DOI: https://doi.org/10.67042/njss.2015.7wp5o4q4

Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

Soils of the degraded derived savanna land in Southwest Nigeria: distribution, morphology and sustainable climate–smart land use plan

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ARTICLE INFO

Article history:
Received February 22nd, 2022
Received in revised form July 13th, 2022
Accepted July 19th, 2022
Available online July 21th, 2022

Keywords:

Derived Savanna
Soil Morphology
Soil Classification
Soil Map
Land Use

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ISSN– Online **2736-1411**
Print **2736-142X**
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ABSTRACT

Southwest Nigeria belongs to the humid tropical climate with a Wet/Dry Forest and a Derived savanna. The studied site is under the latter ecosystem (located around Ilero, 08.05N/03.22E in Kajola Local Government Area of Oyo State) and was a former mechanized farm with a low-intensity land use pattern with seasonal uncontrolled burning/grazing with a subsequently degraded landscapes. And to encourage the habits of sustainable land-use management, the objectives of this study were: [1] to produce a detailed soil map of an approximate 1,293ha [12.93 sq. km] land mass at the soil series level and, [2] to use the soil/landform properties to formulate a land use plan suitable for a sustainable climate-smart watershed management plan. The degraded landscape is characterized by: induced drainage channels at upper physiographic positions and equally devoid of vegetation attributed to cattle grazing; surface gravels/stones/cobbles typical at the middle slope positions; iron coated surface soils on the seepage areas; and common, massive exposure of iron pans on upper slope positions. Ten mapping units identified at Soil Series level [and classified into Soil Taxonomy/World Reference Base] include Shabe (2.6%), Ogboro (9.3%), Iwaji (2.2%), Amodu (1.9%), Tede (2.7%), Iwo (18.1%), Dejo (7.0%), Gambari (9.6%), Shante/ Apomu soil complex (34.3%) and Adio soil (12.3%). Potential common limiting factors for sustainable land use/management are soil erosion, effective soil depth, stoniness, and wetness/drainage. Mixed cropping and agro-forestry are suggested viable land use options for sustainable land use/management that are a conditional factor for climate-smart agriculture and sustainable ecosystem services.

1.0. Introduction

The Derived Savanna (Savanna-Forest Ecotone) is important for two major reasons (as the nation's breadbasket) because it can probably grow the most common arable and tree cash crops of the agro-ecological zone of West Africa and has been noted for unsustainably managed ecosystems leading to degradation. Degraded landscapes have resulted from vegetation removal, agricultural activities, over-exploitation, and over grazing [Hole, 2009; Okusami, 2018]. Ofomata[1982, p120, p.128] strongly reiterated this and that an adequate strategy should be formulated to conserve our land resources through a coordinated and sustained land-use programme. The derived savanna-forest ecotone of Nigeria (West Africa) has been attributed to be a product of inappropriate land use. Studies into these agro -ecologies are needed to formulate appropriate policies on land use towards restoring the degraded land and improving these lands for sustainable land use and its management. Soil survey is always fundamental for sound decisions on land use management/planning. The objectives of this study were to utilize the soil/landform properties and the soil classification, derived from the soil survey of the land area, for formulating a sustainable land use plan for improved agricultural productivity, and ecosystem services and to foster climate-smart land use in general.

2.0. Materials and Methods

2.1. The environment:

Figure 1 shows the location of the studied site. It is claimed to be in transition between the Derived Savanna and the Southern Guinea Savanna with rainfall distribution strongly similar to those recorded for Ago Are [50.9 km

away from Ilero via Saki – Iseyin Road and Otu – Oke Iho], as documented in Table 1.

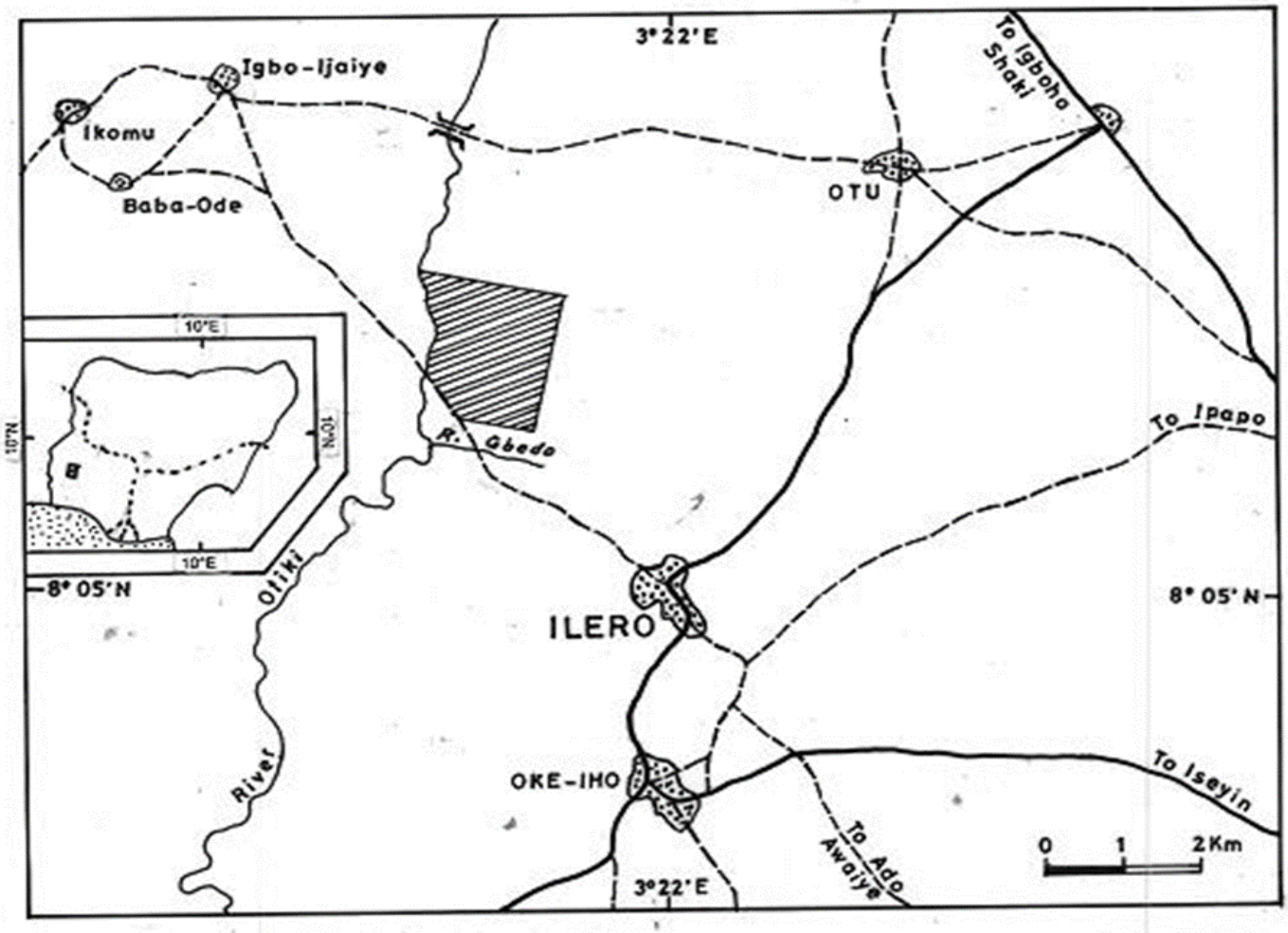

FIG. 1.:LOCATION OF STUDY SITE STIPPLED AND SOME OTHER REFERENCE POINTS IN OYO STATE OF SOUTHWEST NIGERIA.

Table 1: Monthly Average [mm] Rainfall For Ten Years [1982 – 1991 at Ilero].

MONTH	AVERAGE [MM]
JANUARY	11.86
FEBRUARY	12,59
MARCH	46.03
APRIL	72.78
MAY	171.51
JUNE	154.21
JULY	206.47
AUGUST	170.50
SEPTEMBER	177.23
OCTOBER	80.12
NOVEMBER	00.16
DECEMBER	1.76
ANNUAL AVG.	1105.22

[Source: Nigerian Tobacco Company (NTC)Ago Are]

2.2. Soil Studies:

A rigid grid survey system was used to access the soil variability using the 1:50,000 Topomap of IKOMU S.E. SHEET 220 [Federal Surveys, 1967] as the base map after cartographic adjustment to the appropriate scale of 1: 10,000 compatible with the scale of publication of the soil map.. The mapping units used were based on the works of Ojo-Atere *et al*. [1973] and Murdoch *et al*. [1976], which in turn derived their principles mostly from the works of Smyth and Montgomery [1962]. Supporting analytical data used [see Okusami, 2018] include soil separates, soil pH, total N, available P, exchangeable bases and exchange

acidity including exchange aluminum; and X-ray mineralogy data of the clay fraction (Table 2, adapted from Okusami,2018).

Table 2: Clay Mineralogy Distribution for some soils of the Derived Savanna, Southwest Nigeria

Soil Series	Dominant Clay Minerals	Soil Series	Dominant Clay Minerals
Shabe	Kaolinite, mica	Iwo	Kaolinite, montmorillonite, mica
Ogboro	Kaolinite, mica	Gambari	Kaolinite, mica
Iwaji	N/A	Dejo	Kaolinite, montmorillonite, mica
Amodu	Kaolinite, mica	Shante/Apomu	Kaolinite, mica
Tede	Kaolinite, mica	Adio	Kaolinite, montmorillonite, mica

2.3. Land Evaluation

A land use rating was used with Land Suitability of FAO (1983) and Land Capability Classification of Kliengebiel and Montgomery (1973, in Singer *et al*., 1979), basically using the land utilization types [LUT] as documented in Table 3. However, Emphasis was placed on the former because it is more appropriate to the scale of the soil map and more frequently used in Nigeria's agronomic landscape.

The rating for Land Suitability was based on the limitations of the soils for sustainable cultivation of different identified land utilization types based on observation [actual] made on land use types and potential land use types that may be profitable for sustainable land use.

Vegetation/Land use characterization followed the grid system laid out for the soil survey work. This consisted of going through transects and documenting information on plant species identifiable on the spot. Where the latter was not possible, samples were collected for laboratory studies to properly identify plant species.

Table 3: Land Utilization Types' [LUT] Environmental Requirements For Ilero Land Use Plan.

LAND UTILIZATION TYPES [LUT]	RAINFALL [mm] Annual	TEMPERATURE Avg. Daily ° C	GROWTH PERIOD Days[months]	SOIL FACTORS	ERODIBILTY INDEX	SOURCES OF INFORMATION.
MAIZE Zea mays	600-900 [well distributed]	20-25◦C No Frost	90 (early maturing) 160 (late varieties)	●Well-drained ●EC≤5mmhos cm ●High Org. matter	High	●ILACO, 1981, p475-476.
SORGHUM Sorghum vulgare	250≥600 [drought Tolerant]	30◦C [Optimum] No Frost	Avg. 120 [3-7]	●Wetland soils Tolerant ●poor soils tolerant ●EC≤ 6mmhos cm	High	●ILACO, 1981, p 476-477
BEANS Phaseolus Vulgaris				●Loamy, sandy ●well- drained ●pH ≥ 7.00		Learn2Grow.com
COWPEA Vigna unguculata	400-700 [drought tolerant]	30◦C [Optimum]	Vegetative Period best During peaks of Rains.	●Well- drained ●Sandy soils ●pH5.6-6.0 ●More tolerant to low fertility and acid soils ●lightly tolerant to waterlogging		
PIGEON-PEAS Cajanus cajan	Drought resistant	65≥86◦F		●Well- drained ●pH4.5-8.4 ●Tolerant to low Soil fertility, and especially low P levels.		●United States Department of Agriculture / Natural Resources Conservation Service ●ILACO, 1981, p561.
CASSAVA Manihot Esculenta	≥500, Well Distributed [Very high Rainfall]; Drought Resistant;	No Frost	[12-24]; harvesting can be left in the soil for several months [an advantage]	●GoodStructure ●Good internal Drainage ●Fairly light soil ●High O.M. ●pH6-9		●ILACO, 1981, p478-479.
YAM. Dioscorea	Very High Rainfall	High-Temperature Favour				●ViCAARP ●ILACO, 1981, p561.
ORANGE Citrus spp.	>1,100	25◦C, optimum avg. daily, [13-35], No frost.		●Deep, well Drained, ●Sandy loams most suitable, ●No salinesoil, ●ECe>3.5 ●pH>5		●ILACO, 1981, p494-495.
MANGO	>300	<45◦C				Ap-mango-soils-climate.html
CASHEW Anacardium occidentale	1000-2000, Warm humid tropical conditions/ hot dry tropics around sea level.	24-28◦C, optimum [also in a range of 7-40◦C]	Loves sun; has an extensive root system and deep taproot; requires Pronounced dry season of 3-4 months. In areas with two dry seasons in a year, trees usually flower twice a year.	●All soils Including sandy soils. ●minimal fertility		●Widiatmaka et al., 2014.

3.0. Results and Discussion

Soil Distribution – Soil Morphology

The occurrence of strong soil-landscape relationships is influenced by physiography (and less by rock types). A toposequence typical of soils formed on the Basement Complex found within Humid Tropical Nigeria [as reviewed in Okusami and Muda, 2000] is present as outlined in Figure 2 and as previously discussed in Okusami [2018]. This has strongly influenced the soil distribution pattern in Figure 2.

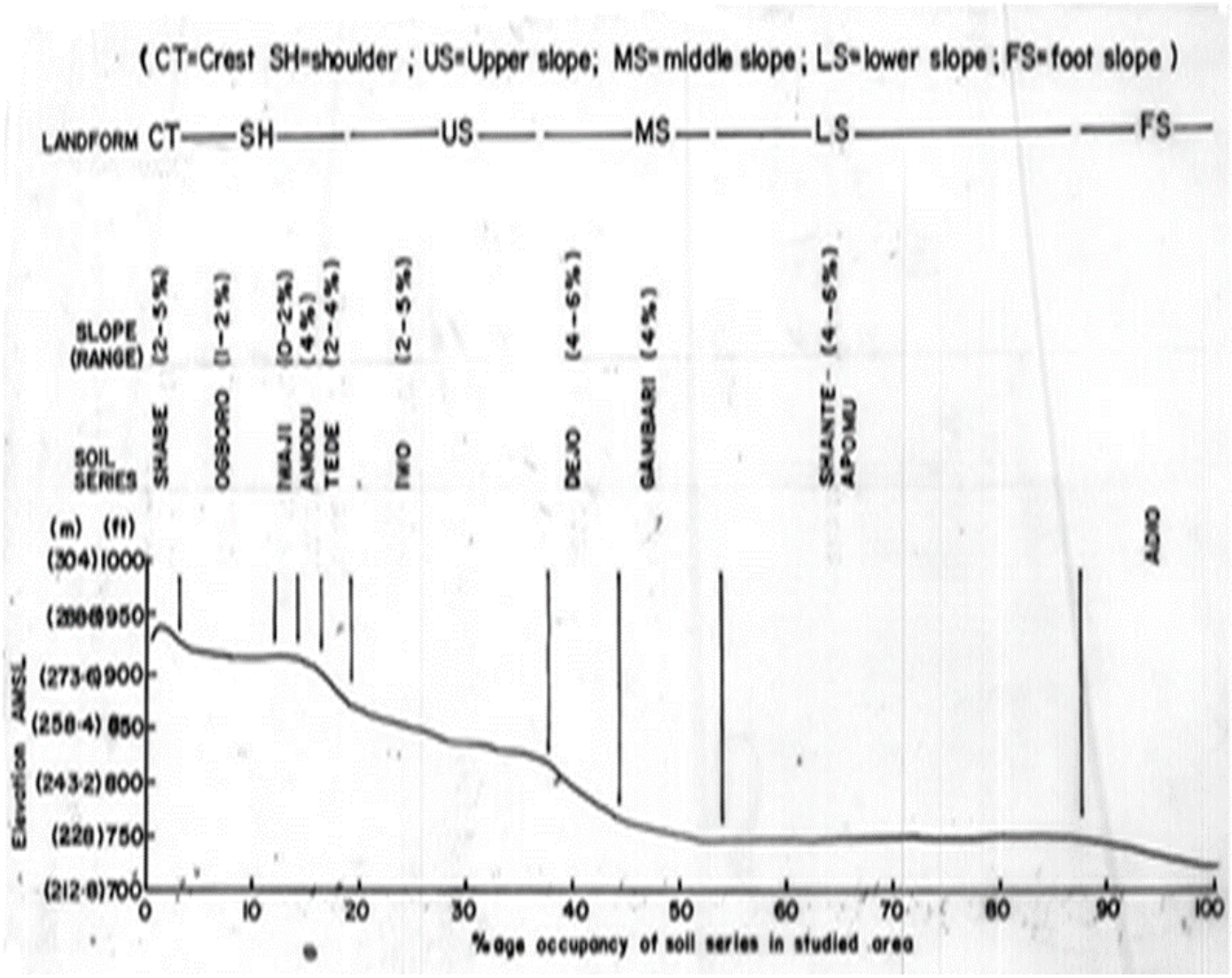

Figure 2. Soil – Landscape Relationships as Observed at the Studied Site in Ilero, Oyo State of South-west Nigeria [Okusami, 2018].

Although the rock types and past landform processes have modified the landscapes so that they are not consistently repeatable [Okusami, 2018], soils on the crest and shoulder/upper slope positions are well-drained to moderately well-drained. They are characterized by multi-layered parent materials with different slope formations that could sometimes be practically level, thus giving a beveled land impression (e.g. Amodu series).

They all have quartz gravels/stones/cobbles at various depths, including concretions and nodules in some instances [Tables 4 and 5]. Many streams (rivulets) originate from the base of the upper slope positions or from the transition zone between the upper slope and middle slope positions. The upper/middle slope (back slope) consists of soil drainage classes that varied from well-drained (e.g. Iwo series) to poorly/imperfectly drained soils on the middle slope/lower slope (Gambari, Dejo and Shante/Apomu series). Few of the soil types- Shante/Apomu and Dejo series - are also somewhat poorly drained. The valley bottoms are mostly U-shaped and eroding as typified by the Adio series. Their extent- the wetness- could stretch upslope into the fringes and middle-slope/upper-slope positions if seepage points occur in these areas. Terrain features that indicate degraded landscape include the seepage points, surface gravels, and exposed iron pans. The seepage areas have iron coated surfaces indicating an anaerobic-aerobic transformation of the subsoil colloidal flow of iron and fine clay particles. Soils are acid with a strong influence by exchangeable Al. Table 5 contains excerpts of soil chemistry indicators of the soil fertility of the different mapping units.

Detailed soil morphology and the environment for the individual mapping units are illustrated below [Table 4] in a sequence correlated to the soil-landscape relationship, as illustrated in Figures 2 and 3.

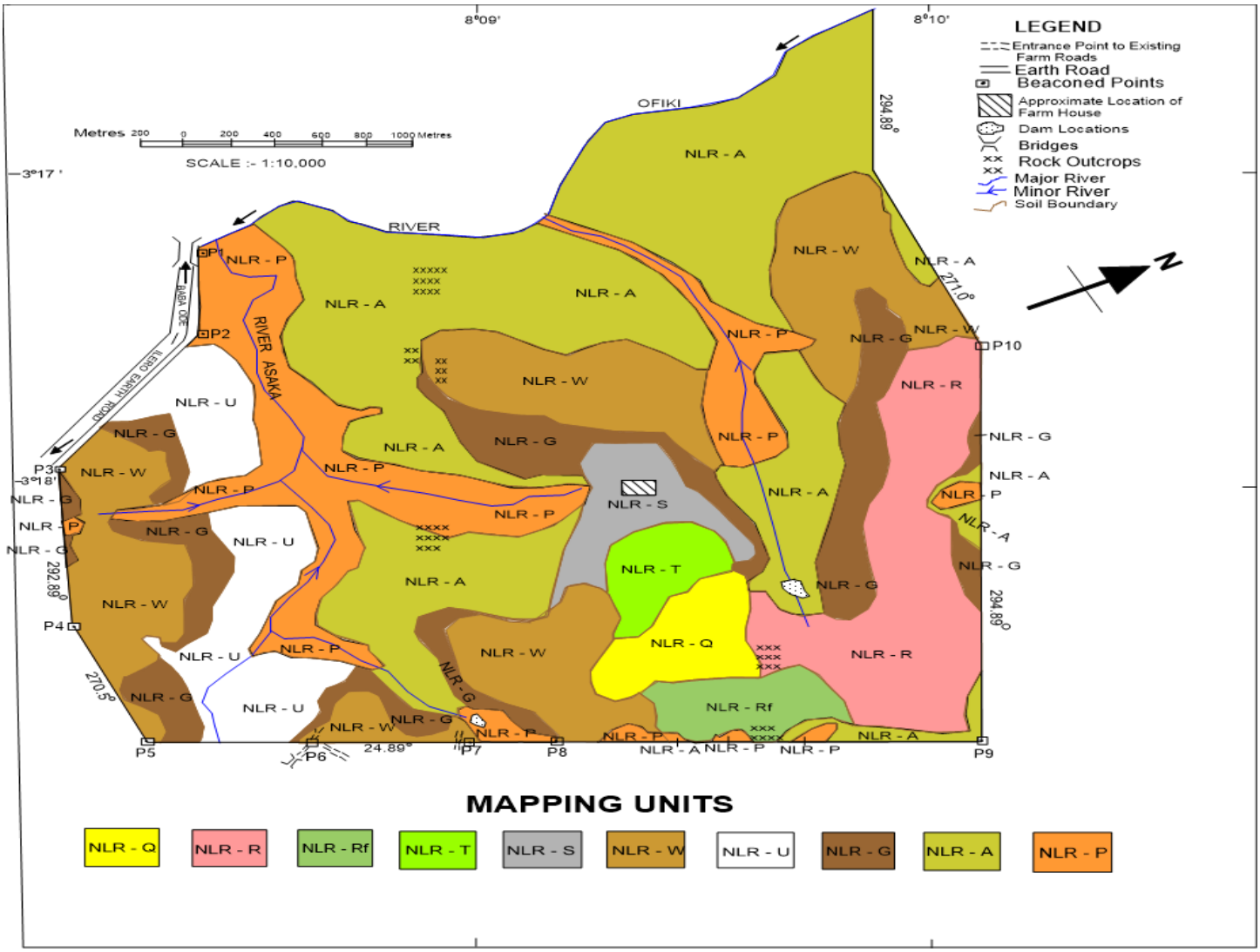

Figure 3. Soil Map of Ilero Area Study Site in Oyo State of Southwest Nigeria.

Table 4i[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT: NLR- Q Soil	**DATE: December 5, 1992**
LOCATION: FORMER MECHANIZED FARM AT ILERO Descriptive – Coordinates/GPS - ELEVATION [m] ROCK FORMATION: ●Basement Complex Formations : Igneous – Possibly Granite Metamorphic – ●Sedimentary - PHYSIOGRAPHY: Topography [Relief] – Moderately Undulating Landform / Land Element –Crest Position on Landscape - Crest but convex. A ridge-like physiographic unit Slope / Gradient – 1-2% (2-5%) Form OR Shape – Moderately Convex Microtopography - VEGETATION AND LAND USE: Shrub-grassland mostly. Previously cultivated but now used for range AUTHOR [S]: T. A. Okusami SAMPLE CODE NUMBER : -	SOIL CLASSIFICATION:Q Soil Series – Shabe Series Soil Taxonomy – Rhodic kandiustults WRB – Haplic Skelectic Rhodic Acrisols [clayic , cutanic] CLIMATE PARENT MATERIAL: In-situ, formed in basement complex, possibly granite. In – Situ/Residual – √ Transported - Transported Over In-situ/Residual SOIL – WATER RELATIONSHIPS : Drainage Class – Well-drained Depth to Groundwater - > 2m Soil Moisture Conditions - Dry- Slightly Moist - Moist – √ Wet – SURFACE CHARACTERISTICS : Rock Outcrops – None Observed Coarse Fragments – Erosion – Very Slight Types Sealing / Cracks - INSTITUTION: Obafemi Awolowo University. Ile-Ife. PICTURE NUMBER /IDENTIFIER:-

Table 4i[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	DEPTH [cm]	DESCRIPTION
A1	0-10	Dark yellowish brown (10 YR 3/4) (10 YR 4/4, dry); slightly gravelly (<15% by volume) coarse sandy clay loam; moderate, medium and coarse granular; soft (dry), friable (moist): few and very fine pores; common, very fine and fine roots; clear and smooth boundary.
B1	10-30	Yellowish red (5 YR 4/6): slightly gravelly sandy clay loam; moderate, medium and coarse subangular blocky; friable (moist); slightly hard (dry), firm (moist); common, fine and medium pores (tubular); few, fine and medium roots; abrupt (texture) and diffuse (colour) slightly wavy boundary.
B2	30-70	Dark red (2.5 YR 3/6); extremely gravelly (60-95% by volume) sandy clay (with many flakes of muscovite mica); moderate, medium, coarse subangular blocky; firm (moist); very few medium, coarse and few fine roots; diffuse, smooth boundary. Here the quartz vein diffuses.
BC1	70-123	Dark red (2.5 YR 3/6); extremely gravelly sandy clay; moderate, medium and coarse subangular blocky; firm (moist); few, very fine roots; diffuse, smooth boundary (except in the area of a quartz vein which is a plentiful source of muscovite mica and quartz); firm (moist)
BC2	123-150	Dark red (2.5 YR 3/6); very gravelly (35-60% by volume); sandy clay loam; moderate, medium, coarse subangular blocky; firm (moist); few, very fine roots.
C1	150-175	Auger sample; very gravelly sandy clay loam.
Cr2	175-200	Auger sample; very gravelly sandy clay loam.

DIAGNOSTIC/SUMMARY: [SHABE SERIES]. This unit occupies the crestal position [also the peak within the land mapped]. It consists of a shallow surface soil horizon sitting over extremely gravelly sandy clay horizon - Brownish sandy clay loam over yellowish red and dark red, very gravelly sandy clay subsoil; quartz vein [possibly granite] – the source of quartz and plentiful muscovite mica; the quartz vein diffuses with [at Bt2] depth, contributing to the gravel content decreasing with depth . Profile lacks concretions; roots although few and very fine, occur at or > 150cm.

This profile correlates with the Shabe series described in Murdoch *et al*. [1976b] except for the absence of concretions

[Laboratory analysis indicated: the dominance of kaolinite secondary mineral in the clay fraction; neutral surface soil horizon with increasing acidity down the inspected soil profile].

Table 4ii[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT: NLR- R Soil.	**DATE: December 4, 1992**
LOCATION: FORMER MECHANIZED FARM ATILERO Descriptive – Coordinates/GPS - ELEVATION [m] ROCK FORMATION: ●Basement Complex; √ Igneous – Metamorphic – ●Sedimentary - PHYSIOGRAPHY: Topography [Relief]– Moderately Undulating Landform / Land Element – Crest Position on Landscape - Crestal Position but almost on the edge of the wide crestal, plateau-like positions Slope / Gradient – 1-2% Form OR Shape – Microtopography - VEGETATION AND LAND USE: Wooded savanna. About to be burnt for grass growth rejuvenation for cattle grazing.	SOIL CLASSIFICATION: R Soil type Series – Ogboro series Soil Taxonomy – Typic or Dystric Haplustepts WRB –Ferralic Cambisols [ochric] CLIMATE PARENT MATERIAL: Colluvial over in situ, all derived from basement complex material. In – Situ/Residual – Transported - Transported Over In-Situ/Residual √ SOIL – WATER RELATIONSHIPS : Drainage Class – Well-drained Depth to Groundwater - >200cm Soil Moisture Conditions - Dry- Topsoil Slightly Moist – Lower Subsoil Horizons Moist – Wet – SURFACE CHARACTERISTICS: Rock Outcrops – none observed Coarse Fragments – None observed Erosion – Very Slight Types Sealing / Cracks -
AUTHOR [S]: T. A. Okusami SAMPLE CODE NUMBER : -	INSTITUTION: Obafemi Awolowo University. Ile-Ife. PICTURE NUMBER /IDENTIFIER: -

Table 4ii[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	DEPTH [cm]	DESCRIPTION
A1	0-10	Dark brown (10 YR 3/3); coarse sandy loam; weak medium angular blocky; soft (dry), friable (moist): many and very fine pores; common, fine and medium roots; diffuses, smooth boundary.
A2	10-30	Dark Yellowish brown (10 YR 4/4): coarse sandy clay loam; occasional quartz, weak, medium angular blocky; soft (dry); friable (moist); common, medium and coarse roots; abrupt, slightly wavy boundary.
2C1	30-52	Dark red (2.5 YR 3/6); extremely gravelly (quartz and concretions) sandy loam; single grain; slightly hard (dry), loose (moist); very frequent concretions; common, fine, few, medium and coarse roots; diffuse, smooth boundary.
2C2	52-75	Dark red (2.5 YR 3/6); extremely gravelly (60-95% quartz and concretions)coarse sandy clay; single grain; slightly hard (dry), loose (moist); (45-80% by volume of concretions) ; common and fine, few and coarse roots; abrupt, smooth boundary.
3C	75-120	Red (2.5 YR 4/6); gravelly (15-35% by volume); sandy clay loam; weak, medium and coarse angular blocky; firm (moist); very few, fine and medium roots.

OTHER OBSERVATIONS [e.g., deviation from modal soil profile descriptions.]

DIAGNOSTIC SUMMARY: [OGBORO SERIES] Series is closely associated with the Shabe series and occupies an upper slope/shoulder position.Shallow soil [about 50 – 70cm solum]; brownish and coarse sandy loam over dark red /red extremely gravelly – gravels are both quartz and concretionary [15-80% by volume; deeper subsoil horizons can be very hard and/or ferruginized [saprolitic].

Identifies well with the classification as Ogboro series [as in Muurdoch *et al*., 1976b] with a possibility of also being classified as Titiale series. The feldspar emphasized in the Titiale series is not very obvious in this mapping unit as found during mapping work. [Profile described here has a mediumacid soil horizons with the exception of the topsoil that is slightly acid].

DIAGNOSTIC/SUMMARY: IWAJI SERIES;Iwaji series occupies an almost equivalent elevation as the Ogboro

Table 4iii[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT: NLR-R_f Soil	**DATE: December 7, 1992**
LOCATION: FORMER MECHANIZED FARM ATILERO Descriptive – Coordinates/GPS -	SOIL CLASSIFICATION: R_f Soil type Series – Iwaji series Soil Taxonomy – Oxic [?] Typic Haplustepts WRB – Skeletic Ferralic Cambisols [Ferric]
ELEVATION [m] ROCK FORMATION: ●Basement Complex formations; Igneous – Metamorphic – ●Sedimentary -	CLIMATE PARENT MATERIAL: Dominantly in situ formed in basement complex. In – Situ/Residual – Transported -
PHYSIOGRAPHY: Topography [Relief]– Moderately Undulating Landform / Land Element –Upper Slope Position on Landscape - Plateau-like, upper slope position Slope / Gradient – 2-4% Form OR Shape – Microtopography -	SOIL – WATER RELATIONSHIPS: Drainage Class – Moderately Well-drained Depth to Groundwater - >2m Soil Moisture Conditions [dominant at the Time of Description] - Dry- √ Slightly Moist - Moist – Wet –
VEGETATION AND LAND USE: Wooded savanna.	SURFACE CHARACTERISTICS: Rock Outcrops – none observed Coarse Fragments – Erosion – Slight Types Sealing / Cracks -
AUTHOR [S]: T. A. Okusami SAMPLE CODE NUMBER : -	INSTITUTION: Obafemi Awolowo University, Ile-Ife PICTURE NUMBER /IDENTIFIER: -

Table 4iii[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	DEPTH [cm]	DESCRIPTION
	0-10	Black (5 YR 2.5/1) (dark grey, 5 YR 4/1, dry); non-gravelly sandy loam; weak, medium granular; friable (moist): no nodules/concretions; clear, smooth boundary.
	10-20	Dark reddish-brown (5 YR 3/2), (reddish-brown, 5 YR 5/3, dry); gravelly sandy loam; frequent platy and angular stones and cobbles; few rounded concretions; abrupt smooth.
	20-50	Dark red (2.5 YR 3/6); (Red, 2.5 YR 4/4, dry) slightly gravelly sandy loam; firm (moist); no modules or concretions; clear, smooth boundary.
	50+	Red (10 YR 4/8, dry) and (2.5 YR 5/8, dry); sandy loam; hard (dry); the presence of tiny shiny flakes of muscovite mica. Possibility of a ferruginised saprolite.

series and is equally associated with Shabe series; it is a shallow pedon with soil range between 40 – 60 cm; the saprolite is ferruginous and therefore hard ; rock outcrops also characterize its environment and usually occupies the transition to the adjacent mid-slope soils;

Soil has black/brownish top-soils over dark red and variegated red loamy subsoil horizons; ferruginized saprolitic material with possible tiny muscovite mica; gravels may be platy and angular – stones, cobbles with few rounded concretions; moderately well – drained. [Surface soil horizons have neutral acidity with slightly acid subsoil horizons]

Table 4iv[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT: NLR-T soil	DATE: December 6, 1992
LOCATION: FORMER MECHANIZED FARM AT ILERO	SOIL CLASSIFICATION: T Soil type
Descriptive –	Series – Amodu series
	Soil Taxonomy – Rhodic Kandiustults
Coordinates/GPS -	WRB –Haplic Acrisols [clayic]
ELEVATION [m]	CLIMATE
ROCK FORMATION:	PARENT MATERIA: Formed in the granitic type of parent material. Possibly colluvial over granitic in-situ material.
●Basement Complex Formations; √[amphibolite in origin]	
Igneous –	In – Situ/Residual –
Metamorphic –	Transported -
●Sedimentary -	Transported Over In Situ/ Residual - √
PHYSIOGRAPHY:	SOIL – WATER RELATIONSHIPS:
Topography [Relief]– Moderately Undulating	Drainage Class – Well-drained
Landform / Land Element –Upper Slope	Depth to Groundwater - >200cm
Position on Landscape - Upper slope, gradually slopping	Prevailing Soil Moisture Conditions At Time of Description -
Slope / Gradient – 4%	Dry-√
Form OR Shape –	Slightly Moist -
Microtopography -	Moist –
	Wet –
VEGETATION AND LAND USE: Densely wooded savanna.	SURFACE CHARACTERISTICS:
	Rock Outcrops – none observed
	Coarse Fragments –
	Erosion – Gullied road, (now turned as drainage channel of the land Types
	Sealing / Cracks -
AUTHOR [S]: T. A. Okusami	INSTITUTION: Obafemi Awolowo University, Ile-Ife
SAMPLE CODE NUMBER : -	PICTURE NUMBER /IDENTIFIER: -

Table 4iv[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	DEPTH [cm]	DESCRIPTION
A	0-18	Dark yellowish brown (10 YR 3/4), (10 YR 3/6, dry); coarse sandy loam; moderate, medium and coarse angular blocky; slightly hard (dry), very friable (moist): many, very fine pores; few, coarse and common, fine and medium roots; clear, smooth boundary.
BA	18-35	Dark reddish-brown (5 YR 3/4), (yellowish red,5 YR 4/6, dry); coarse sandy clay loam; strong, medium and coarse angular blocky; slightly hard/hard (dry), very friable (moist); many very fine, and common, medium pores; few, fine, medium and coarse roots; diffuse, smooth boundary.
B	35-62	Dark red (2.5 YR 3/6); sandy clay; moderate, fine and medium angular blocky; hard (dry), firm (moist); common, fine and medium pores; few, fine and medium roots; diffuse, smooth boundary.
BC	62-150	Dark red (10 R 3/6); sandy clay; moderate, medium and coarse angular blocky; hard (dry), firm (moist); many; fine pores; very few, fine and medium roots; abrupt, smooth boundary.
2C	150-160	Auger sample. There is a very thin stone line on the saprolitic material.

Table 4iii[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	DEPTH [cm]	DESCRIPTION
	0-10	Black (5 YR 2.5/1) (dark grey, 5 YR 4/1, dry); non-gravelly sandy loam; weak, medium granular; friable (moist): no nodules/concretions; clear, smooth boundary.
	10-20	Dark reddish-brown (5 YR 3/2), (reddish-brown, 5 YR 5/3, dry); gravelly sandy loam; frequent platy and angular stones and cobbles; few rounded concretions; abrupt smooth.
	20-50	Dark red (2.5 YR 3/6); (Red, 2.5 YR 4/4, dry) slightly gravelly sandy loam; firm (moist); no modules or concretions; clear, smooth boundary.
	50+	Red (10 YR 4/8, dry) and (2.5 YR 5/8, dry); sandy loam; hard (dry); the presence of tiny shiny flakes of muscovite mica. Possibility of a ferruginised saprolite.

DIAGNOSTIC/SUMMARY: IWAJI SERIES;Iwaji series occupies an almost equivalent elevation as the Ogboro series and is equally associated with Shabe series; it is a shallow pedon with soil range between 40 – 60 cm; the saprolite is ferruginous and therefore hard ; rock outcrops also characterize its environment and usually occupies the transition to the adjacent mid-slope soils;

Soil has black/brownish top-soils over dark red and variegated red loamy subsoil horizons; ferruginized saprolitic material with possible tiny muscovite mica; gravels may be platy and angular – stones, cobbles with few rounded concretions; moderately well – drained. [Surface soil horizons have neutral acidity with slightly acid subsoil horizons]

Table 4iv[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT: NLR-T soil	**DATE: December 6, 1992**
LOCATION: FORMER MECHANIZED FARM AT ILERO	SOIL CLASSIFICATION: T Soil type
Descriptive –	Series – Amodu series
	Soil Taxonomy – Rhodic Kandiustults
Coordinates/GPS -	WRB –Haplic Acrisols [clayic]
ELEVATION [m]	CLIMATE
ROCK FORMATION:	PARENT MATERIA: Formed in the granitic type of parent material. Possibly colluvial over granitic in-situ material.
●Basement Complex Formations; √[amphibolite in origin]	
Igneous –	In – Situ/Residual –
Metamorphic –	Transported -
●Sedimentary -	Transported Over In Situ/ Residual - √
PHYSIOGRAPHY:	SOIL – WATER RELATIONSHIPS:
Topography [Relief]– Moderately Undulating	Drainage Class – Well-drained
Landform / Land Element –Upper Slope	Depth to Groundwater - >200cm
Position on Landscape - Upper slope, gradually slopping	Prevailing Soil Moisture Conditions At Time of Description -
Slope / Gradient – 4%	
Form OR Shape –	Dry-√
Microtopography -	Slightly Moist -
	Moist –
	Wet –
VEGETATION AND LAND USE: Densely wooded savanna.	SURFACE CHARACTERISTICS:
	Rock Outcrops – none observed
	Coarse Fragments –
	Erosion – Gullied road, (now turned as drainage channel of the land Types
	Sealing / Cracks -
AUTHOR [S]: T. A. Okusami	INSTITUTION: Obafemi Awolowo University, Ile-Ife
SAMPLE CODE NUMBER : -	PICTURE NUMBER /IDENTIFIER: -

Table 4iv[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	DEPTH [cm]	DESCRIPTION
A	0-18	Dark yellowish brown (10 YR 3/4), (10 YR 3/6, dry); coarse sandy loam; moderate, medium and coarse angular blocky; slightly hard (dry), very friable (moist): many, very fine pores; few, coarse and common, fine and medium roots; clear, smooth boundary.
BA	18-35	Dark reddish-brown (5 YR 3/4), (yellowish red,5 YR 4/6, dry); coarse sandy clay loam; strong, medium and coarse angular blocky; slightly hard/hard (dry), very friable (moist); many very fine, and common, medium pores; few, fine, medium and coarse roots; diffuse, smooth boundary.
B	35-62	Dark red (2.5 YR 3/6); sandy clay; moderate, fine and medium angular blocky; hard (dry), firm (moist); common, fine and medium pores; few, fine and medium roots; diffuse, smooth boundary.
BC	62-150	Dark red (10 R 3/6); sandy clay; moderate, medium and coarse angular blocky; hard (dry), firm (moist); many; fine pores; very few, fine and medium roots; abrupt, smooth boundary.
2C	150-160	Auger sample. There is a very thin stone line on the saprolitic material.

OTHER OBSERVATIONS [e.g., deviation from modal soil profile descriptions.]

DIAGNOSTIC SUMMARY : AMODU SERIES ;Amodu series occupies a shoulder/upper-slope but sloping position and also adjacent to the Shabe series ; Topsoil is dark yellowish-brown to dark reddish brown and coarse sandy loam/sandy clay loam over dark red sandy clay sitting on thin stone lines at deeper depth [-150-160cm- in this instance] mostly fine quartz gravels that is practically inseparable from the saprolite below; colluvial over granitic [amphibole] derived parent material; there is evidence of clay accumulation; [laboratory analysis indicated kaolinite clay mineral dominant, equally evident by the low ECEC; topsoil horizons are medium to slightly acid with the subsoil horizons being strongly acid .].

Table 4v[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT: NLR- S Soil	**DATE: December 7, 1992**
LOCATION: FORMER MECHANIZED FARM ATILERO Descriptive – Coordinates/GPS -	SOIL CLASSIFCATION: S Soil type Series – Tede series Soil Taxonomy – Fluventic Dystrustepts WRB –chromic Cambisols
ELEVATION [m] ROCK FORMATION: ●Basement Complex Formations ; √ Igneous – Granite in origin Metamorphic – ●Sedimentary -	CLIMATE PARENT MATERIAL: Colluvial material over material directly formed in granitic material. In – Situ/Residual – Transported -
PHYSIOGRAPHY: Topography [Relief] – Moderately Undulating Landform / Land Element – Crest Position on Landscape - Crestal position, plateau-like Slope / Gradient – 2-4% Form OR Shape – Microtopography -	SOIL – WATER RELATIONSHIPS: Drainage Class – Moderately well-drained Depth to Groundwater - >200cm Prevailing Soil Moisture Conditions At Time of Description - Dry-√ , Top horizons Slightly Moist - Moist – √, Sob-soil horizons Wet –
VEGETATION AND LAND USE: Wooded Savanna.	SURFACE CHARACTERISTICS: Rock Outcrops – none observed Coarse Fragments – Not Common Erosion – Gully development on the slopes Types Sealing / Cracks -
AUTHOR [S]: T. A. Okusami - SAMPLE CODE NUMBER : -	INSTITUTION: Obafemi Awolowo University, Ile-Ife PICTURE NUMBER /IDENTIFIER: -

Table 4v[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	**DEPTH [cm]**	**DESCRIPTION**
A1	0-16	Dark greyish brown (10 YR 4/2), (Grayish brown, 10 YR 5/2, dry) sandy loam; moderate, medium and coarse subangular blocky; hard (dry), friable (moist); common, fine and medium roots; abrupt, slightly wavy boundary.
2BC1	16-65	Upper stone-line, Dark brown (10 YR 4/2), (Brown, 10 YR 5/3, dry); extremely gravelly (60-95% by volume, mostly/ frequently angular quartz stones/cobbles/gravels and concretionary gravels) coarse sandy loam; single grain; loose (dry); loose (moist); concretions are very (frequent (45-60% by volume), angular and rounded and very dark grey (10 R 3/1); common, very fine and few roots; clear and smooth boundary (in terms of colour.
2BC2	65-95	Middle-stone line, yellowish-brown (10 YR 5/4); extremely gravelly (60-95% by volume) sandy clay loam; concretions constitute 45-80% by volume of the gravel content, and are very dark grey (10 YR 3/1) less than yellowish red (5 YR 5/8); single grain; loose (dry); loose (moist); few, very fine roots; abrupt and smooth boundary.
3BC1	95-130	Lower stone line position, Red (2.5 YR 4/8) with light yellowish brown (10 YR 6/4) mottle; very gravelly (35-60% by volume) sandy clay; concretions are very frequent (45-80% by volume of the gravels) and are mostly very dark grey (10 YR 3/1); single grain o massive; hard (dry), firm (moist), very few, very fine roots; abrupt, smooth boundary.
3BC2	130-160	Red (2.5 YR 4/8); and brownish yellow (10 YR 6/8) with common, medium, distinct brown (10 YR 5/3) mottles, with black irregularly shaped frequent (15-45% by volume gravel size nodules) (soft); non-gravelly (<15%) clay; very firm (moist); no roots observed in this profile.
3C	160-190	Yellowish red (5 YR 5/8), brownish-yellow (10 YR 6/8) and pale brown (10 YR 6/3); no nodules or concretions; sampled with auger.

DIAGNOSTIC/SUMMARY: TEDE SERIES: Tede series occupies lower upland physiographic position with a plateau-like surface but that gradually slopes towards the transition to the soils on the mid-slope position.

Thin surface, colluvial horizon over granitic derived parent material ; thick stone line spanning shallow depth to deeper depth [may be 16 – 130 cm] with frequent angular quartz stones/cobbles/gravel sizes and very frequent, angular and round-
ed concretions [10 YR 3/1] at deeper horizons [e.g., 130-160cm] with the existence of black irregularly shaped frequent gravel size nodules; variegated saprolite with neither concretions nor nodules; the presence of nodules is an evidence of juvenile horizon development ; there are evidences of roots growing through the stone-line; moderately well-drained [laboratory analysis indicated kaolinite clay

Table 4vi[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT :NLR- W Soil	**DATE: December 1, 1992**
LOCATION: FORMER MECHANIZED FARM AT ILERO Descriptive – Coordinates/GPS -	SOIL CLASSIFICATION: W Soil type Series – Iwo series Soil Taxonomy – Typic Paleustults OR Kandic Paleustalfs WRB –Pisoplinthic Alisols [clayic, colluvic]
ELEVATION [m] ROCK FORMATION: ●Basement Complex Formations; √ Igneous – granite Metamorphic – ●Sedimentary - PHYSIOGRAPHY: Topography [Relief] – Moderately Undulating Landform / Land Element – Crest Position on Landscape - Crestal position, plateau-like Slope / Gradient – 2-5% [Typically 1-2%] Form OR Shape – Microtopography -	CLIMATE PARENT MATERIAL: Colluvial over in situ formed material from basement complex rocks/granitic. In – Situ/Residual – Transported - Transported Over In-Situ/Residual- √ SOIL – WATER RELATIONSHIPS: Drainage Class – Well-drained/moderately well-drained Depth to Groundwater – none on site Prevailing Soil Moisture Conditions at the Time of Description - Dry- √, Surface Slightly Moist - √, Subsoil Moist – Wet –
VEGETATION AND LAND USE: Grassland with occasional shrubs regrowth	SURFACE CHARACTERISTICS: Rock Outcrops – Occasional outcrop of petroplinthite Coarse Fragments – Erosion – few around Types Sealing / Cracks -
AUTHOR [S]: T. A. Okusami	INSTITUTION: Obafemi Awolowo University, Ile-Ife.
SAMPLE CODE NUMBER : -	PICTURE NUMBER /IDENTIFIER: -

Table 4vi[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	**DEPTH [cm]**	**DESCRIPTION**
A	0-13	Dark yellowish-brown (10 YR 4/4), yellowish-brown (10 YR 5/4, dry), loam; moderate, medium and coarse crumb; slightly hard (dry), friable (moist) common, very fine, tubular and few coarse pores; common, very fine and fine roots; clear, smooth boundary.
B1	13-28	Dark brown (7.5 YR 4/4), (strong brown, 7.5 YR 4/6, dry); sandy clay; weak, medium and coarse subangular blocky; hard (dry), friable (moist); few, very fine and fine roots; diffuse, smooth boundary. (Ap evidence, remnants of charcoal seen in cut profile surface, i.e. ploughing of the land before the field was abandoned).
B2	28-55	Strong brown (7.5 YR 4/6) (7.5 YR 5/6, dry) slightly gravelly (<15% by volume) clay; moderate, medium and coarse subangular blocky; hard (dry), friable (moist); few, fine roots; abrupt, slightly wavy boundary. (Relict Ap3)
2BC	55-100	Yellowish red (5 YR 4/6) ; extremely gravelly (60-95% by volume) clay ; [coarse materials – gravels, cobbles, stones and mostly angular concretions are frequent (15-45 % by volume) but also angular and mostly gravel size and dark reddish brown [interior] (5 YR 2.5/2); massive; very hard [dry], loose [moist]; few, very fine roots; abrupt, wavy boundary.
3BC1????? CHECK	100-120	Yellowish red (5 YR 4/6); slightly gravelly (5-10%, quartz, by volume) clay; weak, medium and coarse subangular blocky; friable (moist); patchy, thin clay mineral cutans; diffuse smooth boundary.
3BC2	120-160	Yellowish red (5 YR 4/6) and strong brown (7.5 YR 5/6); and few [5-15 % by volume] very dark grey [10 YR 3/1] nodules; clay; weak, medium and coarse subangular blocky; hard [dry], friable [moist].
3C	160-190	Sampled with an auger, but highly variegated

mineral dominant; with slightly acid surface soil horizons and strongly acid subsoil horizons].

DIAGNOSTIC/SUMMARY:IWO SERIES: Iwo series occupies a lower upland position but yet plateau-like ; yellowish-brown or dark brown/brown loamy or sandy clay topsoil horizons over subsoil horizons that are either strong brown [B horizons] or yellowish-red [transitional horizons] to a variegated saprolitic material; a mid-profile, very gravelly [stone line], granite – like clay horizon with coarse materials that are of gravel, cobble, and stone sizes and angular; concretions are frequent [usually 15-45% by volume] and mostly angular but gravel size with 5 YR 2.5/2 interior; deeper subsoil horizons have nodules whereas concretions exist mostly in middle horizons; few patchy thin clay mineral cutans at transitional horizon [[3BCt3] and few] 5 -15% by volume] nodules at 3BCt4. [Examined clay mineralogy consisted of dominant kaolinite clay mineral and mica; base saturation is uniquely relatively higher than other upland position pedons].

Owutu series [as in Murdoch *et al*., 1976b] constitutes a dominant inclusion and occupies the sloping land that surrounds the Plateau – like surface of the Iwo series. Owutu

Table 4vii[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT:NLR- U Soil	**DATE: December 1, 1992**
LOCATION: FORMER MECHANIZED FARM ATILERO Descriptive – Coordinates/GPS - ELEVATION [m] ROCK FORMATION: ●Basement Complex Formations: √ Igneous – Metamorphic – ●Sedimentary - PHYSIOGRAPHY: Topography [Relief]– Moderately Undulating Landform / Land Element –Middle Slope Position on Landscape - Middle slope Slope / Gradient – 4-6% Form OR Shape – Microtopography - VEGETATION AND LAND USE: Grassland/shrubs	SOIL CLASSIFICATION: U Soil type Series – Dejo series Soil Taxonomy – Fluvaquentic Epiaquept WRB –Pisoplinthic Cambisols [oxyaquic] CLIMATE PARENT MATERIAL: Colluvial over in situ In – Situ/Residual – Transported - Transported Over In-Situ /Residual- √ SOIL – WATER RELATIONSHIPS: Drainage Class – Somewhat poorly drained Depth to Groundwater – approximately 90cm Prevailing Soil Moisture Conditions at Time of Description - Dry- √, Topsoil Slightly Moist - Moist – √, subsoil Wet – √, subsoil SURFACE CHARACTERISTICS: Rock Outcrops – none Coarse Fragments – Erosion – rills/gullies facilitated by cattle tracks Types Sealing / Cracks -
AUTHOR [S]: T. A. Okusami	INSTITUTION:Obafemi Awolowo University, Ile-Ife.
SAMPLE CODE NUMBER : -	PICTURE NUMBER /IDENTIFIER: -

Table 4vii[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	**DEPTH [cm]**	**DESCRIPTION**
A	0-15	Very dark greyish brown (10 YR 3/2), Grayish brown (10 YR 5/2, dry), coarse sandy loam; moderate, medium and coarse granular, slightly hard (dry), friable (moist); frequent, fine and medium roots; clear and smooth boundary.
B	15-30	Dark brown (10 YR 4/3), (Light yellowish brown (10 YR 6/4, dry); with common fine and faint yellowish brown (10 YR 5/6) mottle; slightly gravelly (<15% by volume) coarse sandy clay loam, few (5-15% by volume of gravels) angular concretions; weak, medium subangular blocky; hard (dry), friable (moist); few, fine roots; abrupt, smooth boundary.
2BC1	30-80	Brown (10 YR 5/3); extremely gravelly (60-95% by volume) sandy clay; gravels consist of very frequent (45-80% by volume) concretions and quartz; concretions are black (10 YR 2/1 inner), and yellowish red (5 YR 5/8, outer); single grain; very few, fine roots, diffuse, smooth boundary.
3BC2	80-110	Gray (10 YR 5/1) and many prominent medium brownish yellow (10 YR 6/8) mottles; gravelly (15-35% by volume) sandy clay; mostly quartz; massive; slightly sticky (wet) or slightly plastic (wet); very few, very fine roots; abrupt, smooth boundary.
3C	110-150	Gray (10 YR 5/1) and (10 YR 6/1) with common, medium/coarse, prominent yellowish brown (10 YR 5/6) mottle; clay; massive; non-sticky, non-plastic (wet).

series is a little bit more concretionary in subsoil horizons but with identical soil morphology as in Iwo series.

OTHER OBSERVATIONS [e.g., deviation from modal soil profile descriptions.]

DIAGNOSTIC/SUMMARY: DEJO SERIES ; Dejo series occupies the middle slope position with a very dark greyish brown, loamy topsoil over gravelly concretionary sandy clay on grey gravelly sandy clay matrix horizons with yellowish-brown mottles; the middle horizons are slightly to extremely gravelly [with very frequent concretions and quartz] sandy clay ; mostly quartz at lower horizons [80-110cm] with a grey matrix with brownish-yellow or yellowish- brown mottles and clayey [saprolite usually encountered at 100cm from the surface; shallow water table [may be observed at about 90cm during the beginning of the dry season period]; somewhat poorly drained; [clay mineralogy indicated dominance of kaolinite clay mineral; the soil is slightly acid]

Lanlate series as described in Murdoch et al. [1976b] has close similarities. It has been identified to occur downslope from the position that the Dejo series normally occupies. Lanlate series has a shorter stone line depth that is mostly made up of quartz and concretionary gravels. It is a poorly drained soil with gleyed subsoil horizon. Its subsoil clay pan contains frequent tiny flakes of white mica. It will come under identical pedogenesis as Dejo series.

DIAGNOSTIC/SUMMARY: GAMBARI SERIES; Occupies middleslope position. Shallow soils, brownish sandy topsoil [topsoil gravels of cobble and stone sizes are possible] with gravelly sandy clay on petroplinthite at shallow depth of 60± 20cm; few dark concretions.

Table 4viii[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT:NLR- G Soil	**DATE: December 1, 1992**
LOCATION: FORMER MECHANIZED FARM AT ILERO	SOIL CLASSIFICATION: G Soil type
Descriptive –	Series – Gambari series
	Soil Taxonomy – Lithic Haplustepts
Coordinates/GPS -	WRB –Petroplinthite Cambisols [geoabruptic]
ELEVATION [m]	CLIMATE
ROCK FORMATION:	PARENT MATERIAL: Colluvial
●Basement Complex Formations; √	In – Situ/Residual –
Igneous –	Transported -√
Metamorphic –	Transported Over In-Situ/Residual-
Sedimentary -	
PHYSIOGRAPHY:	SOIL – WATER RELATIONSHIPS:
Topography [Relief] Moderately Undulating –	Drainage Class – Well-drained
Landform / Land Element –Upper/Middle Slope	Depth to Groundwater – not sighted
Position on Landscape - Transitional [upper and middle slopes]	Prevailing Soil Moisture Conditions at the Time of Description -
Slope / Gradient – 4%/	
Form OR Shape –Linear	Dry- √
Microtopography -	Slightly Moist -
	Moist –
	Wet –
VEGETATION AND LAND USE: Sparse grassland/ Grazing Land	SURFACE CHARACTERISTICS:
	Rock Outcrops – an occasional outcrop of petro-plinthite
	Coarse Fragments –
	Erosion – exposed petro - plinthite Types
	Sealing / Cracks -
AUTHOR [S]: T. A. Okusami	INSTITUTION: Obafemi Awolowo University, Ile-Ife.
SAMPLE CODE NUMBER : -	PICTURE NUMBER /IDENTIFIER: -

Table 4viii[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	**DEPTH [cm]**	**DESCRIPTION**
A	0-12	Dark brown (10 YR 3/3), brown (10 YR 5/3, dry), loamy coarse sand; weak, medium granular; slightly hard (dry), very friable (moist); common, fine and medium roots; clear and smooth boundary.
AC	12-25	Dark brown (10 YR 4/3), (yellowish-brown (10 YR 5/4, dry); slightly gravelly (<15% by volume) coarse sand; weak, fine and medium granular, slightly hard (dry), very friable (moist); common, fine and medium roots; abrupt, smooth boundary.
2C	25-60	Dark yellowish brown (10 YR 4/4); very gravelly (35-60% by volume) sandy clay; gravels are dominantly quartz of various sizes (i.e.; cobbles/stones inclusive), concretions are dark coloured and few; loose (dry), loose (moist); few, fine and medium roots; diffuse, smooth boundary.
	60+	Petroplithites –continuous cementation

Table 4ix[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT:NLR-A Soil	**DATE: December 4, 1992**
LOCATION: FORMER MECHANIZED FARM AT ILERO Descriptive – Coordinates/GPS - ELEVATION [m] ROCK FORMATION: ●Basement Complex Formations; derived from Igneous – Metamorphic – ●Sedimentary - PHYSIOGRAPHY: Topography [Relief]– Moderately Undulating Landform / Land Element –Lower Slope Position on Landscape - Lower/almost linear Slope / Gradient – 4-6% Form OR Shape – Microtopography - VEGETATION AND LAND USE: Shrub regrowth; grassland; scattered matured mango trees	SOIL CLASSIFICATION: A Soil type Series – Shante/Apomu Series Soil Taxonomy – Ustoxic OR Aquic Quartzipsamments WRB – Albic OR Gleyic Arenosols [colluvic] CLIMATE PARENT MATERIAL: Colluvial In – Situ/Residual – Transported -√ Transported over In-Situ/Residual. SOIL – WATER RELATIONSHIPS: Drainage Class – Moderately well-drained Depth to Groundwater – not sighted Prevailing Soil Moisture Conditions at Time of Description - Dry-√, Topsoil. Slightly Moist - Moist – √, subsoil Wet – √, deeper subsoil. SURFACE CHARACTERISTICS: Rock Outcrops – none sighted Coarse Fragments – Erosion – shallow gullies, typically draining the upland : Types Sealing / Cracks -
AUTHOR [S] :T. A. Okusami	INSTITUTION: Obafemi Awolowo University, Ile-Ife.
SAMPLE CODE NUMBER : -	PICTURE NUMBER /IDENTIFIER: -

Table 4ix[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	**DEPTH [cm]**	**DESCRIPTION**
A1	0-5	Very dark grey (10 YR 3/1), very dark greyish brown (10 YR 3/2, dry), loamy coarse sand; weak, fine granular; soft (dry), very friable (moist); common, fine and medium roots; clear and smooth boundary.
A2	5-35	Very dark grey (10 YR 3/1), (very dark greyish brown (10 YR 3/2, dry); loamy coarse sand; weak, fine and medium angular blocky; soft (dry), very friable (moist); very few coarse, and few medium roots; clear, slightly wavy boundary.
A3	35-45	Dark brown (10 YR 4/3); coarse loamy sand; single grain; loose (moist); very few, medium and coarse roots; diffuse, smooth boundary.
C1	45-90	Dark yellowish brown (10 YR 4/6); coarse sand; single grain; loose (moist); very few, fine/medium/ coarse roots
C2	90-140	Sampled with an auger. Identical to above horizon
C3	140-190	Light yellowish brown (10 YR 6/4) with yellowish red (5 YR 5/8) nodules

This mapping unit/soil series encompasses all possible variations as described in Murdoch *et al*. [1976b, p.6] and Ojo – Atere *et al*. [1973]. It is classified as the Gambari series in consonance with Smyth and Montgomery [1962].

DIAGNOSTIC/SUMMARY: SHANTE/APOMU; This is a complex mapping unit that occupies middle to lower slope positions. The Apomu series occupies a lower slope position than that of the Ashante series. Apomu therefore will easily come under the influence of higher groundwater table and for a longer duration than possible under Ashante series. Ashante is considered as moderately well-drained while Apomu is imperfectly to somewhat poorly drained.

It is a sandy soil identified as Shante or Apomu series [colluvial in origin] varies from loamy sand to greater depth to those with sand over quartz/concretions at 60-80cm to those with sand sitting on plinthites at 65cm; greyish sandy topsoil horizons over brownish and/or yellowish red mottles in subsoil horizons; moderately well drained. [mineralogical analysis indicated a dominant kaolinite clay mineral]

Variation: Apomu gravelly (Soil, wet at shallow depth [80cm.as observed on Nov. 14, 1992). Consists of grassland with scattered wooded shrubs. Loamy sandy (0-25cm) over sand (25-60cm) over concretionary/quartz gravelly (subrounded) at 60-80cm.

Table 4x[a]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

MAPPING/SOIL UNIT: NLR- P Soil	**DATE: December 7, 1992**
LOCATION: FORMER MECHANIZED FARM AT ILERO Descriptive – Coordinates/GPS -	SOIL CLASSIFICATION: P Soil type Series – Adio series Soil Taxonomy – Aquic Ustifluvents WRB –Gleyic Fluvisols [loamic]
ELEVATION [m] ROCK FORMATION: ●Basement Complex Formations; derived from Igneous – Metamorphic – Sedimentary -	CLIMATE PARENT MATERIAL: Colluvial/alluvial materials In – Situ/Residual – Transported -√ Transported over In-Situ/Residual
PHYSIOGRAPHY: Topography [Relief] – Moderately Undulating Landform / Land Element – Lower Slope Position on Landscape - Valley bottom/Fringe Slope / Gradient – 2% Form OR Shape – Microtopography -	SOIL – WATER RELATIONSHIPS: Drainage Class – Somewhat poorly-drained Depth to Groundwater – not sighted Prevailing Soil Moisture Conditions at Time of Description - Dry- Slightly Moist - Moist – √ Wet –
VEGETATION AND LAND USE: Wooded grassland	SURFACE CHARACTERISTICS: Rock Outcrops – Coarse Fragments – √ Erosion – Quartz stone on surface soil Types Sealing / Cracks -
AUTHOR [S]: T. A. Okusami	INSTITUTION: Obafemi Awolowo University, Ile-Ife.
SAMPLE CODE NUMBER : -	PICTURE NUMBER /IDENTIFIER: -

Table 4x[b]: Soil Morphology and Related Environmental Factors of the Mapping Units for Soils at Ilero Study Site of SouthWest Nigeria

HORIZON	**DIMENSION DEPTH [cm]**	**DESCRIPTION**
A1	0-12	Black (7.5 YR 2/0); sandy clay loam; strong, medium and coarse subangular blocky; hard/very hard (dry), firm (moist); man, very fine and fine pores, common, medium roots; diffuse smooth boundary)
A2	12-24	Very dark grey (10 YR 3/1), sandy clay loam; strong, medium and coarse subangular blocky; hard/very hard (dry), firm (moist) many very fine and fine pores; few medium and coarse roots; abrupt, smooth boundary.
2BA	24-36	Very dark grey (10 YR 3/1); gravelly (15-35% by volume), mostly quartz with very few concretions, sandy clay loam; weak, fine and medium subangular blocky; hard (dry), firm (moist); many very fine pores; few, medium and coarse roots; abrupt/clear, smooth boundary.
3BC	36-110	Dark grey (2.5 YR 4/0) with common, medium, distinct brownish yellow (10 YR 6/8) mottles; clay; weak, fine and medium subangular blocky; firm [moist]; common very fine pores; few fine roots; abrupt smooth boundary.
4C	110-135	Dark grey (2.5 YR 4/0) with common, medium, distinct brownish yellow (10 YR 6/8) and few, medium, prominent yellowish red (5 YR 5/8) mottles; slightly gravelly (<15% by volume quartz and concretion) sandy clay; massive, very firm (moist) (very few concretions); abrupt, smooth boundary.
5C	135+	Dark grey (2.5 YR 4/0) with common, medium prominent brownish yellow (10 YR 6/8) mottles; clay; massive; very firm (moist)

Another variation consists of loamy sand (0-25cm) over loamy coarse sand (25-40cm) over loamy coarse sand (40-65cm, C) on Plinthite at 65cm (2C) (with patches of red)

DIAGNOSTIC/SUMMARY: ADIO SERIES; Adio series occupies the fringe and valley bottom positions. It is unrestricted in terms of elevation. Usually it extends from middle slope/upper slope transition areas into the valley bottom of the larger rivers, [i.e., Asaka and Ofiki]

Soil can be predominantly black/grey clay loam to sandy clay; fine gravel size quartz/concretions may be present with the concretions mostly few; colluvial and alluvial parent materials; somewhat poorly drained. [clay mineral-

Table 5: Characteristics and Classification for some Soils of Derived Savanna Southwest Nigeria

Soils//Physiography	Brief Soil Morphology and Classification	pH[2] H_2O	Bases[2] emol/kg .soil	AIS[1,2] %	O.C[2] gkg^{-1}
CREST/RIDGE (Shabe)	Brownish sandy clay loam over yellowish red and dark red, very gravelly clay subsoil. Quartz vein present, muscovite mica are common. **Typic Kandiustult/Haplic Acrisols**	6.70-5.90	3.9-4.8	3.5-14.2	13-3
SHOULDER (Amodu)	Gradually sloping. Lower elevation relative to Shabe. Brownish, coarse sandy loam over dark red sandy clay sitting on thin stone line mostly of fine quartz gravels. **Rhodic Kandiustults/ Rhodic Nitisols, Haplic Acrisols**	6.10-5.30	3.9-2.7	6.8-12.0	20-4
(Ogboro)	Plateau-like. Very shallow soils. Black/brownish topsoils over dark red and variegated extremely gravelly (quartz and concretions). Saprolite could be hard. **Ustoxic Dystropepts/ Dystric Cambisols**	6.40-5.60	4.8-2.3	3.9-9.1	9-1
(Iwaji)	Very shallow soils. Black/brownish topsoils over dark red and variegated red loamy, subsoil horizons. Ferruginised saprolitic material. Gravel/stone cobble quartz and gravel size concretions present. **Oxic/Lithic Dystropepts/Dystric Cambisols, Petroferric Phase**	6.60-6.05	8.3-1.9	5.6-20.4	20-4
SHOULDER SLOPE/ UPPER SLOPE TRANSITION (Tede)	Upland, plateau-like but gradually sloping. Grayish brown sandy loam over thick stone line, underlain by mottled, red clay materials. Stone line is made up of gravel, stone and cobble sizes, and concretions. **Lithic Dystropepts/Rudi-Chromic Cambisols**	6.60-5.40	4.7-11.1	8.1-2.6	11-3
UPPER SLOPE (Iwo)	Brownish loamy or sandy clay topsoil horizons over mid-profile very gravelly (stone line) clay horizon over yellowish red clayey lower horizons. Stone line mostly of gravel/stone sizes. **Kandic Paleustults/Rudi-haplic Alisols**	5.80-5.50	6.4-20.8	94-97	13-4
MIDDLE SLOPE (Dejo)	A grayish brown, loamy topsoil over gravelly concretionary sandy clay on gray, gravelly sandy clay matrix horizons with yellowish brown mottles. Imperfectly to poorly drained. **Plinthaquepts/Plinthic-Gleyic Cambisols**	6.30-5.50	4.7-23.8	92-98	9-2
(Gambari)	Brownish sandy topsoil with gravelly sandy clay on petroplinthites at shallow depth (60 20cm) **Lithic Ruptic-Ultic Dystroochrepts/Ferralic Cambisols, Petroferic Phase**	6.30-5.75	5.8-3.9	94-91	16-7
LOWER SLOPE/ (FOOT SLOPE) A (Shante/Apomu)	Grayish sandy topsoil horizon over brownish and/or yellowish red mottles in subsoil horizons. Concretions may be present at lower depth. Moderately well to imperfectly drained. **Ustic, Aquic Quartzipsamments/Haplic, Gleyic Arenosols**	6.60-5.10	5.1-1.3	94-76	7-1
VALLEY BOTTOM/ FRINGE/(TOE SLOPE) P (Adio)	Lower slope/fringe and valley bottom positions. Black/gray clay loam to sandy clay. Fine gravel size quartz/concretions may be present. Mottling is also common. Poorly drained. **Aquic Udifluvents/Gleyic-Dystric Fluvisols**	6.95-6.80	7.6-20.2	96-90	27-6

[1].Based on Effective Cation Exchange Capacity [2]. Ranges-Surface Soil to subsoil

ogy analysis indicated a dominant kaolinite clay mineral; the soil has neutral acidity throughout the solum.

3.1. Land Use Plan

The land use plan design is anchored on both the Land Capability Classification and Land Suitability Evaluation principles.It involved identifying the most suitable land utilization types and their land [soil] use requirements.The latter is derived from studies of the vegetation/land use as the soil mapping units identification progressed during field work. This contributed to the review documented in Table 2 under the Materials and Methodology section and it principally was on the annual/perennial crops to the exclusion of the permanent trees observed. Most of the land investigated had a history of having been mechanically cultivated in the late 70s and 80s [1977 – 1989, anonymous] and after that abandoned. As at the time of this study the three types of land use observed are as documented below:

I. Undisturbed Land

II. Abandoned Farm Land / Fallowed land,

III. Cultivated Land

The Undisturbed Land was occupied mainly by trees, lianes and undercover grasses. The trees which are typical savanna trees include *Leucaena leucocephala*; *Daniellia oliveri*; *Viterellia paradoxa* [*Butryospermum paradoxa*]; *Parkia biglobosa* [P. *clappertonians*]; *Bosqueia angolensis*; *Burkea Africana*; *Anthocleista djalonensis*; *Cola argentea* . The lianes are Entanda *gigas*and Mucuna *flagellipes*. The undercover grass found is *Rothboelia cochinchinensis*.

The Abandoned or Fallow Land areas were taken over by grasses, leguminous weeds and few woody shrubs. The woody shrubs are mainly Vernonia species, notably V. stenoslegia and V. tenoriana. The most dominant grasses found were *Hyparrhenia involucrate, Andropogon tectorum, Andropogon schirensis, Pennisetum polystachyon,Ctenium sp*. The legumes encountered were Tephrosia *linearis*, T. *bracteolate*, *Crotolaria retusa, Cassia occidentalis*, *Desmodium scorpiurus*, D. *tortusum, Indigofera mucunoides, Clitoria ternatea*.

The Cultivated Land areas included small scale farms around human habitation. *Zea mays* [maize] was the most prevalent crop followed by Manihot *esculentis*[cassava], *Dioscorea* sp. [yams], Sorghum bicolor and *Cajanus cajan*. The latter was planted with less zeal. Varieties of Capsicum frutescens [chilli pepper] were scattered between stands of the main crops. *Musa sapientum* [banana] and *Carica papaya* were also present around human habitation.

Sustainable land use plans and management practices were developed using the common land utilization types of the local population [Table 3] viz., cereals – maize and sorghum; pulses – cowpea and phaseolus sp., including pigeon pea, i.e., *Cajanus cajan*; tuber crops – cassava and yam; tree crops – oranges [citrus sp.], cashew and mango. Other tree crops found mostly under undisturbed land could easily be adapted to form potential alternative land utilizations where land cover crops/trees are appropriate for soil conservation/management purposes.

All the identified land utilization types in this study are those that thrive in humid tropical and subtropical environments. A savanna environment actually enhances their photosynthetic capacity and therefore, higher production under optimum management should be envisaged. Ilero is part of the old Western State Savanna of Nigeria that has been described as having a periodically dry savanna climate [Murdoch *et al*., 1976b, p9].. These authors, also in a review, put the annual rainfall at a range of 1120 – 1350mm [approximately for a catchment that includes

Ilero] for the old geographically designated Western State Savanna of Nigeria, and that the rain falls effectively within April and October with a single peak and a very little dry spell in August. The total rainfall and its distribution and soil requirements are therefore those land qualities that would come into focus in deciding the compatibility of land utilization types and land qualities for this study.

Table 6: Ecological Requirements for Selected Annual Crops [After Ilaco, 1981]

Drought-Resistant Crops	Lower Temperatures Favour	Very High Rainfall Tolerance	Wide Climatic Tolerance
Sorghum	Tomato	Rice	Maize
Cassava		Cassava	Soya Bean
Pigeon Pea		Yam	Cowpea
Sun Flower			Phaseolus
Water Melon			Sweet Potato

Table 6 contains information on ecological requirements [or advantages] of some of the land utilization types previously identified and that are considered equivalent in requirements within the selected perennial crops. Of these perennial crops, only mango and cashew actually need the long, dry season for fruiting purposes. Citrus, on its own, requires sufficient water and air humidity to be prolific. Its optimum water requirements cannot, therefore, be met by the rainfall pattern in this area of study. It is only mango and cashew [see Ilaco, 1981] that have rainfall requirements that can be met by the annual distribution of rainfall in Ilero.

Land Suitability Ratings: Maize requires a loamy/sandy clay soil texture and an effective soil depth at or greater than 60-90cm and cannot tolerate short periods of waterlogging. It thrives in normally encountered soil pH within the tropics, i.e., pH5.6 – pH7.5.

Sorghum, also a cereal, will tolerate all types of soil texture but also requires an effective soil depth at or greater than 60 – 90 cm. It will tolerate short periods of water logging. It is drought tolerant. The range of soil pH tolerated is, however, within, pH 4.5 – 8.5.

Table 7: Land Use Potential for some Soils of Derived Savanna of Southwest Nigeria

Units (Series)	[1]LCC	[2]LSC	Recommended Land Use/Management
Shabe	IIes	[3]All	Best under tree cash crops for soil and water conservation purposes. Will also sustain arable crops with appropriate crop combination and organic matter/soil management operations.
Ogboro	IIIfe	Cassava, Yam, Pigeon Pea & Cashew	Best under such Savanna trees as Vitrellia paradoxa and Parkia biglobosa. Will provide protection and offer economic returns – examples of naturally adapted plants with unexploited economic returns
Iwaji	IVfe	None	.....ditto.....
Amodu	IIe	All	.....ditto.....
Tede	IVse	None	.....ditto.....
Iwo	IIe	All	Will sustain arable crops with appropriate crop combination and organic matter/soil management operations
Dejo	IIIe	None	Permanent protective cover that could be adapted for fuel wood/socio-cultural use. Exploitation must be under adequate management.
Gambari	IVf	None	Protective afforestation
Shante/Apomu	IIe t	All except maize	Permanent tree crops and/or root/tuber crops. Soil conservation and organic matter management required.
Adio	Vw	None	Hydromorphic land use. Dry season cropping to vegetables or early season cultivation to early maturing arables. Soil conservation management required.

[1]. Land Capability Classification: Limiting Factors: e = soil erosion; f = effective soil depth; s = stoniness; t = soil texture; w = wetness/ drainage
[2]. Land Suitability Classification: [3]. Land Utilization types = maize, sorghum, cowpea, beans, pigeon pea, cassava, yam, orange, cashew, mango

The root crops, i.e., cassava and yam have an almost identical soil requirements; loamy sand/sandy loam to sandy clay or sandy clay loam soil; deep effective soil [> 90cm] ; a narrow soil pH range, 5.5 to 6.5 and low tolerance to a short period of waterlogging. However, cassava tolerates poor soil acidity more than yam. It is also drought tolerant. The pulses as exemplified by the cowpea and phaseolus sp. have identical soil requirements as the above root crops and a medium soil fertility requirement. They will also tolerate a wider latitude of soil pH, i.e., 5.5 – 7.5, and have a moderate tolerance to short periods of waterlogging.

Pigeon pea [a perennial legume] deserves special treatment. It has been described as a tropical crop but more so in the acid areas because of its deep rooting habit. It is

fairly drought resistant because of this habit. It is also a multipurpose crop – the seeds are used as pulse, the green parts of the plant supply forage, the crop can be used as a cover crop and wind break, the dry stems are useful for fuel and thatching, and also useful as plot divider and for soil erosion control purposes [Cobley, 1965].

The fruit trees considered are cashew and mango. Cashew requires a loamy sand/sandy loam soil with an effective soil depth that is at or greater than 90cm. It thrives in medium to neutral soil pH [5.5 – 7.0] and has moderate soil nutrient requirements. It has a low tolerance to short periods of waterlogging. Cashew has been said to grow well where other more sophisticated commercial crops will not. The cashew tree is endowed with a strong ramifying root system that strongly binds the soil in which it is growing. This enables it to serve as a wind breaker and an agent against soil erosion [Russel, 1968].

Mango requires a loamy or clayey soil that is deep [>90cm] and fertile. It does well in the soil pH range of 5.5 to 7.5 and will moderately tolerate a short period of waterlogging.

Land use requirement for all arable crops within the humid and sub-humid tropics has a need to conserve soils against soil physical degradation. All soil types under row crops at any slope has to be protected against soil erosion, especially where there is a lithologic discontinuity within pedons that may lead to non-steady state infiltration/permeability and will quickly create a horizontal/lateral flow leading to sheet and subsequent gully erosion.

Table 7 and Figure 4 contain the rating for the mapping units. A land capability classification up to the subclass is also given.

The ratings show that mapping units NLR-Q [Shabe series], NLR-T [Amodu series], and NLR-W [Iwo series] are suitable for all land utilization types considered. The most limiting factors are stone content within the soils and erosion hazards. It is noteworthy that sorghum and cowpea have been evaluated as dry season arable crops.

Factors identified to be most limiting are effective soil depth [f], stoniness [s] erosion hazard [e], hard pan within soils [h] and wetness [w].

Pigeon pea can be used as a dry season crop. When it grows as a perennial, then erosion hazard has to come into consideration with other limiting factors identified for a dry season crop.

Other tree crops [as identified above under vegetation/land use] could easily be adapted as alternative potential land utilizations where land cover crops/trees are needed for

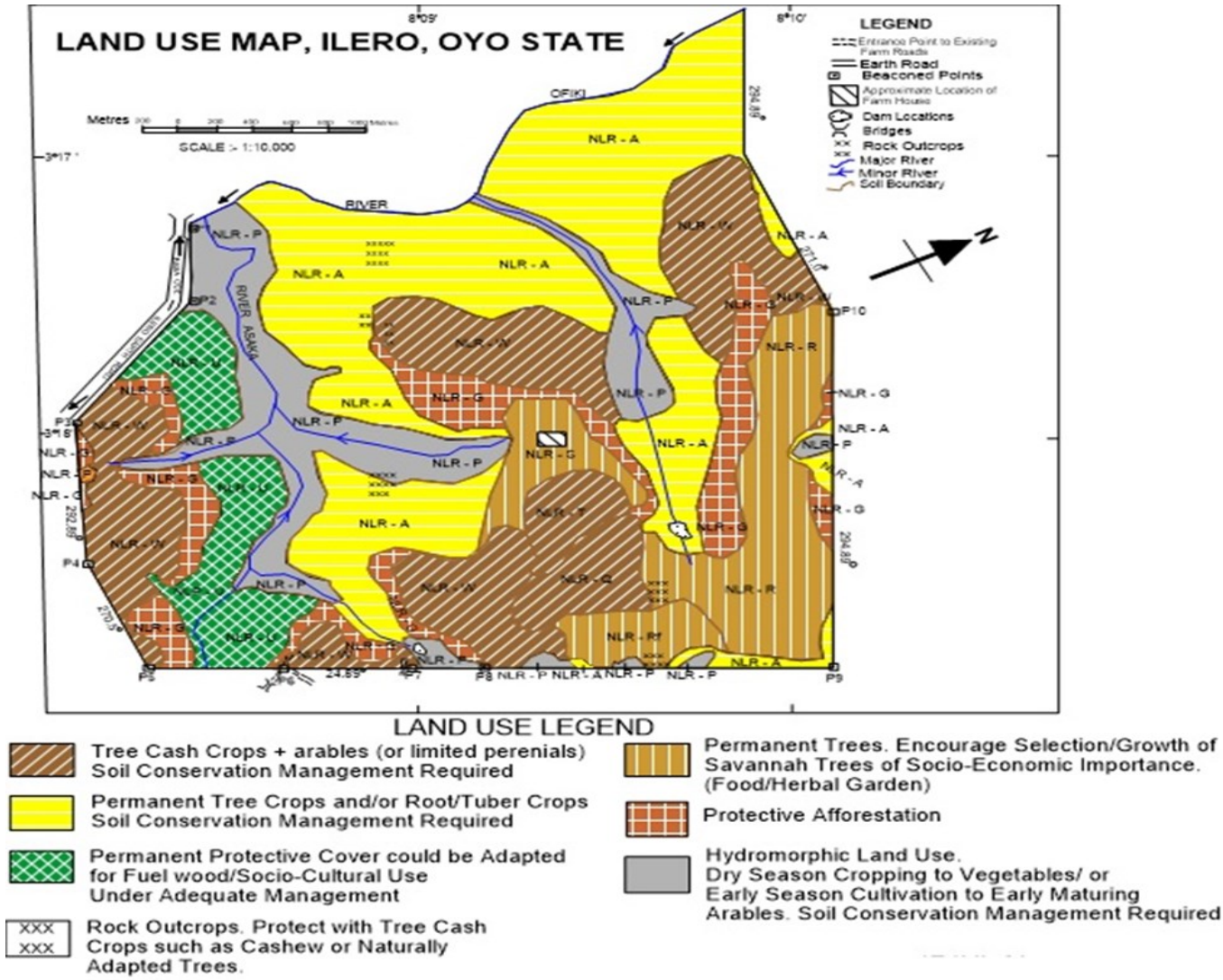

Figure 4: Land Use Map, Ilero, Oyo State

soil conservation/management purposes and even for rehabilitation of some of the degraded terrains and for sustainable ecosystem services and climate change mitigation through organic carbon sequestration.

4.0. Conclusion

Past land use practices and uncontrolled annual burning are responsible for the degraded landscapes as evident in the exposures of subsoil ironpan and the very coarse soil materials resulting into seepage points and puddled land surfaces from herd trafficking during the dry season. Most of the soils have very gravelly subsoil horizons. Some soil units are shallow because of subsoil petroplinthites or ferric saprolites. Subsoil acid horizons, where present, are also indicative of soil (chemical) degradation. Land use management indicates that most soils would be sustainable only under tree cash crops, or under a mixture of arable, perennials and tree crops. Soil nutrient management is a component of land use management and is required for optimum soil productivity.

5.0. Acknowledgement

Professor Illoh of the Department of Botany at Obafemi Awolowo University is a Plant Taxonomist, and he identified the plants discussed under the Vegetation / Land Use subsection. L appreciate his time and knowledge of plant species.

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