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Integrating indigenous knowledge and soil science approaches to detailed soil survey in Kaduna State, Nigeria

Raji, B. A.[1]*, Malgwi, W. B.[1], Berding, F. R.[2] and Chude, V. O.[2]

[1]Department of Soil Science, Ahmadu Bello University, Zaria, Nigeria.
[2]National Special Program for Food Security (NSPFS), FAO Nigeria Office, Abuja, Nigeria.

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Farmers' knowledge about their soils and their management constitutes a complex wisdom system, which if integrated with modern soil science, could provide the necessary synergy for sustainable agricultural development. A field work was undertaken in parts of Kaduna State to ascertain the indigenous knowledge of farmers and compared it with scientific classification of the same soils. The farmers used non-taxonomic classification with two levels of classification, topography or position in the landscape and inherent fertility as the first classifiers, while soil colour, surface characteristics and texture were the second. Overall, the indigenous classification used morphological and physical properties of the surface horizon as their main diagnostic attributes. In the Jagindi site, farmers were able to classify the soil units into *Tudu Jar-Kasa* and *Tudu Yunbu* for the soil units JD1 and JD2 respectively while the seasonally flooded unit; JD3 was classified as *Fadama*, an indigenous soil name that has been found acceptable in scientific literature. Correlation would be easier with the World Reference Base (WRB) system, which also place emphasis on morphological properties observable in the field as shown by the chromic subgroup in WRB and *Jar* (red) in the indigenous classification of soil unit JD1. The indigenous classification scheme in the study areas, though simple, was adequate in most cases in grouping soils into classes that could be managed using similar management practices, re-emphasizing the use-oriented nature of indigenous classification. For sustainable development in the study areas and to improve communication between the scientists, the extension agents and the farmers, it is suggested that local soil name be integrated into the soil map legend.

Key words: Conventional soil survey, *Fadama*, indigenous knowledge, Nigeria.

INTRODUCTION

The soil resource of any country is its most valuable natural resource which requires careful management for sustainable development. Soil information is required for soil-related agrotechnology transfer (Braimoh, 2002), the basis for the planning and execution of sustainable agricultural landuse and development and other non-agricultural projects (Braimoh, 2002). Given the central role of soil resources information to sustainable development, soil survey at various scales has been carried out in many countries of the world, including Nigeria. However, according to Tabor and Hutchinson (1994), most soil resource survey information in developing countries are not effectively utilized, because the audience they are intended to serve perceives them as irrelevant and totally 'foreign' to them (Ettema, 1994). If the resulting soil maps ever reach the farmers, they often contain scientific terms which are inherently complex and alien to them. They also contain recommendations on sole crops which are often not of interest to farmers who are interested in mixed farming

*Corresponding author. E-mail: rajibash2009@gmail.com.

(Osunade, 1994). Another reason of interest is that while farmers' focus is primarily use-oriented and concern with the surface horizons that are most relevant for agricultural production, the scientist is more focus on the deeper soil horizons; subject to pedogenesis and soil forming factors (Kundirir et al., 1997; Corbeels et al., 2000).

As imported scientific interpretation of soils in developing countries has failed to bring about the desired sustainable development, it has become more and more apparent that the indigenous knowledge of soils (ethnopedology) could offer many insights about sustainable management of soils in these countries (Hecht, 1990; Osunade, 1994; Corbeels et al., 2000). In a worldwide review of ethnopedological research (EPR), Barrera-Bassols and Zinck (2000) reported an average of 33 studies per year worldwide with Africa having the highest number of EPR. The increasing interest in indigenous soil knowledge (ISK) is fully justified. For one thing, detailed soil survey is often faster and cheaper using indigenous soil classification than conventional soil survey techniques (Tabor, 1990). In addition, communication between farmers, scientists and extensionists will be greatly improved if local soil nomenclature is incorporated into soil survey reports and maps (Dialla, 1993; Niemeijer, 1995; Talawar and Rhoades, 1998). However, in practice, there are some complications. The most important ones being the heterogeneity of local soil knowledge even within a single village (Tabor, 1990) and, the problem of correlation between local soil types with scientific groupings (Niemeijer, 1995). The question is whether scientific and indigenous knowledge could be linked to improve the success of cooperation in sustainable agricultural development?

Study area

To test the hypothesis two locations were selected within Kaduna State. These were National Special Program for Food Security (NSPFS) sites at Likoro and Jagindi. The Likoro site is located on the Nigerian topographic map sheet 102 (Zaria) SE which is defined by latitudes 11° 09' 40'' and 11° 10' 08'' N and longitudes 7° 48' 57'' and 7° 50' 57''E. The Jagindi site is located on the Jama'a sheet No. 188 NW and is defined by latitudes 9° 23' 43'' and 9° 24' 33'' N and longitudes 8°12' 14'' and 8° 13' 06'' E. The inhabitants of the two sites were mostly Hausa – Fulani except that the Jagindi site was located within an area inhibited by the Southern Kaduna indigenes. Even then the bulk of the farmers at the two locations remain Hausa / Fulani, while Hausa is the language of communication.

The project site at Jagindi has a humid Southern Guinea Savanna climate while the Likoro site has a tropical Northern Guinea Savanna climate, characterized by a long dry season and a shorter wet season. The rains usually start in April/May with the intensity and amount rising gradually to a peak in August and ends first week of October. The average mean monthly temperature over most of the survey area was 24 to 38°C. The harmattan months, November to January, are usually cool, with monthly means in the range of 21 to 24°C (Kowal and Knabe, 1972). Within the study sites, rainfed cultivation of annual crops like sorghum, millet, cowpea and soya beans take place on the upland while small scale irrigation of maize, vegetables, and rice commonly take place during the dry season on the *Fadama* soil units.

The study sites lie within the Kaduna Plains. Generally, the landforms of the project sites were one of a gently undulating to flat plains with only slight contrasting features except for the soil Unit JD 2 which was highly dissected with broad U-shaped valleys. Much of the site in Likoro lies between 600 and 700 m above sea level rising to between 700 and 800 m in the Jagindi site. The geology of the Kaduna plains, that is, the study sites; Likoro and Jagindi, was of the Nigerian Basement Complex as described by McCurry (1976) and Maclead et al. (1971). In general, the geology of the sites was underlain by rocks of the lower Palaeozoic to Precambrian Basement complex. In the Likoro site, the Basement complex rocks were dominated by gneisses with scattered occurrence of older granite. Rock outcrops were few and low lying and were found mainly within the older granites. The geology of the Jagindi site is described by Maclead et al. (1971) as being dominated by newer basalt emplaced in the quaternary.

The objective of this paper is to test the integrated use of indigenous and scientific knowledge in a detailed soil survey of two agricultural sites in Kaduna State of Nigeria.

MATERIALS AND METHODS

Field studies

The conventional method of soil survey involving the rigid grid procedure with boundary transects checking was adapted for the survey. For both sites, traverses and auger points were at 100 m interval. During the actual soil survey work, two farmers were selected from among the villagers to partake in the field work. The age of the farmers within the study area is between 25 and 35 years old. Structured questionnaires were prepared (Table 1). At each auger points, one of the farmers was first asked to answer the structured questionnaires concerning the soils, while the other was asked to confirm or give alternative answers. Thereafter, the scientists proceeded with augering and recorded their observations. The attention of the farmers was drawn to soil variability with depth.

Augering was made to a depth of 125 cm or to an impenetrable layer whichever is deeper. Soil descriptions were made at 25 cm depth interval or according to horizontal sequence where possible. At each observation point, the local relief, soil erosion or deposition hazard, rock outcrops, surface characteristics, vegetation and land use were recorded. The full range of soil morphological characteristics was recorded. The auger descriptions were classified and plotted along the traverses on a base map, along with the farmers' local soil name and soil boundary lines were drawn to delineate soil mapping unit polygons. Bulk soil samples were taken from the soil profiles, put in plastic bags and labeled.

Table 1. Structured questionnaire asked the farmers.

What is the local name of this soil?
Why is the name given to the soil?
What is the source of the name?
How do you recognize the soil?
What properties or indicators would you use in recognizing the soil?
For farming which one do you prefer?
Why do you prefer that one over the others?
Which of the soils yield better?
How much labour do you require to farm the soil
What kind of crops would do better on each soil type?
How much energy is required to till the land?
Which of the soil type would require too much fertilizer?
How did you know all the different soils?

Laboratory studies

Soil samples collected from the soil profiles pits were air-dried, ground and sieved to remove materials larger than 2 mm. The amount of gravel in each of the soil samples was weighed and the percentage gravel recorded. Soil pH was determined in 1: 2.5 soil/water suspensions using a glass electrode pH meter. Organic carbon was determined by the wet combustion method of Walkley-Black (Nelson and Summer, 1982). Particle-size distribution was determined by the hydrometer method using sodium hexametaphosphate (Calgon) as the dispersant (Gee and Bauder, 1986). Exchangeable bases (Ca, Mg, K, and Na) were brought into solution by repeated extraction procedure with neutral 1 M NH_4OAc (pH 7) solution (IITA, 1979); Ca^{2+} and Mg^{2+} in solution were read on an atomic absorption spectrophotometer; while K^+ and Na^+ were read on the flame photometer. Cation exchange capacity was determined by the 1 N NH_4OAc saturation method while the effective cation exchange capacity (ECEC) was calculated as the sum of the exchangeable bases and exchange acidity. Exchangeable acidity was by the 1 N KCl method. Available phosphorus was extracted by the Bray-1 method (Bray and Kurtz, 1945) and P in solution determined colorimetrically using the ascorbic acid method (Murphy and Riley, 1962). Electrical conductivity (EC) was measured in a 1:2.5 saturation extract (Richards, 1954).

RESULTS AND DISCUSSION

Scientists' classification of the soils

A total of three soil mapping units were delineated at Jagindi while four mapping units were identified at the Likoro site. Delineation by the scientists was based on both morphological and chemical properties of the soil and had as diagnostic attributes, properties related to pedogenesis. The farmers map delineation was however based mainly on soil surface characteristics. While the indigenous classification had two levels, the scientist had four levels of classification (Table 2) with similarity at the highest level between the two classifications. Even at the highest level of classification, while the farmers had principally two landscape types (*Fadama* and Upland), the scientists could have up to six landscape types (Table 2). Details of the soil properties of each soil units for only the Jagindi site are discussed below while cross references are made to the Likoro sites.

Jagindi site

Soil unit JD1

Soil unit JD1 was deep, well drained soils occupying nearly level to moderately sloping (4 to 7% slope) crest to middle slope positions of the upland. The soils colour range from brown (10YR 4/3) to dark brown (10YR 3/3) sandy loam over strong brown (7.5YR 5/6) to red (2.5YR 4/6) sandy clay loam to clay loam subsoil. The soils were weakly structured in the upper horizons to moderately structured subangular blocky in the subsoil. The clay content increased sharply from the Ap horizon from about 7% to over 40% in the subsoil indicating possible argilluviation or increased weathering in the subsoil (Table 3). On the field, the whole of the unit was observed to be under cultivation with limited soil erosion.

Soil unit JD2

The soils were deep and imperfectly drained. They were found in many topographic positions ranging from crest, upper slope and middle slope positions in a highly dissected upland. Soils of this unit were sandy loam

Table 2. Criteria for classification by scientists and indigenous farmers.

Diagnostic attribute	Indigenous	Level	scientist	Diagnostic attribute
Position in landscape	Landscape (*Tudu* and *Fadama*)	1	Landscape	Similar relief types, example, valley, mountain, plateau, hill, etc
Soil colour, texture, drainage, soil surface characteristics	Surface Soil morphology	2	Relief	Combination of topography, example, terrace, glacis etc
-	-	3	Lithology	Geology or hard rock, example, limestone, alluvial etc
-	-	4	Landform	Basic geoforms, example, levee, basin etc.

Table 3. Physico-chemical properties of the soil mapping units at Jagindi site, Kaduna State.

Pedon JDIP1			Soil unit JDI							Exchangeable Bases (cmol kg^{-1})						
Horizon	Depth (cm)	Sand	Silt	Clay	Textural class	pH	ECe (dSm^{-1})	Organic carbon (%)	Available phosphorus (mg kg^{-1})	Ca	Mg	K	Na	Total Exch. CEC (cmol kg^{-1})	Bases (cmol kg^{-1})	Acidity(cmol kg^{-1})
Ap	0-20	81	12	7	LS	5.4	0.06	0.54	5.84	1.70	0.95	0.55	0.08	3.28	0.4	15.8
Bt1	20-37	43	12	45	C	5.5	0.06	0.46	2.28	2.00	1.05	0.46	0.09	3.60	0.2	18.3
Bt2	37-140	41	10	49	C	5.7	0.06	0.23	3.65	1.50	0.70	2.51	0.06	2.77	0.2	7.7
									Soil unit JD2							
Pedon JD2P2																
Ap	0-28	69	18	13	SL	5.2	0.10	0.60	42.95	2.20	0.85	0.33	0.10	3.48	0.6	6.8
AB	28-63	31	26	43	C	4.8	0.07	0.56	10.30	2.70	1.30	0.34	0.10	4.44	1.2	10.5
Bt1	63-107	25	22	53	C	5.7	0.04	0.35	6.22	3.00	1.75	0.33	0.10	5.18	0.2	12.1
Bt2	107-135	41	20	39	CL	5.5	0.08	0.15	6.02	3.10	1.60	0.28	0.12	5.15	0.2	10.8
									Soil unit JD3							
Pedon JD3P1																
Ap	0-34	35	36	29	CL	4.7	0.02	1.52	8.61	2.00	1.05	0.26	0.10	3.41	1.8	11.9
AC	34-71	27	42	31	CL	5.0	0.06	0.93	4.37	2.40	1.20	0.11	0.10	3.81	1.2	12.4
C1	71-119	13	38	49	C	4.2	0.06	1.08	3.31	2.60	1.45	0.13	0.13	4.31	2.2	12.8
C2	119-160	17	34	49	C	5.0	0.02	1.00	2.96	2.90	1.60	0.16	0.15	4.81	1.2	13.7

underlain by sandy clay loam horizons at depth. Fine mica flakes could be found in all horizons while cracks, 1 mm wide extend to a depth of 70 cm. In some cases distinct mottles and gleying occur mostly in the subsoil. This unit was the least cultivated and remnants of the forest reserve could be found along valley of streams. Total porosity values were also less than 40% except in the Ap horizon where 45% was recorded. These total porosity values were below the optimum values for normal crop growth suggesting impeded air and water circulation in the soils. These soils were therefore, structurally weak and prone to severe erosion. On the field, the bulk of the unit was observed to be under secondary forest regrowth and limited crop cultivation.

Soil unit JD3

This mapping unit included deep, imperfectly to well drained, very dark brown (10YR 3/2) sandy loamy to clay loam surface horizons, overlying brown (10YR 4/3) to dark grayish brown 10YR 4/2) sandy loam to sandy clay loam or clay loam subsoil. The soils occupied nearly level to level (0 to 2%) seasonally flooded positions (*Fadama*) along the river and constituted about 10% of the total site area. Although levees and basins could be identified within the present floodplain they could however, not be mapped out. The structure was predominantly weak but tended towards granular structureless with depth. Common fine mica flakes and soft iron nodules occurred especially in the subsoil.

The soils of the three units; JD1, JD2 and JD3 all had strong acid reaction in the Ap horizon to moderately acid reactions in the subsoil. Exchangeable bases, CEC, ECe, base saturation were all low except in profile JD1P1 where moderate values were obtained for CEC and BS. Both cation exchange capacity (CEC) and effective cation exchange capacity (ECEC) of the soil were also low in the Ap horizon but moderate in the subsoil, the distribution was similar to the pattern of clay distribution. Total exchangeable bases increased with soil depth, indicative of possible leaching of bases downward. Organic carbon and the other organic matter based nutrients like total nitrogen and available phosphorus were all low except in the available phosphorus content of the Ap horizon of profile JD2P2 where values as high as 42 mg kg^{-1} was recorded (Table 3). However, cationic micronutrients and boron were moderate in content and theoretically, would be adequate in the first few years of cropping. The very low values of electrical conductivity of less than 0.08 dSm^{-1}, indicate that salinization is presently not a problem. Sodication is also not likely to pose management problems because of the very low ESP and SAR values that are less than 1% and 0.10 in all the horizons. In summary, the soils of unit JD1 were classified as Typic Haplustults and Fluventic Dystrustepts while soils of JD2 were also classified as Typic Haplustults and Ombroaquic Haplustults by the USDA Soil Taxonomy (Soil Survey Staff, 1981) and Chromic Acrisols and Epidystric Cambisols for soil unit JD1while soils of JD2 were mostly Chromic Acrisols and Haplic Acrisols by WRB system (FAO/ISSS/ISRIC, 1998) (Table 4).

However, soils of unit JD3 (the *Fadama* unit) were classified as Mollic Ustifluvents by the USDA Soil Taxonomy (Soil Survey Staff, 1981) and Umbric Gleysols and Epigleyic Fluvisols by WRB system (FAO/ISSS/ISRIC, 1998)

Farmers' classification of the soils

Fadama/Tsaki Kogi/Baki Kogi (soil unit JD3)

The hydromorphic soil units or the soil unit occupying valley floors and low lying flat lands adjacent to rivers were also identified by all the farmers from the two sites. The famers' and the scientist's maps were similar but the main differences were found in the total land area marked as *Fadama* by the farmers. This was because all low lying areas adjacent to the river were considered *Fadama,* which were considered so purely from use-oriented perspective. This further elaborates the fact that farmers' restrict their classification to mostly limiting factors similar to what is obtainable in Fertility Capability Classification (FCC) or in land suitability classification system. There were similarities in the semantics used at the two study areas because of the common language of communication which is Hausa, but there were very slight dialectic differences. Farmers in the two sites named the hydromorphic soils as *Fadama* at the first level of classification but in addition farmers in Jagindi refer to it as *Tsaki Kogi,* while those at Likoro calls it *Baki kogi*. When translated they mean literarily "middle of the river" and "back of the river" respectively. The two mean virtually the same and refer to the same soil materials. The units, according to the farmers were more fertile than other soil units and were lands liable to periodic flooding by river and suitable for the cultivation of rice, sugar cane and vegetables. The unit was also used for the dry season farming because of the nearness to the river. The farmers' perception of the *Fadama* soils was quite similar to the scientists' perception. However, the scientists' could further subdivide the *Fadama* into levee and basins, depending on the scale of the survey, and based on the vertical variability which farmers though were aware, but do not take into account in their classification. During the course of interview, the farmers claimed that *yashi*, *farin kasa* and *bakin kasa* were other soil types that could also be found in some other *Fadama* areas. Literally, *yashi* means sand, *farin* means light coloured while *bakin* refers to dark coloured. In effect the *Fadama* landscape could be sub-divided, at the second level of classification, based on soil colour and texture (Figure 1).

Table 4. Summary of soil classification.

Site	Soil unit	Soil taxonomy	WRB	Indigenous
	LKIP1	Petroferric Haplustult	Chromic Acrisol	*Tudu Jar Kasa*
	LK1P2	Typic Haplustult	Haplic Acrisol	
	LK2P1	Typic Dystrustept	Hyperdystric Cambisols	*Tudu Mara-mara*
	LK2P2	Lithic Dystrustept	Hyperdystric Cambisols	
Likoro	LK3P1	Petroferric Haplustult	Haplic Acrisol	*Tudu Mara-mara*
	LK3P2	Petroferric Haplustult	Chromic Plinthosol	
	LK4P1	Vertic Ustorthent	Umbric Gleysols	*Fadama Baki-Kogi*
	LK4P2	Vertic Ustorthent	Mollic Gleysol	
	JD1P1	Typic Haplustult	Chromic Acrisol	*Tudu Jar-Kasa*
	JD1P2	Fluventic Dystrustept	Chromic Acrisol	
	JD2P1	Typic Haplustult	Haplic Acrisol	*Tudu Yunbu*
	JD2P2	Ombroaquic Haplustult	Chromic Acrisol	
Jagindi				
	JD3P1	Mollic Ustifluvent	Umbric Gleysol	*Fadama Tsaki-Kogi*
	JD3P2	Mollic Ustifluvent	Epigleyic Fluvisol	

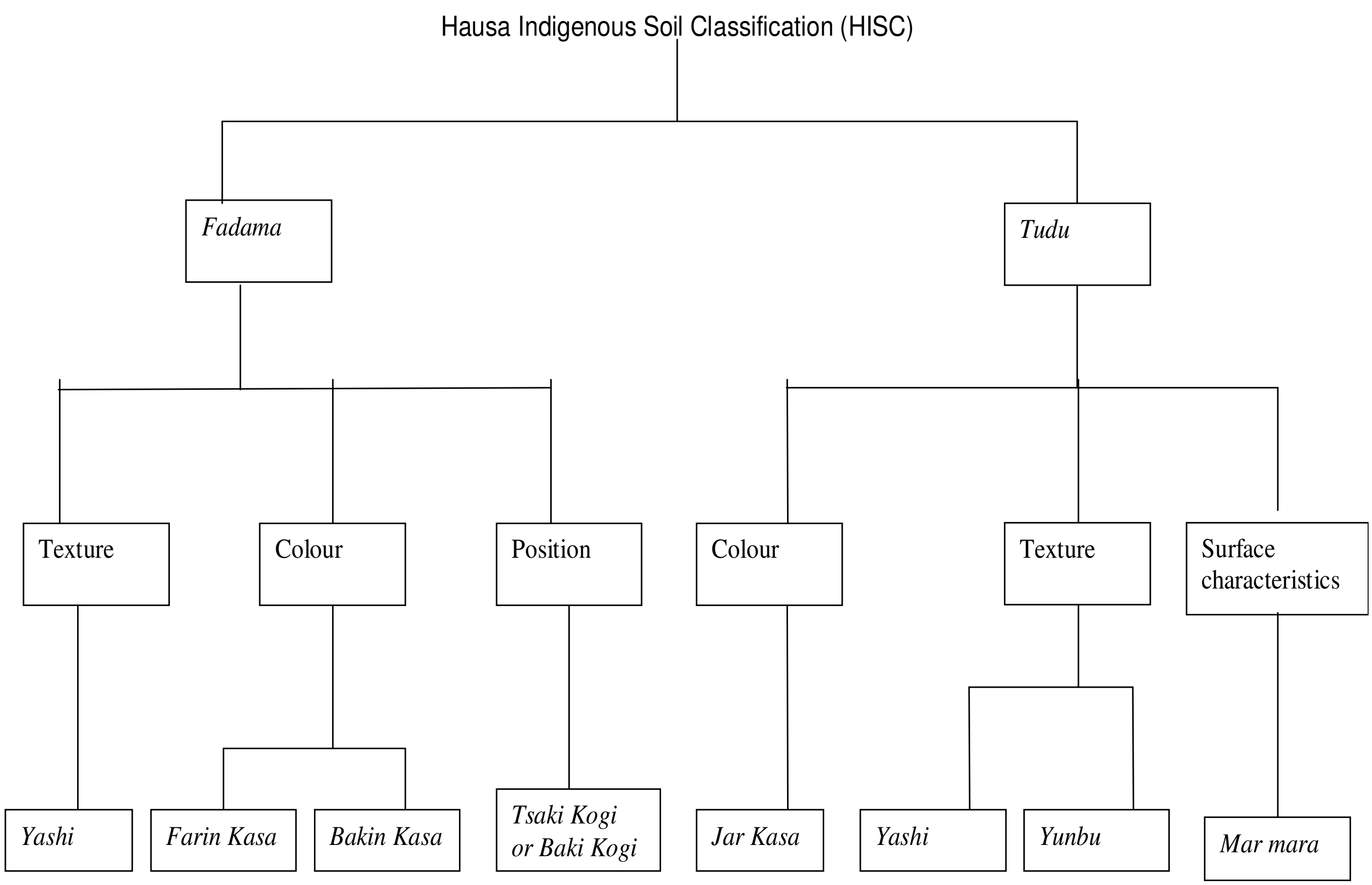

Figure 1. Structure of the Hausa indigenous soil classification (HISC) scheme.

Tudu/Jar Kasa/Jar (soil units JD1 and JD2)

All the upland soils were classified by farmers as *Tudu* which literarily means upland, or well drained soils. According to the farmers, the unit is best suited for crops like sorghum, millet or maize and is not as fertile as the *Fadama* soils. In the Jagindi site, soil unit JD1 which was classified as Chromic Acrisol by the WRB system was classified by the farmers as *Tudu Jar Kasa* while similar soils in the Likoro site was also classified as *Tudu Jar* by the farmers of the site (Figure 1). Chromic refers to the redder hues which were also recognized by the farmers as *Jar* (meaning red) in their classification. In the Jagindi site, soil unit JD2 which was highly dissected, imperfectly drained and had clay loam in the Ap horizon was classified as *Tudu Yunbu* by the farmers. Literarily it means clay or upland clayey soils with poor drainage. In the upland, farmers also claimed that *yashi* and *Mar mara* were two other soil types common within the *Tudu* landscape but which were however not encountered in the present study area. *Mar mara* means rocks or laterite and it refers to soils which have surface gravels, stones or rock outcrop that impede cultivation. In effect the *Tudu* was sub-divided based on texture, soil surface characteristics and soil colour, similar to what was done in the *Fadama*.

Conclusion

In conclusion, it was apparent that the farmers within the study areas have a fair knowledge of their soils in terms of soil colour, texture, surface characteristics, drainage and inherent soil fertility (Taylor-Powell et al., 1991; Guillet, 1992). As a first classifier, the farmers use position in the landscape while as second classifier, soil colour, texture, surface characteristics and drainage were used. Some of these properties have great pedo-transfer functions. Soil colour for instance is associated with organic matter content, soil moisture, drainage and the sesquioxide contents. Their classification scheme, though looks simple (two levels only), but was adequate in most cases to group soils into classes that could be managed using similar management practices. A strong correlation of the Hausa indigenous soil classification could be better achieved with the WRB system, both of which have two levels. It was also obvious that the indigenous classification could not differentiate the soils on the bases of subtle differences, especially in the subsoil, unless translated onto the soil surface. However, the farmers' soil map was very similar in outline to the soil map by the scientists. The major difference is in the extent of the mapping units especially the *Fadama*. For sustainable development in the study areas and to improve communication between the scientists, the extension agents and the farmers, an integration of local soil name into the soil map legend will go a long way in this direction.

REFERENCES

Barrera-Bassols N, Zinck JA (2000). Ethnopedology in a worldwide Perspective: An Annotated Bibliography. ITC, p. 77.

Braimoh AK (2002). Integrating indigenous knowledge and soil science to develop a national soil classification system for Nigeria. Agric. Hum. Values, 19: 75-80.

Bray RH, Kurtz LT (1945). Determination of total, organic and available forms of phosphorus in soils. Soil Sci., 59: 39-45.

Corbeels M, Shiferaw A, Haile M (2000). Farmers' knowledge of soil fertility and local management strategies in Tigray, Ethiopia. Managing African soils No 10. International Institute for Environment and Developmet (IIED) Drylands Programme, London.

Dialla BE (1993). Tha Mossi indigenous soil classification in Burkina Faso. Indigenous Knowl. Dev. Monit., 1(3): 17-18.

Ettema CH (1994). Indigenous soil classifications. What are their structure an functions, and How do they compare with scientific soil classifications? Institute of Ecology, University of Georgia, Athens 30602-2202, http://www.nrel.colostate.edu.

FAO, ISRIC, ISSS (1998). World Reference Base for Soil Resources, Food and Agricultural Organization of United Nations, Rome, p. 112.

Gee GW, Bauder JW (1986). Particle-size analysis. In: A Klute (ed). Methods of soil analysis. Part 1. Physical and mineralogical methods, 2nd ed., Agronomy, 9: 383-411.

Guillet DW (1992). Crop choice and soil management. In D.W. Guillet (ed). Covering ground: Communnal water management and the state in the Peruvian highlands. The University of Michigan Press, Ann Arbor, Michigan, USA, pp. 67-84.

Hecht SB (1990). Indigenous soil management in the Latin American tropics: Neglected knowledge of native peoples. In M.A. Altieri and S.B. Hecht (eds), Agroecology and small farm development, Boca Raton, Florida, CRC Press, pp. 151-158.

IITA (1979). Selected methods for soil and plant analysis. International Institute of Tropical Agriculture Manual Series No. 1, Ibadan, p. 62.

Kowal JM, Knabe DT (1972). An agricultural Atlas of the Northern States of Nigeria with Explanatory Notes, Ahmadu Bello University Press, Zaria, p. 111.

Kundiri AM, Jarvis MG, Bullock P (1997). Traditional soil and land appraisal on *Fadama* lands in northeast Nigeria. Soil Use Manage., 13: 205-208.

Maclead WN, Turner DC, Wright EP (1971). The geology of the Jos Plateau. General Geology, Fed. Government of Nigeria, Lagos, 1: 91-101.

McCurry P (1976). The geology of the Precambrian to Lower Palaeozoic rocks of northern Nigeria- A review. In: Kogbe, C.A. (ed.) Geology of Nigeria, Elizabethan Publishing Co., Ibadan, Nigeria, p 15-38.

Murphy T, Riley JP (1962). A modified single solution method for the determination of phosphate in natural water. Anal. Chim. Acta, 27: 31-36.

Nelson DW, Sommers LE (1982). Total C, organic C and organic matter. In: A.L. Page, R.H. Miller, and D.R. Keeney (ed.). Methods of Soil analysis. Part 2, Chemical and microbiological properties. 2nd ed. Agronomy, 9: 539-579.

Niemeijer D (1995). Indigenous soil classifications: Complications and considerations. Indigenous knowl. Dev. Monit., 3: 20-21.

Osunade MAA (1994). Indigenous climate knowledge and agricultural practices in southwestern Nigeria. Malaysian J. Trop. Geogr., 25(1): 21-28.

Richards LA (1954). Diagnosis and improvement of saline and alkali soils. USDA Handbook 60, US Govt. Printing Office, Washington D.C., p. 503.

Soil Survey Staff (1981). Examination and description of soils in the field, In Soil Survey Manual, USDA Agricultural Handbook 18, United States Government Printing Office, Washington, D.C. p. 503.

Soil Survey Staff (1999). Soil Taxonomy: A basic System of Soil Classification for making and interpreting Soil Surveys. Second edition, USDA Agric. Handbook 436, US Govt. Printing Office, Washington, D.C., p. 863.

Tabor J (1990). Ethnopedology: using indigenous knowledge to classify soils. Aridd lands Newslett., 30: 28-90.

Tabor JA, Hutchinson CF (1994). Using indigenous knowledge, remote sensing and GIS for sustainable development. Indigenous Knowl. Dev. Monit., 2(1): 17-19.

Talawar S, Rhoades RE (1998). Scientifican and local classification and management of soils. Agric. Hum. Values, 15(1): 3-14.
Taylor-Powell E (1991). A. Manu; SC. Geiger; M. Ouattara and ASR. Juo. Integrated management of agriculturl watersheds: land tenure and indigenous knowledge of soil and crop management. Texas Trop. Soils Bull., 30. 91-04.