senegalensis, Bridelia ferruginea, Cassia singueana, Piliostigma thonningii, Ziziphus mauritania, Dichroastachys glomerata, Guiera senegalensis* and *Terminalia avicennioides* in order of importance.

Scattered emergent trees included *Parkia clappertoniana* and *Butyrospermum paradoxum*, while herbaceous plants in the community included *Stylochiton lancifolious, Indigofera pulchra, Waltheria indica, Asparagus africanus, Borreria radiata*, and *Tephrosia bracteolata*.

Dominant grass species included mainly *Andropogon pseudopricus, Andropogon gayanus, Pennisetum pedicellatum, Loudetia togoensis* and *Aristida kerstingii.*

ii) Open Combretaceous Shrub Savanna.

This vegetation community was associated mainly with shallow to very shallow, gravelly loam soils with underlying ironpan (petroplinthite) layer within 30 - 50 cm or less from the soil surface.

The dominant Combretaceous species which occupied 60 - 80 % of the mapping unit were *Combretum glutinosum, Combretum molle* and *Anogeissus leiocarpus.* Other shrubs which occupied 20 - 40 % of the mapping unit included *Terminalia avicennioides, Diospyros mespiliformis, Annona senegalensis, Feretia apodanthera, Securinega virosa* and *Cassia singueana* in order of importance.

Scattered emergent trees in this mapping unit included *Khaya senegalensis* and *Parkia clappertoniana* while the herbaceous plants included *Stylochiton lancefolious, Tephrosia bracteolata, Asparagus africanus, Kaempferia aethiopica, Aneilema lanceolatum, Zonia glochidiata* and *Lepidagathis collinum.*

(iii) Open *Acacia seyal* Shrub Savanna.

This vegetation community was associated with deep, slowly parmeable, clayey sodic soils. *Acacia seyal* constituted 80 % of the mapping unit, while 20 % of the area was occupied by *Combretum molle, Cassia singueana* and *Piliostigma reticulatum.*

Few of the scattered emergent trees included *Lannea barteri* and *Anogeissus leiocarpus.* The abundant herbaceous species in the community were *Barreria radiata, Crotalaria naragutensis* and *Tephrosia bracteolata.*

The most dominant grass species included *Loudetia togoensis, Pennisetum pedicellatum, Aristida kerstingii, Aristida funiculata, Andropogon pseudopricus, Ctenium newtonii* and *Sporobulus festivus.*

SOIL CHARACTERISTICS WITHIN VEGETATION COMMUNITIES MORPHOLOGICAL PROPERTIES.

Field morphological descriptions of representative pedons within each of the three vegetation communities are sented in Table I.

Soils under the *Securinaga/Combretum* vegetation community (Pedons 1, 2 and 3) occupy nearly level (0 - 1 slope) summit to backslope positions of the landscape. The soils are developed from an admixture of loess and weathered granitic rocks. Like most soils developed on Basement Complex rocks in the Nigerian Savanna region (ESU & OJANUGA, 1985; ESU *et al.*, 1987; MOSUGU, 1989), the soils have weak surface soil aggregates with moderate to strong subangular blocky subsoils. The soils are deep to moderately deep to an underlying plinthite layer, and a well developed argillic B horizon occurs within 55 - 75 cm of the soil surface. The rather dense argillic and plinthite layer in the subsoil, causes impeded drainage subsurface conditions during the rainy season which is evidenced by the occurrence of distinct to prominent strong brown (7.5YR 5/8) and reddish (2.5 YR 4/8) mottles within the Btg and Btgv horizons. In general, however, the soils are well-drained to moderately well-drained.

Tab.I. - Field morphological description of representative pedons+

Horizon	Depth cm	Matrix colour	Mottling	Texture	Structure	Consis-tence	Boun-dary	Clay films
			Open *Securinega/Combretum* Shrub Savanna					
Pedon 1								
A	0-17	10YR 4/3	-	l	1 msbk	mvfr	cs	0
AB	17-50	10YR 5/4	f1f	scl	1 msbk	mfr	gs	0
BA	50-75	10YR 6/6	5YR 5/8, f1f	cl	2 msbk	mfr	gs	1
Btg	75-108	10 YR 6/6	2.5YR 4/8,c2d	c	2 msbk	mfr	gs	2
Btgv	108-162	10YR 7/4	2.5YR 4/8,m2p	cl	3 csbk	mfr	-	3
Pedon 2								
A	0-14	10YR 4/3	-	l	1 msbk	mvfr	cs	0
AB	14-34	10YR 5/4	-	cl	1 msbk	mfr	gs	0
BA	34-55	10YR 5/6	7.5YR 5/8, c2f	cl	2 msbk	mfr	gs	1
Btg	55-114	10YR 5/8	7.5YR 5/8, m2d	cl	3 csbk	mfr	gs	2
Btgv	114-156	10YR 7/2	7.5YR 5/8, 2.5YR 4/8, m3p	cl	3 csbk	mfr	-	3
Pedon 3								
A	0-14	10YR 4/3	-	l	1 msbk	mvfr	cs	0
AB	14-24	10YR 5/6	-	cl	1 msbk	mvfr	cs	0
BA	24-56	10YR 6/4	7.5YR 5/8, c2d	cl	2 msbk	mfr	gs	1
Btg	56-96	10YR 7/2	7.5YR 5/8, m2d	cl	2 msbk	mfr	cs	2
Btgv	96-140	10YR 7/4	7.5YR 5/8, 2.5YR 4/8, m3p	cl	3 csbk	mfr	as	3
			Open Combretaceous Shrub Savanna					
Pedon 4								
Ac	0-12	10YR 3/3	-	gr-l	1 msbk	mvfr	gs	0
BAc	12-33	7.5YR 4/4	-	vgr-cl	1 msbk	mfr	aw	0
-	33	- Underlying petroplinthite layer						
Pedon 5								
Ac	0-10	10YR 4/2	-	gr-l	1 msbk	mvfr	as	0
BAc	10-50	10YR 6/4	-	vgr-cl	1 fsbk	mfr	as	0
-	50	- Underlying petroplinthite layer						
Pedon 6								
Ac	0-20	10YR 4/3	-	gr-l	1 msbk	mvfr	cs	0
BAc	20-42	10YR 4/4	-	gr-l	1 msbk	mfr	as	0
-	42	- Underlying petroplinthite layer						

Pedon 7

A	0-10	10YR 3/2	7.5YR 4/4, clf	l	2 msbk	mfr	cs	0
ABn	10-32	10YR 4/3	7.5YR 5/8, c2f	cl	2 msbk	mfr	gs	0
BAgn	32-62	10YR 6/3	7.5YR 5/8, m2d	cl	3 csbk	mfr	cs	0
Bngk	62-123	10YR 6/4	7.5YR 5/8, 10YR 7/2, 2.5YR 4/8, m3p	c	3 csbk	mfl	gs	3
BCgnk	123-160	10YR 6/4		cl	3 csbk	mfl	-	2

Pedon 8

A	0-16	10YR 3/2	7.5YR 5/6, c2f	cl	2 msbk	mfr	as	0
ABn	16-41	10YR 5/3	7.5YR 5/6, m2f	scl	3 csbk	mfr	gs	0
Bgn 1	41-66	10YR 6/4	7.5YR 5/6, m2d	cl	2 msbk	mfi	gs	2
Bgn 2	66-103	10YR 6/2	7.5YR 5/6, m3d	c	3 csbk	mvfi	cs	3
BCgnk	103-125	10YR 6/2	7.5YR 5/6 2.5YR 4/8, m3p	scl	3 csbk	mvfi	-	2

Pedon 9

A	0-12	10YR 3/2	7.5YR 4/4, clf	c	2 msbk	mfr	cs	0
AB	12-29	10YR 5/3	7.5YR 5/8, c2f	c	3 csbk	mfi	cs	0
BAgk	29-61	10YR 6/3	7.5YR 5/8, m3d	c	3 csbk	mvfi	gs	1
Bgnk	61-120	10YR 6/3	7.5YR 5/6, m3d	gr-c	3 csbk	mvfi	gs	3
BCgnk	120-143	10YR 6/3	7.5YR 5/6, m3d	gr-scl	3 csbk	mfi	-	2

+ Symbol used are the same as given in Soil Survey Manual, SSDA Handbook n° 18, pp. 139-140, 1951 and the new Soil Survey Manual, 1981, Chap. 4,

Soils under the Combretaceous shrub savanna are essentially similar morphologically to those of the *Securinega/Combretum* community, when observed from the surface. However, the underlying plinthite in the soils of the Combretaceous community, has advanced close to the surface and hardened irreversibly to ironpan or petroplinthite layer. Consequently, the effective rooting depth is only about 30 to 50 cm, and in several locations within the soil mapping unit, the ironpan has outcropped on the surface. In a semi-detailed soil survey of the Dabai irrigation project area, ESU (1988) similary reported the association of *Combretum glutinosum* and *Combretum molle* with very shallow and concretionary soils underlain by ironpan layer (petroplinthite).

The soils supporting the *Acacia seyal* vegetation community is completely distinct from the others. They are located in the lower slope position of an almost planar physiographic landscape with gradients varying from 2 to 4 % slope. Soil parent material consists of an admixture of loessial-colluvial materials and alluvial deposits of the Kano river, whose terraces they occupy. The soils are deep, poorly drained and are dominantly clayey with very slowly permeable natric B horizons. Many fine mica flake occur troughout the profile depth, while many, soft Fe and Mn nodules as well as $CaCO_3$-Mn concretions are common features in the subsoil. ESU (1989), characterized similar soils in the terrace of the Hadejia river alluvial complex which also lies to some extent within the Kano Plains.

PHYSICO-CHEMICAL PROPERTIES

Data related to the physico-chemical properties of the soils are presented in Table II and III

Tab.II. - Particle size distribution, pH, organic C, total N, available. P and electrical conductivity (EC) of the soils.

Horizon	Depth	Particle size µm Distribution.			pH (H_2O)	Organic C	Total N	Avail. P	Ec
		Sand 50-2000	Silt 2-50	Clay < 2					
	cm	50-2000µ	2-50µ	<2µ		gkg^{-1}	$mgkg^{-1}$		dSm^{-1}
				Open *Securinega/Combretum* Shrub Savanna					
Pedon 1									
A	0-17	50	30	20	6.1	5.2	0.4	8.39	0.05
AB	17-50	48	24	28	5.3	2.2	0.2	8.83	0.01
BA	50-75	44	28	28	5.2	1.6	0.2	10.17	0.01
Btg	75-108	40	20	40	5.2	1.6	0.3	7.75	0.01
Btgv	108-162	42	20	38	6.0	1.2	0.1	7.75	0.03
Pedon 2									
A	0-14	42	36	20	5.7	4.2	0.5	10.63	0.05
AB	14-34	40	32	28	6.0	4.2	0.3	13.05	0.03
BA	34-55	42	30	28	5.4	2.0	0.3	11.10	0.01
Btg	55-114	40	26	34	5.0	1.4	0.2	9.71	0.01
Btgv	114-156	36	26	38	5.5	2.0	0.1	9.27	0.01
Pedon 3									
A	0-14	42	38	20	5.2	5.9	0.6	8.83	0.03
AB	14-24	40	32	28	5.0	4.4	0.4	10.87	0.01
BA	24-56	42	30	28	5.0	1.8	0.3	6.70	0.01
Btg	56-96	40	26	34	5.0	1.4	0.3	6.70	0.01
Btgv	96-140	30	26	38	5.3	0.8	0.1	6.29	0.25
Weighted Average+		41	26	32	5.4	2.1	0.2	8.65	0.04
				Open Combretaceous Shrub Savanna					
Pedon 4									
Ac	0-12	46	30	24	7.1	10.0	0.9	9.05	0.05
BAc	12-33	44	24	32	6.0	4.6	0.4	7.12	0.02
Pedon 5									
Ac	0-10	42	34	24	7.1	11.6	0.7	12.54	0.08
BAc	10-50	44	26	30	6.9	4.2	0.4	6.78	0.03

Pedon 6									
Ac	0-20	44	34	22	6.0	8.2	0.5	7.96	0.05
BAc	20-42	42	30	28	5.8	3.6	0.3	5.89	0.02
Weighted Average+		44	29	28	6.4	6.0	0.5	7.55	0.04
Open *Acacia seyal* Shrub Savanna									
Pedon 7									
A	0-10	50	30	20	7.0	6.0	0.4	7.96	0.06
ABn	10-32	44	26	30	9.2	2.2	0.2	7.54	0.38
BAgn	32-62	44	26	30	9.3	1.8	0.1	11.76	0.45
Bgnk	62-123	30	26	44	9.2	1.4	0.2	10.63	0.07
BCgnk	123-160	42	28	30	9.1	1.0	0.1	10.17	0.43
Pedon 8									
A	0-16	42	28	30	6.4	6.8	0.6	9.36	0.06
ABn	16-41	46	24	30	7.1	4.8	0.3	8.37	0.07
Bgn1	41-66	40	22	38	7.2	1.4	0.1	8.37	0.09
Bgn2	66-103	36	24	40	7.9	2.4	0.3	8.83	0.13
BCgnk	103-125	48	26	26	8.0	2.2	0.3	7.75	0.14
Pedon 9									
A	0-12	30	22	48	6.8	5.6	0.6	8.05	0.07
AB	12-29	30	26	44	7.7	5.2	0.6	8.39	0.07
BAgk	29-61	30	30	40	8.4	2.8	0.4	7.12	0.22
Bgnk	61-120	28	22	50	9.1	2.2	0.3	11.57	0.55
BCgnk	120-143	50	26	24	9.2	1.8	0.2	16.35	0.95
Weighted Average+		37	25	37	8.4	2.6	0.3	9.85	0.28

+ Weighted Average is calculated by multiplying the thickness (cm) of the horizon by the laboratory result, adding an then dividing by the total thickness of horizons.

Particle size distribution data show that both the soils under the *Securinega/Combretum* vegetation and the Combretaceous community have a dominantly fine-loamy particle-size class except for pedon 1 which marginally falls within the fine-clayey particle-size class. However, unlike the soils under the *Securinega/Combretum* vegetation, the soils under the Combretaceous vegetation are very gravelly due to the proximity of the Ap horizon to underlying ironpan layer and Fe-Mn concretions which are often within 30 - 50 cm of the soil surface. The soil mapping unit which supports the *Acacia seyal* vegetation community has a fine-clayey particle-size class.

Weighted average values for organic carbon and total nitrogen were generally low for all the soils (Tab. II).

However, relatively higher values of organic C and total N were recorded in the shallow, gravelly soils of the Combretaceous vegetation. ESU *et al.* (1987), in a study

Tab.III. - Exchangeable cartions, cation exchange capacity (CEC), exchangeable sodium percentage (ESP) and base saturation of the soils.

Horizon	Depth	Exchangeable cations				CEC (pH 7.0)	CEC-Clay	ESP.	Base sat.
		Ca	Mg	K	Na	NH_4OAc	NH_4OAc		
	cm	c mol (+) kg^{-1}						%	
				Open *Securinega/Combretum* Shrub Savanna					
Pedon 1									
A	0-17	1.37	0.76	0.18	0.07	4.6	14	1.52	52
AB	17-50	1.42	0.61	0.05	0.08	6.4	20	1.25	34
BA	50-75	1.60	0.75	0.09	0.09	6.6	22	1.36	38
Btg	75-108	3.40	1.36	0.12	0.11	10.0	24	1.10	50
Btgv	108-162	3.16	1.11	0.08	0.09	7.4	18	1.22	60
Pedon 2									
A	0-14	1.92	0.92	0.12	0.04	5.8	22	0.69	52
AB	14-34	2.12	1.17	0.07	0.08	8.2	24	0.96	42
BA	34-55	1.81	1.17	0.12	0.09	6.6	21	1.36	48
Btg	55-114	2.31	1.47	0.12	0.09	7.8	22	1.15	51
Btgv	114-156	2.56	1.71	0.10	0.03	8.6	21	0.35	51
Pedon 3									
A	0-14	1.25	0.91	0.09	0.04	4.0	10	1.00	57
AB	14-24	0.96	0.81	0.04	0.05	4.0	9	1.25	47
BA	24-56	0.65	0.62	0.04	0.08	3.1	9	2.58	45
Btg	56-96	0.94	0.70	0.06	0.17	3.4	9	5.00	55
Btgv	96-140	0.92	0.61	0.05	0.12	3.3	8	3.64	52
Weighted Average^{+}		1.87	1.01	0.09	0.09	6.3	17	-	-
				Open Combretaceous Shrub Savanna					
Pedon 4									
Ac	0-12	1.75	1.03	0.24	0.04	5.4	8	0.71	57
BAc	12-33	1.37	0.80	0.10	0.04	5.6	12	0.71	42
Pedon 5									
Ac	0-10	2.93	1.03	0.20	0.04	6.4	10	0.63	66
BAc	10-50	1.83	0.77	0.10	0.02	4.8	11	0.42	56
Pedon 6									
Ac	0-20	1.12	0.63	0.16	0.05	3.6	3	1.39	52
BAc	20-42	1.12	0.45	0.15	0.07	5.6	16	1.25	30
Weighted Average^{+}		1.59	0.74	0.14	0.04	5.1	11	0.81	49

Pedon 7									
A	0-10	1.56	0.84	0.13	0.33	4.8	14	6.88	60
ABn	10-32	2.43	0.88	0.11	2.78	7.4	22	37.57	84
BAgn	32-62	3.80	1.02	0.16	3.37	8.8	27	38.30	95
Bgnk	62-123	5.74	1.98	0.26	6.53	15.6	34	41.86	93
BCgnk	123-160	3.77	2.10	0.21	6.09	14.0	46	43.50	87
Pedon 8									
A	0-16	2.06	1.10	0.14	0.16	7.0	15	2.29	49
ABn	16-41	2.30	1.04	0.14	1.13	8.2	22	13.78	57
Bgn1	41-66	2.06	0.78	0.12	0.87	6.0	15	14.50	64
Bgn2	66-103	3.93	1.13	0.19	1.44	11.8	27	12.20	57
BCgnk	103-125	4.80	1.34	0.18	1.65	8.8	31	18.75	91
Pedon 9									
A	0-12	3.62	1.13	0.24	0.12	8.6	14	1.40	59
AB	12-29	11.73	1.65	0.32	0.22	20.6	43	1.07	68
BAgk	29-61	30.56	1.95	0.78	0.98	36.6	89	2.68	94
Bgnk	61-120	29.35	3.35	0.95	5.87	39.9	78	16.77	99
BCgnk	120-143	26.20	3.44	0.87	8.70	39.5	162	21.86	99
Weighted Average$^+$		10.8	1.80	0.38	3.54	18.5	48	22.03	82

+: See tab.II

of toposequences of soils in the Keffy plains in northrtn Nigeria, similary observed that the shallow, concretionary soils with underlying petroplinthite layer had relatively higher inherent fertility status than the associated deep soils.They attributed the trend to a much longer period of fallow due to the difficulties associated with cultivating such soils especially with traditional farm implements.

Available P levels were medium to low, but while the values tended to decrease with depth in the soils of two of the vegetation communities, the trend was reversed in the calcareous, sodic soils occupied by the *Acacia seyal* vegetation. The increase of available P with soil depth however, tended to be more related to a similar increase in exchangeable Ca^{++} content with soil depth.

Weighted average pH values were 5.4, 6.4 and 8.4 for the *Securinega/Combretum,* Combretaceous and *Acacia seyal* vegetation communities respectively (Tab. II). The high degree of alkalinity especially in the subsoil horizons of soils supporting the *Acacia seyal* vegetation, appears to be closely linked with the often significant increases in the exchangeable sodium percentage (ESP) of the subsoils (Tab. III). Weighted average value for the ESP of the soils supporting the *Acacia seyal* vegetation was 22.0 % indicating that the soil are quite sodic, while the values for the other two soils ranged only from 0.8 to 2.3 % (Tab.III). All the soils are however, non-saline as the weighted averages of the electrical conductivity of the saturation extract (EC) ranged only between 0.04 and 0.28 dSm^{-1} (Tab. II).

SOIL CLASSIFICATION

The soils have been classified according to the criteria of the revised legend of the soil map of the world (FAO-UNESCO, 1988).

Soils under the *Securinega/Combretum* vegetation (pedons 1, 2 and 3) have argic B hoorizons which have a cation exchange capacity of less than 24 cmol (+) kg^{-1} clay at least in some part of the B horizon and base saturation of 50 % of more (by NH_4OAC) throughtout the B horizon (Tab. III). The soils also contain plinthite within 125 cm of the surface (Tab. I) and have therefore, been classified as Plinthic Lixisols.

The soils under the dominantly Combretaceous vegetation must have once been Plinthic Lixisols, but the underlying plinthite has advanced close to the soil surface and has consequently hardened irreversibly to ironpan (petroplinthite) usually within 30 - 50 cm of the soil surface. Most of the soils therefore fit in the unit of Eutric (Pedon 5) & Dystric (Pedons 4 and 6) Regosols. However, within the soil mapping unit, there are spots where ironpan outcrop on the soil surface or are within less than 10 cm of the surface. Therefore, the Regosols are associated with portions of Lithic Leptosols in this mapping unit.

Soils under the *Acacia seyal* vegetation have slowly permeable natric B horizon, but do not possess a well defined albic E horizon. Rather, they posess ochric A horizon and display stagnic and gleyic properties. They have therefore, been clasified as Stagni-Gleyic Solonetz.

STATISTICAL ANALYSIS

By constructing histograms for the various soil properties, it was observed that non-normality was exhibited for all the soil properties except for the particle size distribution data (sand, silt and clay). This was further confirmed by the construction of normal probability plots which exhibited curvatures rather than the expected straight line for a normal population. Some workers (OVALLES & COLLINS, 1986; YERIMA, 1986; ESU & ASIRIBO, 1989), have similarly reported that variations in most soil properties do not follow a normal distribution. Hence, for most of the statistical analysis in this study, non parametric tests were used.

A χ^2-test was used for testing the independence between the observed values of the selected physico-chemical properties of the soils and the vegetation types. The test was applied to computer assigned ranks of the soil properties. As shown in Table IV, a higher significant (0.01 level) dependence between the selected soil properties and vegetation types is displayed. This high level of dependence may be attributed to the nonuniformity between the different vegetation communities as exhibited by the soil properties.

The Kruskal-Wallis nonparametric test showed that all the soil properties except particle size data and available P were found to be significant mostly at 1 % level while organic C and total N were significant at 5 % level of significance (Tab. IV). Therefore, it can be concluded that at least two of three vegetation types are different with respect to most of the selected soil properties.

Tab.IV. - Result of the χ^2 -test of independence and the Kruskal-Wallis test for significant differences between the vegetation types.

	Sum of horizon observation ranks					Kruskal-Wallis
	Securinega/ Combretum	Combre taceous	*Acacia seyal*	Total		
Soil property	n = 15	n = 6	n = 15	n = 36	χ^{2+}	χ^2-values
Sand	260.5	146.0	257.5	666	14.9	2.54
Silt	307.5	143.5	215.0	666	26.8	4.65
Clay	248.0	74.5	343.5	666	30.8	5.22
Organic C	217.0	175.0	274.0	666	50.1	6.40 *
Total N	239.5	169.0	257.5	666	36.9	6.39 *
pH in H_2O	127.0	113.0	426.0	666	161.1	26.98 **
Avail. P	285.5	81.0	299.5	666	10.1	1.68
EC	151.5	95.5	419.0	666	131.5	22.36 **
Exch. Ca	190.5	71.5	404.0	666	99.0	15.51 **
Exch. Mg	233.0	64.0	369.0	666	57.2	9.54 **
Exch. K	143.0	130.0	393.0	666	116.5	19.53 **
Exch. Na	199.5	40.5	426.0	666	146.2	24.47 **
CEC (pH 7.0)	208.0	61.0	397.0	666	91.4	15.25 **
ESP	206.5	49.5	410.0	666	115.5	19.26 **
Base saturation	168.0	85.5	412.5	666	114.7	19.18 **

+ All values are significant at 0.01 level (χ^2 - test). ** and * are significant at 0.01 and 0.05 levels respectively (Kruskal-Wallis test).

CONCLUSIONS

This study has contributed to a greater understanding of the relationships between vegetation and soils within the Kano Plains of Nigeria and indeed within the entire semi-arid regions of the tropics supporting mainly shrub savanna vegetation types similar to those reported here.

The major statistically significant vegetation-soil relationships which have been established in this study include (i) the association between a mixture of shrub species dominated by *Securinega virosa* and *Combretum glutinosum* with deep, well-drained and argillic soils which contain plinthite and which are classified as Plinthic Lixisols (FAO-UNESCO, 1988) (ii) the association of Combretaceous shrub species dominated by *Combretum glutinosum*, *Combretum molle* and *Anogeissus leiocarpus* with very shallow, concretionary, loamy soils underlain by ironpan usually within 30 - 50 cm depth or less which are classified as Eutric and Dystric Regosols associated with Lithic Leptosols and (iii) the association between *Acacia seyal* vegetation and clayey, sodic and calcarecus soils having slowly permeable natric B horizons which are classified as Stagni-Gleyic Solonetz.

These established relationships can be used for purposes of extrapolation of soil survey information in future soil survey projects which may cover large hectarages of land and which may involve the use of remote sensing techniques like aerial photography. Once the spectral signatures of the various vegetation types associated with specific soil types are established, the interpretation of the remote sensing data and the establishment of various soil mapping unit polygons should be fairly easy.

ACKNOWLEDGMENTS

Financial assistance for this study was provided by the Institute for Agricultural Research, Ahmadu Bello University, Zaria. We wish to thank Musa Ayuba, Anthony Mutuwa, Julius Ige, Joseph Makama, James Atokitimo and Johnson Odejide for their assistance with the field work.

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