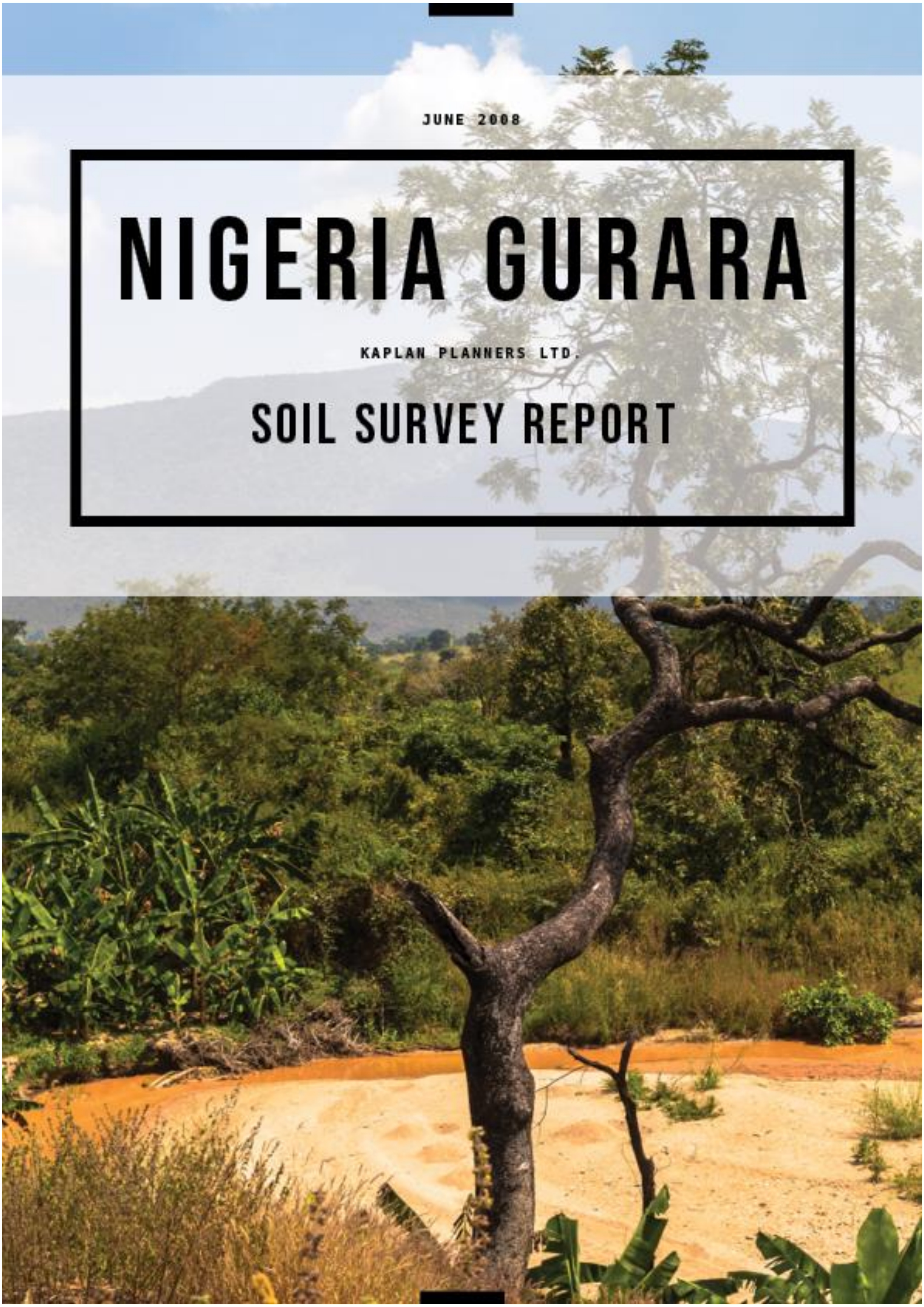
JUNE 2008

NIGERIA GURARA

KAPLAN PLANNERS LTD.

SOIL SURVEY REPORT



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1. INTRODUCTION

1.1 Objectives

The main objective of this soil survey was to identify different soil types in the Gurara River's project area, and to determine their distribution and characteristics. Identification and characterization of the soil properties is essential for intense agricultural projects such as this one. Certain soil characteristics may limit the variety of crops which may be cultivated, or influence decisions regarding agricultural management. The survey is also aimed to assess the layout of the planned agricultural plots, irrigation and drainage systems, and offer recommendations concerning cultivation and irrigation management.

1.2 project background

The current project, the agricultural development south of the Gurara River, in the Jere village's area, is a direct outcome of the building of a large dam on the Gurara River. The new dam has been designed in the framework of the Gurara Water Transfer Project as a multi-purpose dam to augment the supply of water to the Federal Capital Territory Abuja. The dam will allow the development of irrigated agricultural projects downstream. This project is established as a result of the new irrigation opportunities that derived from the new dam construction.

The dam and its impoundment will provide a storage volume of 700 million cubic meters. The dam capacity is sufficient to sustain future water requirements in the domestic, public and industrial sectors and will, in addition, provide a regulated discharge that can be used for electricity generation and irrigation during the dry season, taking full advantage of the reservoir's regulating capacity. These opportunities will enhance the social and economic benefits of the Gurara Water Transfer Project.

Within this framework, the Gurara Reservoir will be connected to the Lower Usman Dam, to design and construct a project that will utilize part of the regulated flow for the irrigation of about 4,000 ha of agricultural land.

2. General Description of the Project Area's characteristics

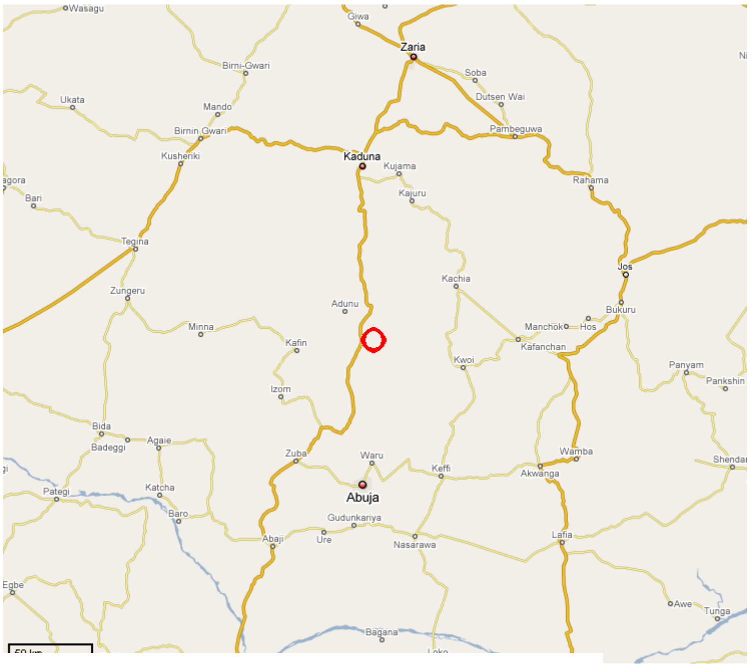
2.1 Location

The project's area is positioned 60 kilometers northwards from Nigeria's capital, Abuja, and covers approximately 8,000 hectares. The area lies south of the Gurara River, and stretches eastward over roughly 12 kilometers from the place where the river and the Lokoya-Kaduna highway meet.

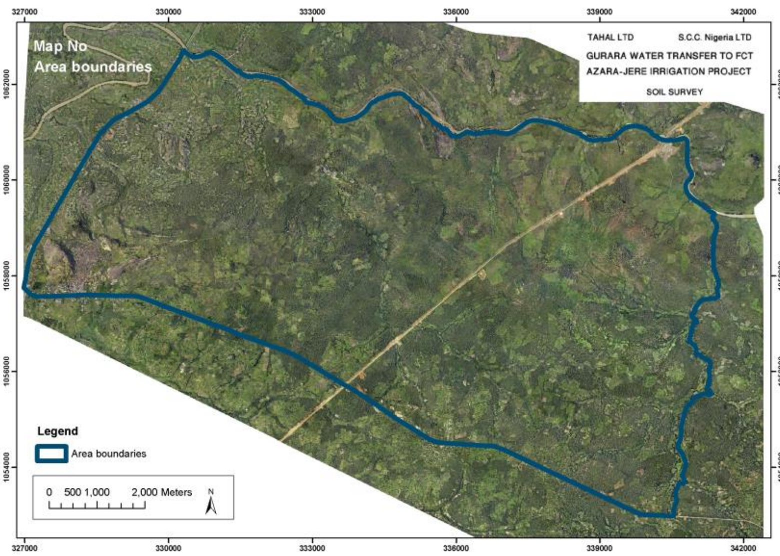
The area's boundaries are: The Gurara River in the north; the main road to Kaduna in the west; a local road in the south; and a tributary flowing northward down to the Gurara River, in the east.

In the eastern part of the project's area, near the inner road is a steep hill 709 meters high (approximately 120 meters higher than the area surrounding it).

A narrow road crosses the area connecting the S.C.C's work site and the southern road. The village Jere lies at the south-western end of the project's area.



Map No. 1 Location of the project area



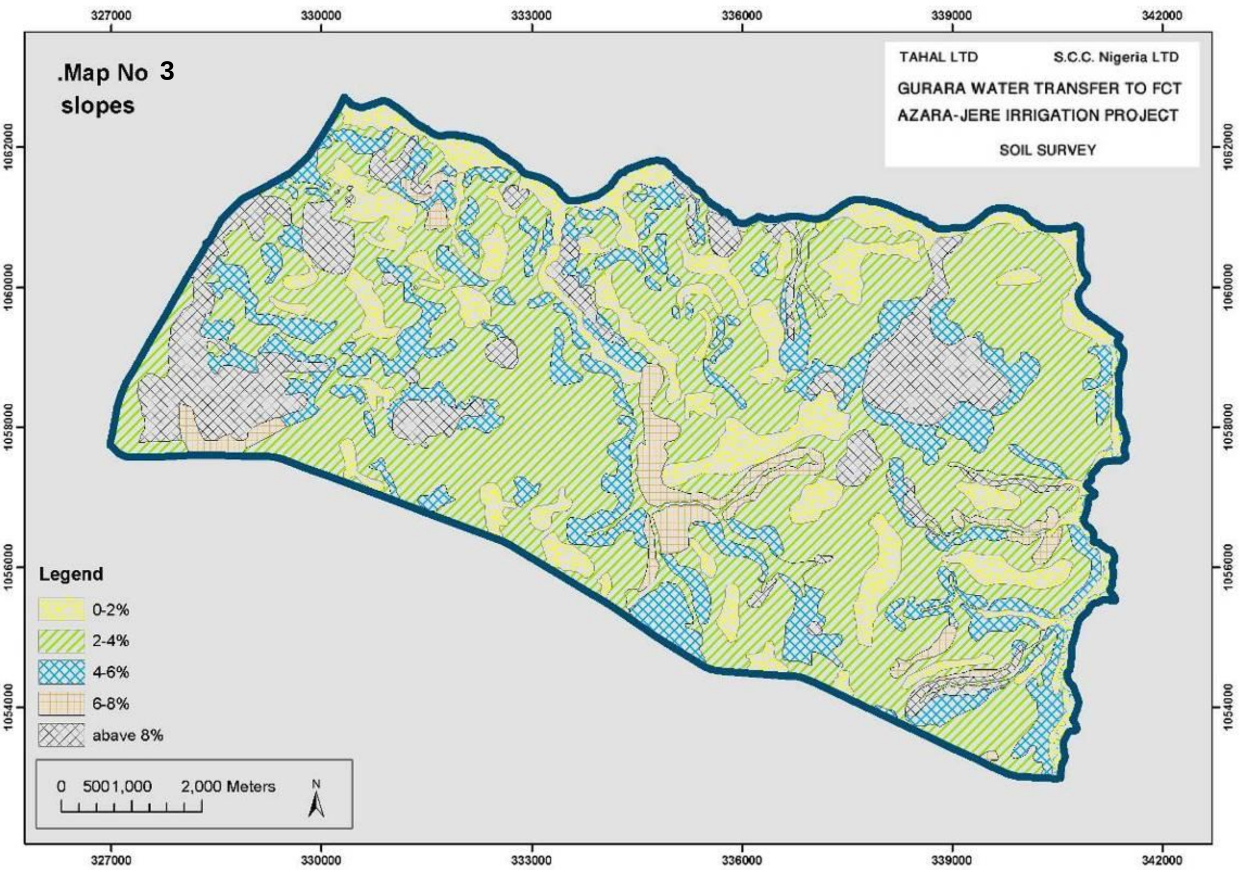
Map No. 2 boundaries of the project area

2.2 Geomorphology

The area is close to the Gurara River, and has a series of ridges stretching north to the river. These ridges are defined by river channels flowing to the river. Rock exposures – usually granite, appear in the area, creating hills rising over the surface. The surface is gently undulating and is made up of a series of moderate ridges which divide between the streams flowing to the Gurara.

There are long narrow plateaus on the ridges. Minor slopes descend from the plateaus to the streams flowing down to the river. The slopes are very moderate, ranging between 0-2% on the plateaus, through a minor slope of 2-4% sloping down towards the rivers. The slope grows near the rivers and may reach 4-8%, but only in very limited places. Steeper slopes, over 8%, appear near the tall rock risings.

A narrow strip of alluvial soil, of roughly a few hundreds of meters, stretches along the Gurara River. A rising of rough material, creating a high terrace known as a levee, near the river, can be seen in parts of the alluvial zone. Over the levee ancient meanders of the river can be seen. These ancient meanders are the lowest places in the area. They create a kind of depression, a "basin", between the hilly area and the river. The levee and the basin are included in the alluvial soils. Due to the limited area of the two phenomena they do not appear on the soil maps. However, it is important to distinguish between them in the local level, due their different physical and hydrological characteristics.



2.3 Climate

2.3.1 Rainfall

The region is characterized by four dry months, from December to March. The rainy season begins around the first week of April and ends around early November. All in all the rainy season is seven months long, and the average rainfall per year is 1430 mm. The mean maximum rainfall recorded for the months of August and September is shown in Table 1.

month		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Rainfall (m"m)	1429.4	1.9	8.9	32.3	67.2	152.5	187.2	237.9	317.1	277.9	134.3	8.6	3.5
Temperature	Mean n	34.4	35.6	36.8	35.7	34.3	31.6	30.6	29.4	31.1	32.9	34.9	33.9
Monthly avara	Mean n	19.8	21.9	22.6	22.3	22.0	21.7	17.8	18.2	18.3	17.9	16.8	15.2
Relative humi	%	60	62	70	69	78	84	84	88	83	75	68	64

Table No. 1 Rainfall

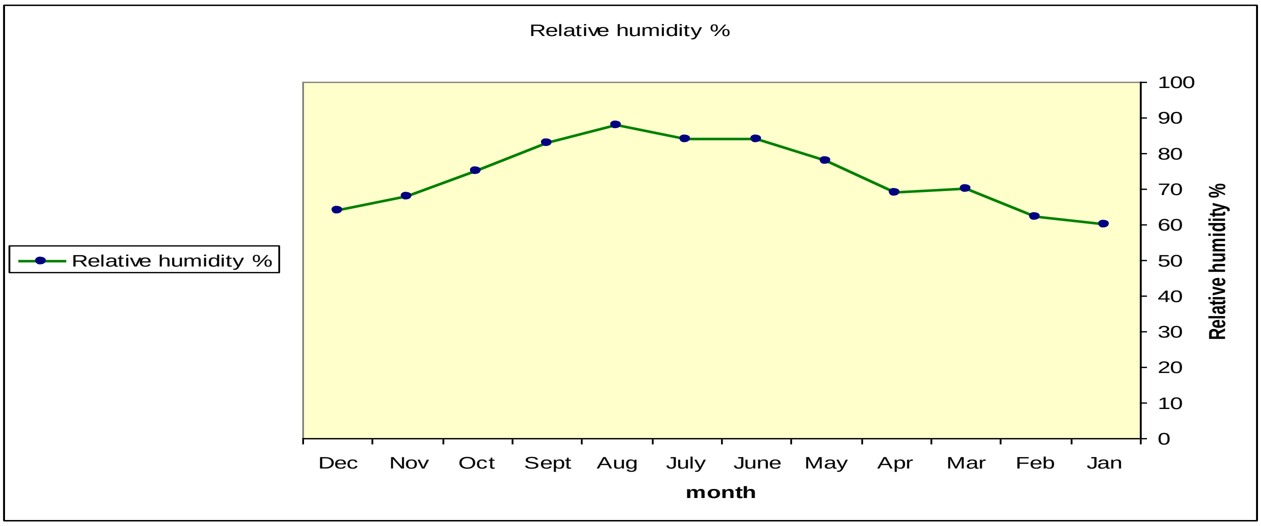


Table No. 2 Humidity

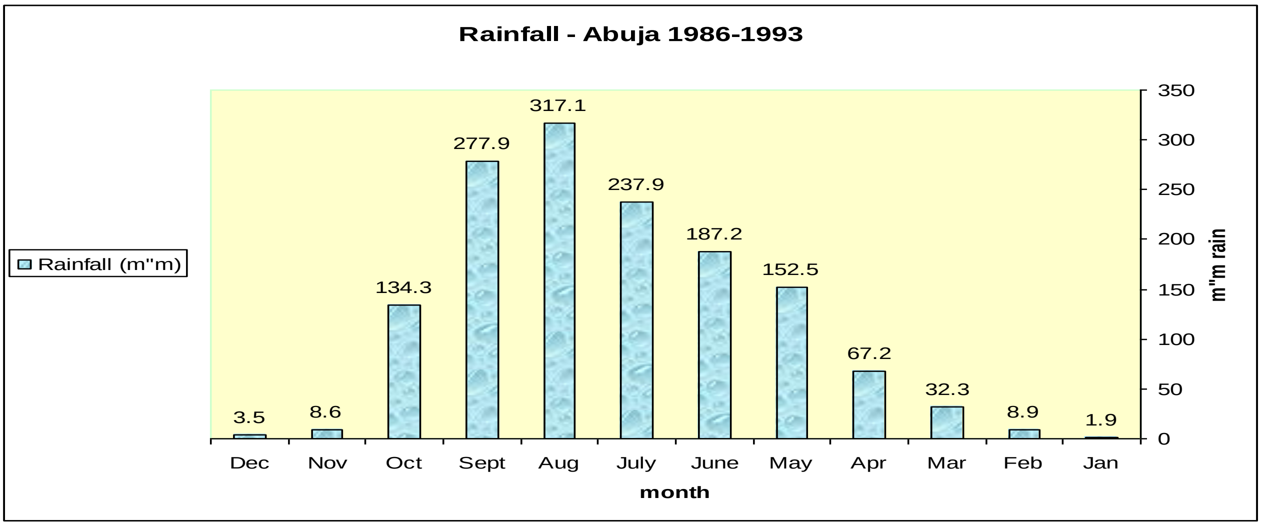


Table No. 3 Rainfall in Abuja

2.3.2 Temperature

The mean minimum and maximum temperatures for the period 1986-1993 are given in table 1. February to March are the hottest months while November and January are the coolest, ranging from 16°C to 40°C.

Humidity records are given in Table 2. The lowest mean relative humidity is 36% for the month of January and the highest 90% for the months of June to August.

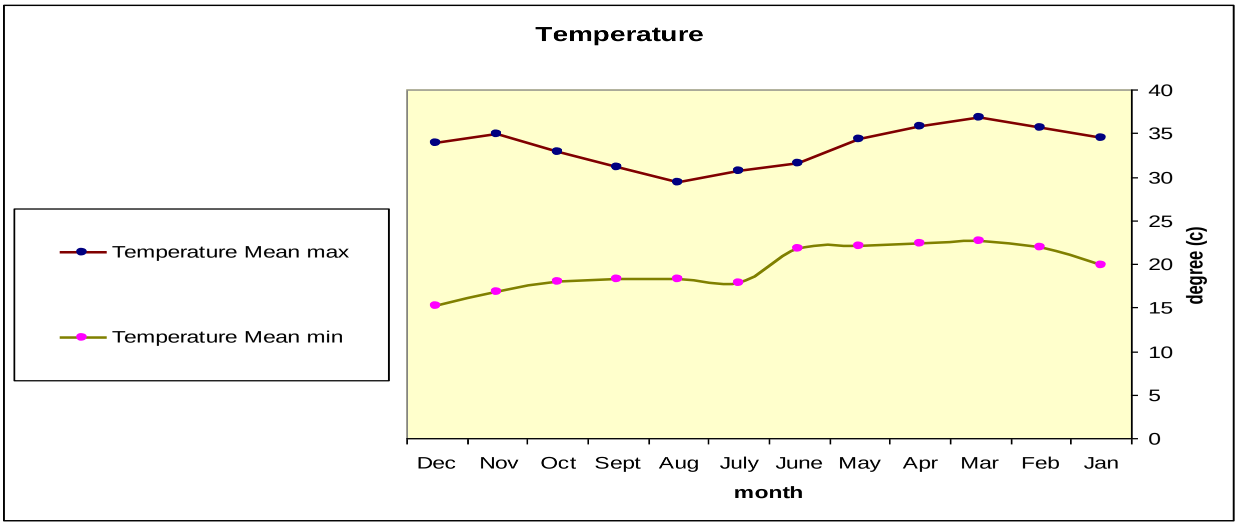


Table No. 4 Temperature

2.3.3 Sunshine Hours

The site is exposed to about 2,500 sunshine hours annually. During the dry months (November-April), the number of sunshine hours is about 8-9 hours a day. The lowest value, 4 hours a day, is reached in the month of August.

2.4 Topography

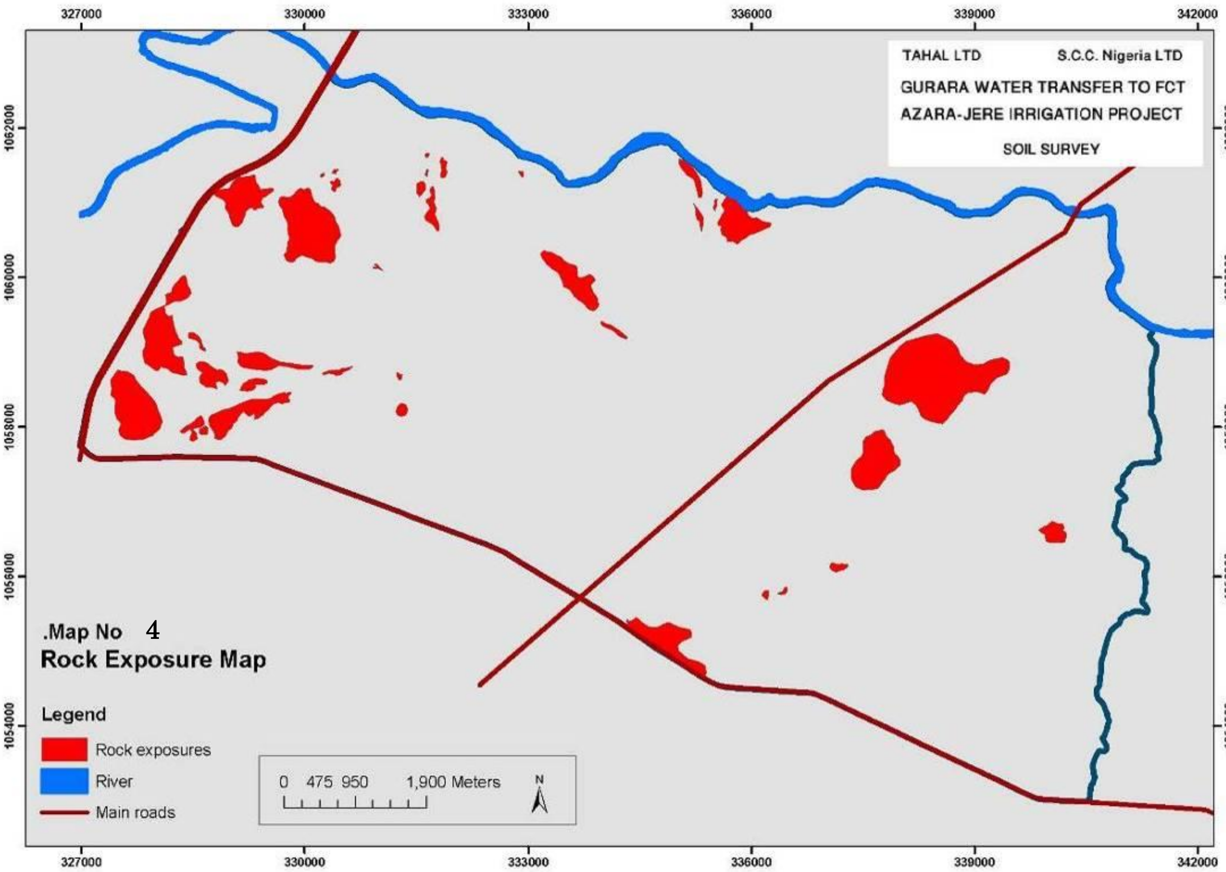
The highest peaks in the area are those of the rocky hills, near the village Jere and in the middle of the area 650 meters over sea level. The height of the plateaus - the watershed line, ranges between 550 to 580 meters over sea level. The height of the alluvic surfaces near the Gurara River ranges between 523 at the higher part of the river, and 515 meters over sea level at the lower end (of the river's flow within the project's area).

2.5 Lithology

Parent material exposures appear in a number of places in the project's area. The rocks are various types of granite and vary in shapes and appearances. The rock exposures were located in three main concentrations. The first is in the east of the area near the village Jere that is surrounded by rocky hills. The second is in the central part of the area near the Gurara River. The third is in the east of the area, in the form of a large piece of rock near the S.C.C camp. Except for these, small rock exposures, of a few hectares, are scattered over the area. It should be noted that there are no rock appearances in the depth of the soil near the rock exposures.

Map No. 4 depicts the spread of rock exposures in the area. The total exposure area is 488 Hectares, 6% of the projects area.

It should be noted that rock exposures were always mapped using aerial photography. During the conduction of the land survey, very small areas, a number of hectares or less, of continuous rock surfaces, were discovered. These areas are too small to be spotted and identified on the aerial photographs; therefore it should be assumed that other small, unmapped, areas of rock exposure will be found.

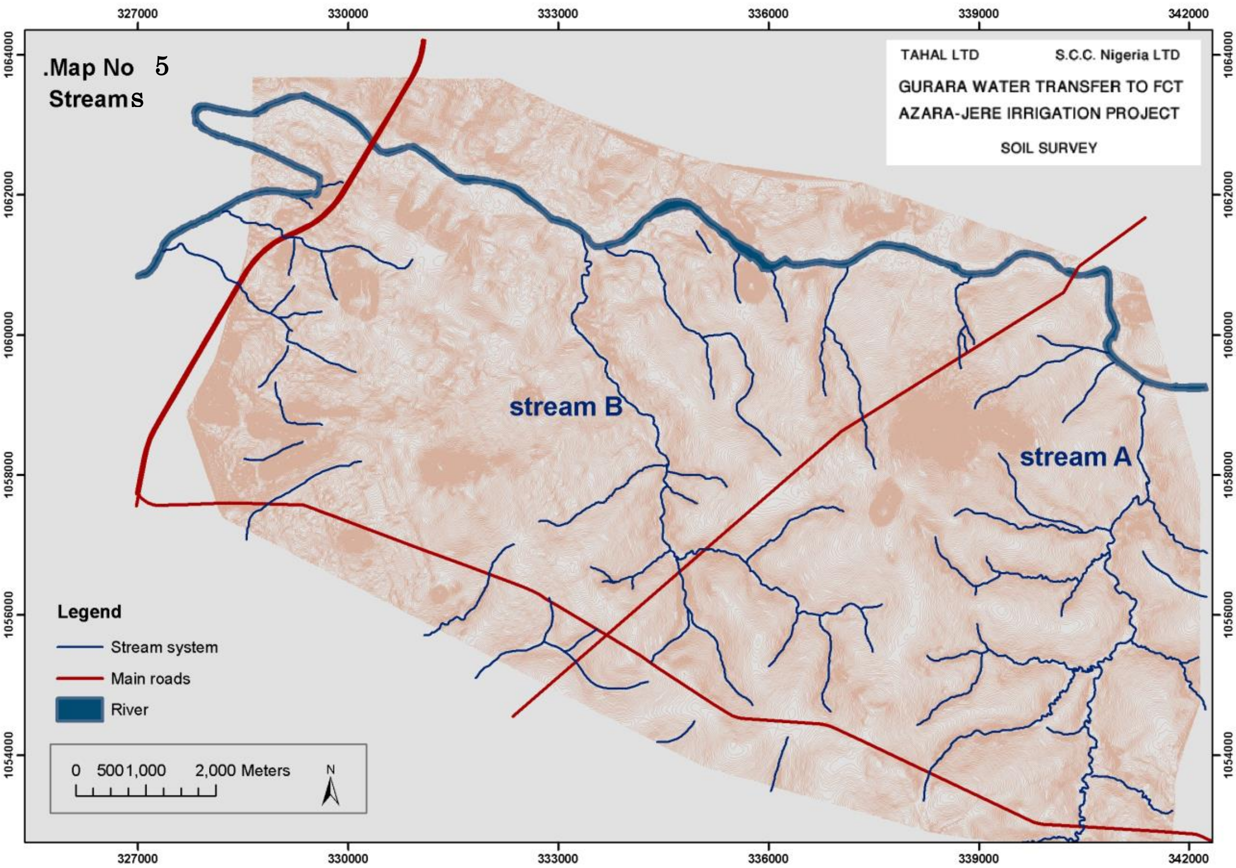


Picture No. 1
Rock surfaces are exposed in certain areas, beyond the wide mapped rock surfaces. The rocks appear as rock plates and large chunks. The surrounding soil is deep and is not affected by stoniness.

Picture No. 2
Rock surfaces and large rocks piled along their edges.

2.6 The drainage system

The Gurara River flows from east to west draining the project. Two, fairly large streams flow south to the Gurara River, creating a secondary division of the project's area. These streams have a series of small tributaries connected to them creating the area's drainage system. Map No. 5 shows the stream and drainage system. One might notice that the two large rivers dominate the eastern part of the project (approximately two thirds of the area). The drainage system in the western part is more complex, and it is impossible to spot one main river flowing through the area and draining it. This part is also characterized by multiple granite rock exposures.
The alluvic areas by the river might be flooded since they have a high level of ground waters and poor inner drainage. The natural drainage in the plateau area is good due to the slope system and the sandy soil. Even so, it should be noted that there is a possibility of inner drainage problems due to the presence of hard laterite layers, which might block the soil and prevent infiltration in the soil profile's depth. Map No. 5 shows the streams draining the area.



Picture No. 3
The Gurara River. Sandy material accumulation on the northern bank.

Picture No. 4
A characteristic view of a tributary flowing to the Gurara River. The tributary's surrounding are usually covered with dense vegetation. Some of the tributaries are cultivated, while water flows in others throughout the year.

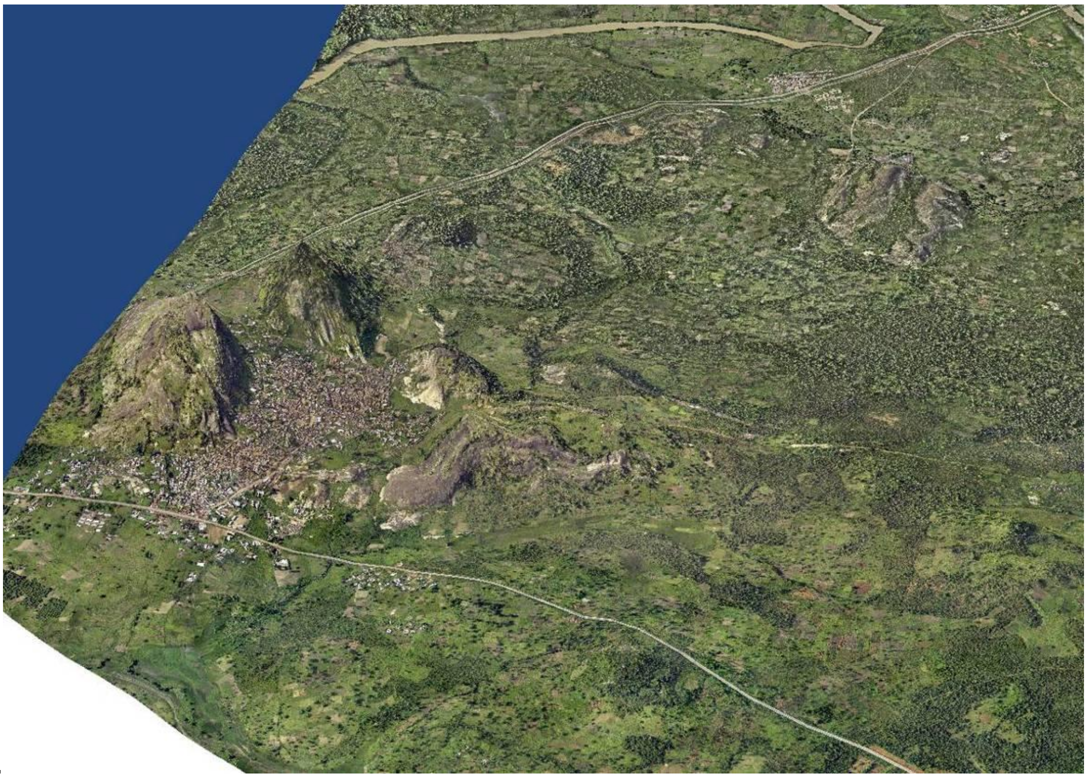
2.7 Vegetation

The area falls within the southern Guinea savanna vegetation zone or transition woodland. Vegetation is mainly transitional between the rainforest to the south and the Sudan savanna to the north, and consists mainly of thick barked trees (Daniellia Oliveri) with tall grass (Andro Pigon tectorum). Vegetation in the Fadama areas is sparse (typically savannah) and consists mainly of stunted trees and tall trees, the latter being concentrated along the river courses. Typical trees in the area include oil palm, locust bean trees and mahogany.

2.8 Land uses

2.8.1 Settlements

The project's area covers approximately – 8000 hectares. Jere, a large village of 2,000 dwellings, lies in the south–eastern part of the area. The village's houses stretch along the main road to the north, and along the road to the east. Except for this village, there are also small village concentrations consisting of a few scattered houses. Map No. 6 shows the population's distribution in the project's area. The area occupied by dwellings covers about 140 hectares, approximately 1.7% of the area.



Map No. 6 settlement distribution

Pictures No.5-7 Various settlement forms.

2.8.2 Agricultural uses

2.8.2.1. Agriculture in Nigeria

Many areas in Nigeria are suitable for agricultural cultivation but only some are cultivated. This is due to a number of different reasons; some of these are rooted in local traditions which limit the selling of family land. According to FAO Nigeria's lands have a low to medium productivity, but will have medium to good productivity with the right management. The main crops in Nigeria are root vegetables such as yam, cassava, sweet potato, cocoa, oil palms, and rubber trees. Other crops are sorghum, corn, millet, cotton, and peanuts in the drier areas (in the north of the country). During the 60's and the 70's Nigeria was one of the main exporters of cocoa, peanuts, rubber, and palm oil products. This changed at the end of the 70's. Nigeria's position as number one exporter of peanuts in the world altered as a result of a drought and a disease which affected the crops. Cocoa growing regained its position as a major export after the replanting of the cocoa plantations with the aid of the world-bank, placing Nigeria at the top of the list of cocoa exporters (after the Ivory Coast and Ghana). About two thirds of Nigeria's population earns their living from agriculture, mostly small farms. A lack of arable soils in certain areas, traditional cultivation methods, a shortage of storage systems for agricultural produce, an inadequate road system and low investment in agriculture are among the reasons for the stagnation of Nigeria's agriculture. The accelerated urbanization and the population's

Picture No. 8
Papaya trees are scattered between the agricultural plots.

Picture No. 9
Banana plantations are scattered between the cultivated areas.

Picture No. 10 A characteristic view of the Gurara River. Mango and banana trees can be observed on the river banks.

growth cause an ongoing shortage in agricultural produce in Nigeria.

2.8.2.2. Agriculture in Gurara

The main type of farming system prevalent in the Gurara area is the traditional family farm. Family farms practice subsistence farming, mainly cultivating root crops, cassava, rice, vegetables, and fruit crops, mostly for self consumption, sometimes combined with commercial production. Work is conducted manually and there is no irrigation or manuring (except for the irrigation in the river's surroundings). Shifting cultivation is the main form of agriculture. The use of chemical fertilizers, herbicides and insecticides is not prevalent. Livestock production exists in the area as well.

Picture No. 11
A large mango tree on the levee near the

Picture No. 12
A watermelon crop.

The project area includes areas in various levels of cultivation; entirely cultivated areas; areas in which agricultural fields lie beside uncultivated land covered with dense vegetation and trees; and entirely uncultivated areas covered with dense vegetation. The agricultural fields are not large 0.5 hectares. The cultivation methods are traditional but there is use of chemical fertilizers, bought nearby in Jere. Except for the areas by the river, there is no irrigation, and the crops are rain-fed. The area is characterized by a variety of field crops and vegetables but also has banana plantations, few orchids and oil palms. Rice (seasonally) and palms are grown near the river, and bananas, peanuts and "garden eggs" (a type of eggplant) are grown on the levee running along the river. A variety of crops are cultivated in the rest of the area including corn,

Picture No. 13
Furrow irrigation near the Gurara River

sorghum, durra, peppers, melons, ginger, tobacco, cassava, "garden eggs" ,shea butter trees, beans and cashews, the most common crop being yam.

Picture No.14
A watermelon and cassava field near the banks of the Gurara River raised furrows, irrigated by flooding.

2.8.2.3. Local Agriculture appearances

A number of occurrences of local agriculture can be found:

a. Intensive cultivation of alluvial areas near the river

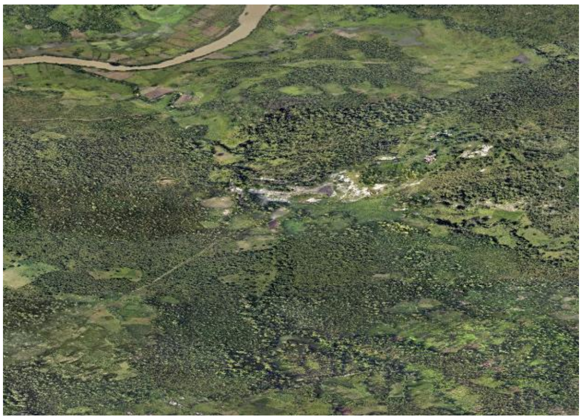
Practically all of the alluvial areas along the Gurara River are cultivated. Rice, cultivated in large, orderly plots is a prominent crop. The area is irrigated by flooding since the water source is the river. In places where a levee appears over the river, vegetables, and even fruit can be found, for example mango. See picture No. 11.

Picture No. 15
Pumping water from the Gurara River with a hose, and drawing them to the fields for irrigation purposes.

b. Intensive cultivation in the west of the area

The western part of the project's area, near the village Jere, is cultivated quite intensively. The plots are small and tilled by families, approximately 0.3-0.5 Hectares. The area is not irrigated, the main crops are yam, peanuts, millet, corn, and cassava.

Picture No. 16 shows a characteristic view of the cultivated land in the west of the area.



Picture No. 16
Intensive agriculture in the west of the area

c. Alternating cultivation

The eastern part of the project’s area as well as parts of the center, are characterized by cultivated plots which appear between areas of natural forest. It may be assumed that this is a shifting cultivation culture, and that the natural forest too, was subject to agricultural cultivation. When observing the aerial photographs one can see patches of former cultivation. As customary in tropical areas, the farmers set fire to the land at the end of the agricultural cycle, as part of the surface management, before cultivating it again.

d. Continuous natural forest areas

The central parts of this area, especially those on both sides of the road going up to the S.C.C camp, are surrounded by a dense natural forest. No cultivated areas can be spotted in this forest, and it is likely it had not been cultivated in the past either (there is a certain correlation between the dense forest cover and the absence of agriculture, and between the appearance of laterite soil with continuous iron structure, which limits agricultural cultivation.

the area.

Picture No.18
Cultivation plots are burnt, as part of a routine farming method of pruning and burning, in order to prepare the soil for cultivation. At the far end of the area banana trees can be seen.

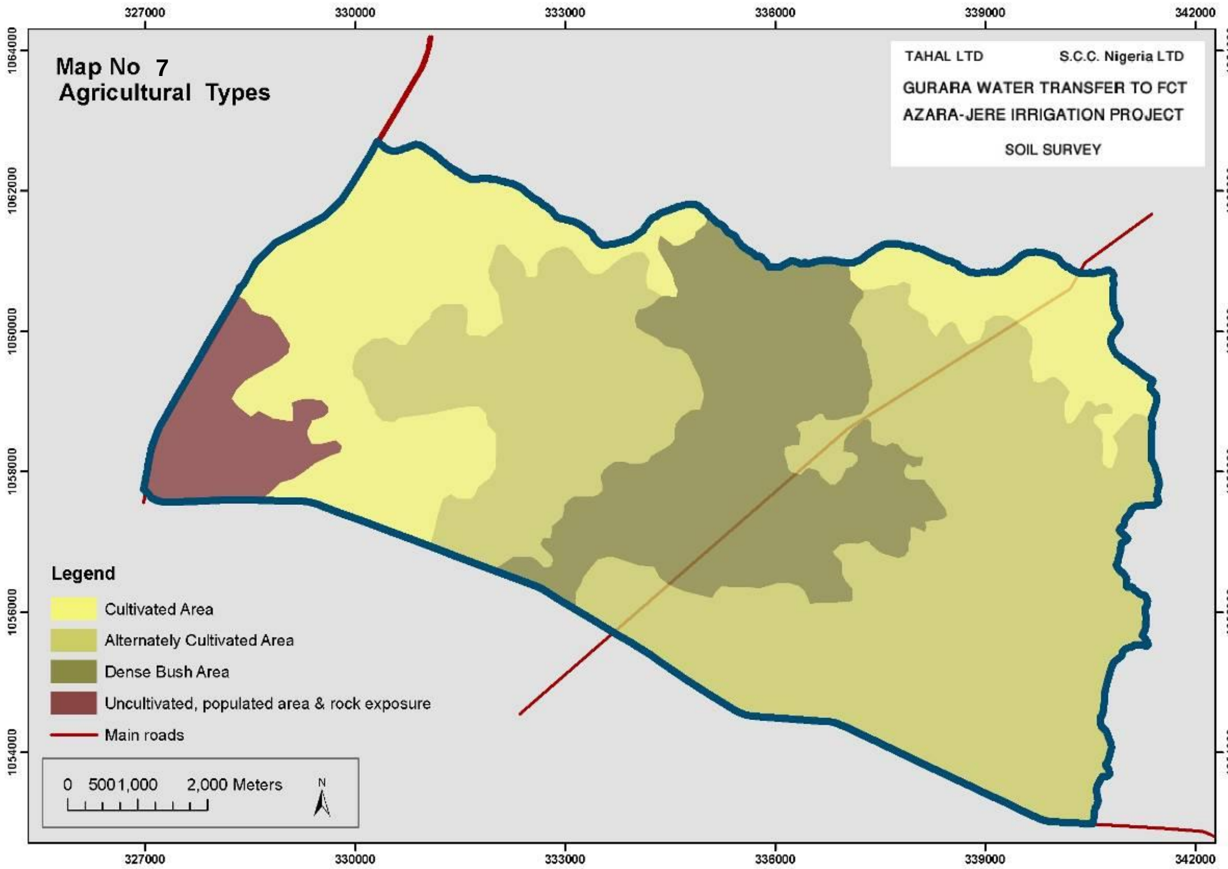
Picture No. 20
A dense grove in the central part of the area. The appearance of hard laterite stones on the surface can be observed (in the left corner).

Picture No. 19
Supervised burning as part of the area's preparation for cultivation.

Pictures No. 21, 22 A yam crop, the yam is one of the most common crops in the area

Picture No. 23 Millet - a common crop in the project's area.

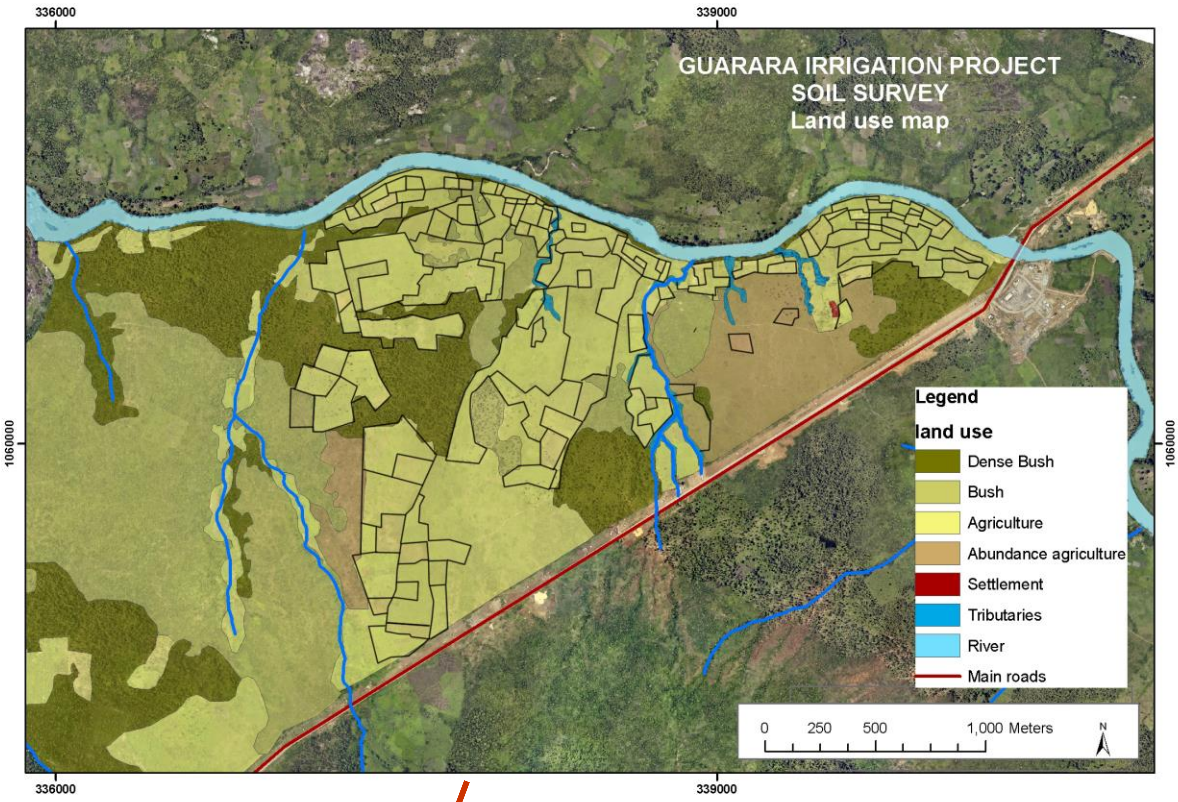
Pictures No.24 Guinea Comm- a common crop in the project's area.



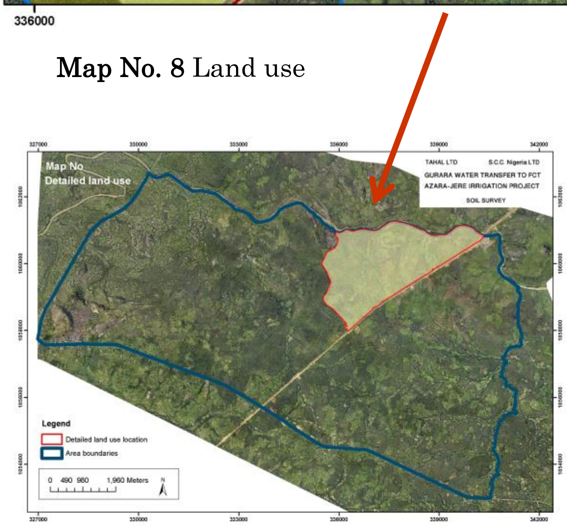
Map No. 7 A detailed account of land use. The plot pattern and the relation between the cultivated plots and natural land can be observed.

Map No. 8 provides a general presentation of the different types of agriculture, including the four kinds mentioned above.

In addition, an analysis of higher precision was made, showing the detailed land use distribution of the areas. This mapping was conducted in the northern part of the area, in an area of roughly 400 hectares.



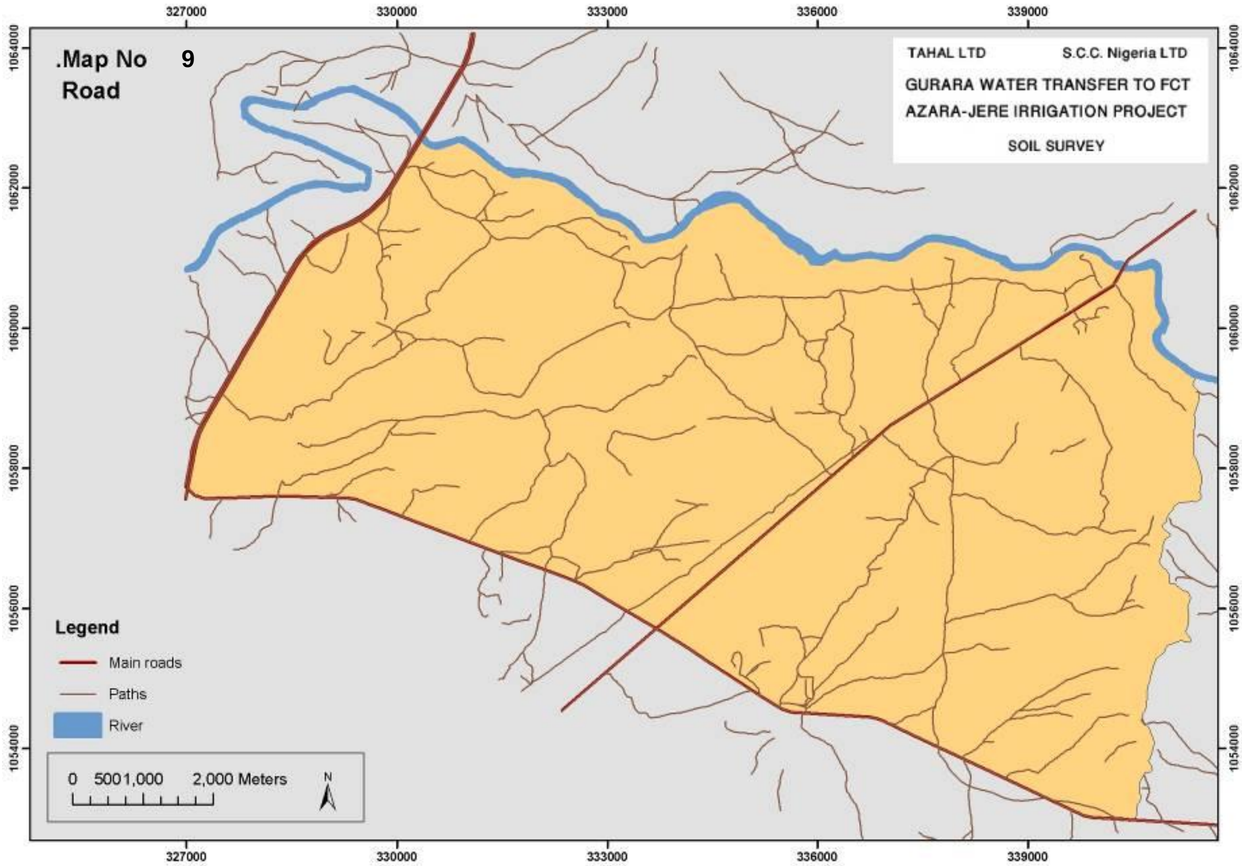
Map No. 8 Land use



2.9 The road system

The road system in the project's area includes main roads, secondary roads, dirt roads, and paths. The road system is depicted in map No. 9

The main road: Lokoya-Kaduna highway, is the western boundary of the project. A road going eastwards from Jere in the direction of Kwoi defines the boundaries of the project area from the south. An inner road crosses the area, leading from the southern road to the S.C.C camp. Apart from this road system, dirt roads and many paths create a local road network.



3. Survey Methods

3.1 General:

The survey was conducted between the 1st to the 10th of February 2008. For this high intensity survey, 200 boreholes were dug using a JCB tractor, which allows a large number of boreholes to be dug in a short period of time. The borehole density was appropriate for highly-detailed surveys. The soil properties for each borehole were photographed and described in detail according to the guidelines provided by the USDA Soil Survey Manual (Soil Survey Staff, **Soil Survey Manual**, United States Department of Agriculture, 1962). Samples from selected boreholes were sent to the laboratory for chemical and physical testing purposes. The soil properties which were observed in the field include:

- Depth
- Structure
- Texture
- Color
- Stoniness
- Drainage

In addition, general observations in the field were made relating to topography, relief, geomorphologic features, vegetation and hydrology. These observations assist in accurately identifying the different soil types and provide clues to determining the origin and boundaries of each soil unit.

3.2 Photo interpretation

Ideally, prior to the soil survey, the surveyor interprets aerial photos in order to obtain a general understanding for the area and the distribution of soil units. The aerial photographs are updated, year 2007, and were made in high quality. They were deciphered on computer screen. The scale, the computer enables one to work with, and according to which the deciphering was conducted is 1:1000 and more.

The aerial photography included elevation lines at two meter intervals, and made the creation of three dimensional simulations possible. Deciphering the aerial photography helped in creating the background maps for the understanding of the area, including:

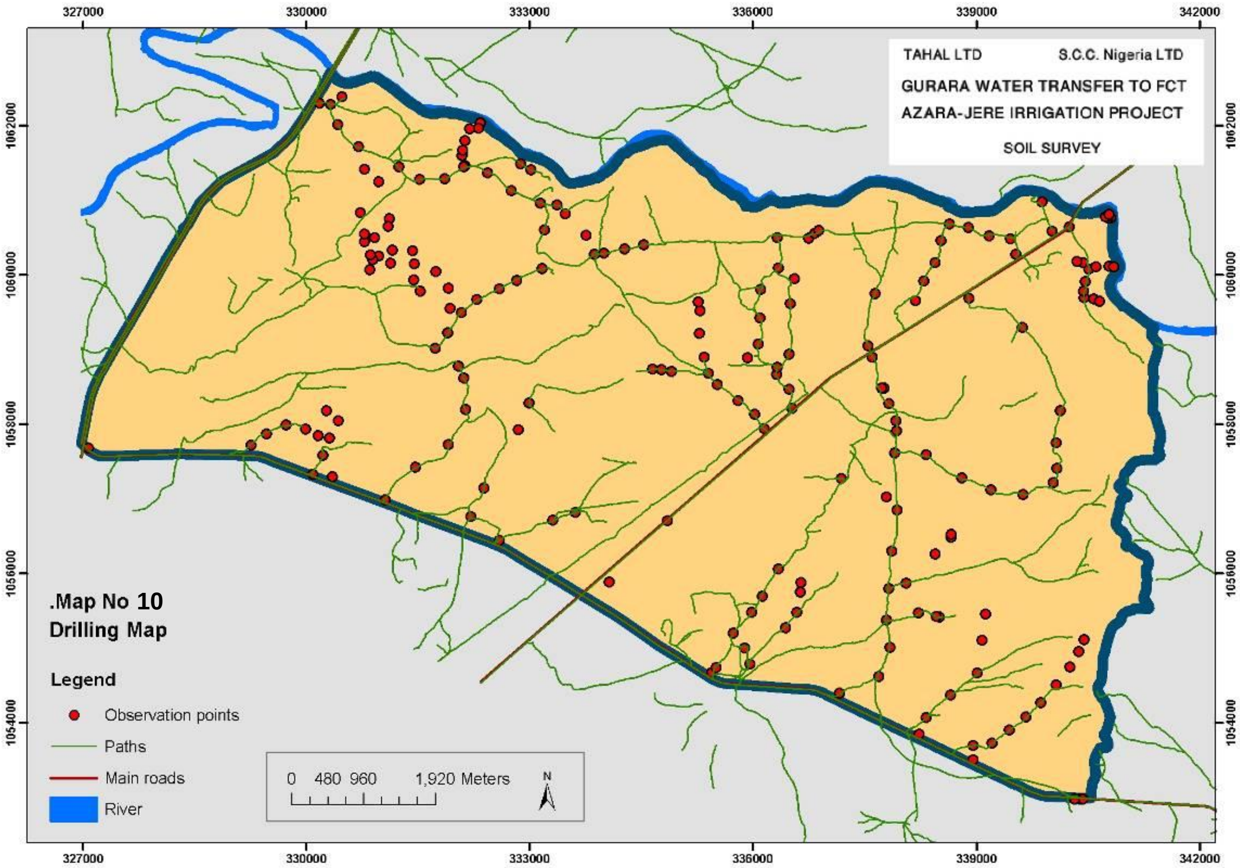
- Deciphering the drainage system, the stream lines, and the watershed lines.
- Deciphering the road system and the population distribution.

- A general interpretation of the land use distribution, the various cultivation areas, and the natural forest.
- The slope map, and, based on it, a map of units of equal heights.

This interpretation provides very valuable information, especially regarding the definition of the boundaries between the soil units.

3.3 Drillings

Map No. presents the drilling points locations. The drilling conducted by JCB were made mostly in adjacent to trails and roads. In some cases, when large areas were not accessible by any road or trail, the survey team was forced to open new roads in the forest and to locate drilling points along those trails.



4. FINDINGS

4.1 Soil Categories

Two dominant categories of soil types can be distinguished by their texture and color, which also coincide with the landscape units of the area.

1. Upland soils characterized by their coarse texture and variable kinds of drainage conditions are found in the higher elevated areas. The source of this soil is weathered granite rock in the area. Laterite horizons in varying degrees of hardness appear in these soils.
2. Lowland soils found in the river basin. These soils are compact and dark, have a large variety of textures, and lie along the Gurara River and its tributaries. The source of this soil is alluvial material transported by the streams from distant areas.

4.2 Cross Section

The following cross section (see illustration No. 1) of the project area depicts the gently undulating topography and the distribution of the soil units accordingly.

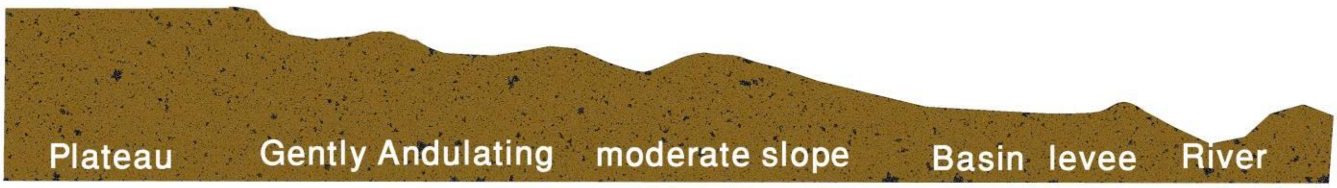


Illustration No. 1 Cross Section

4.3. Main soil appearances, laterite soils, Oxisols:

The project area, like many other areas in Nigeria, is dominated by lateritic soils (of the oxisol type). These soils are characteristic in tropical areas, which are constantly in conditions of heat, humidity and precipitation.

Picture No. 25
Lumps of hard metallic laterite, appear as hard stones tightly pressed to the surface, creating an impermeable cover. This situation is common in steep areas where the laterite is exposed. A close view of the rock allows us to discern between the rock's different shades, as a result of different oxidation and reduction situations.

Picture No. 26
Rounded iron concretions in a characteristic horizon of lateritic soil.

Laterite forms in hot and wet tropical areas which is enriched in iron and aluminum and develops by intensive and long lasting weathering of the underlying parent rock. The percolating rain water causes dissolution of primary rock minerals and decrease of easily soluble elements as sodium, potassium, calcium, magnesium and silicon. This gives rise to a residual concentration of more insoluble elements predominantly iron and aluminum. Laterites consist mainly of the minerals kaolinite, goethite, hematite and gibbsite which form in the course of weathering. Laterites contain quartz as relatively stable relic mineral from the parent rock. The iron oxides goethite and hematite cause the red-brown color of laterites.

Laterite covers have mostly a thickness of a few meters but occasionally they can be much thicker. Their formation is favored by a slight relief which prevents erosion of the surface cover. Lateritic soils form the uppermost part of the laterite cover; in soil science specific names (oxisol, latosol, ferallitic soil) are given for them.

Laterites can be as well soft and friable as firm and physically resistant. Indurated varieties are sometimes cut into blocks and used as brickstones for house-building—the term derives from Latin *later* = brickstone. And so, all these appearances are common in the Gurara River's area. In the western part of the project's area, a lateritic material block "industry", was found.

Picture No. 27
Rounded iron concretions in a characteristic horizon of lateritic

4. 4 Soil characteristics:

The cation exchange capacity of the clay is very low. In mature soils, it is about 2-5 meq per 100 grams of clay. Most of this absorption capacity is due to the organic material in the soil, which contains almost all the nutrient reserves of the soils. This organic matter is rapidly degrading because of the hot and humid weather. Therefore, the nutrients are kept for a short period only. Actually, the nutrients supply is continually reproduced by the degradation of plant and animal remnants (in a functioning ecological system).

Picture No. 28
Iron manganese concretions, in a soil chunk going through a lateritization process

These soils have a typical oxy horizon. The texture difference between the horizons is not significant. There is no clay movement and the transition from horizon A to B is gradual. The color of the Lithosols is red, brown or yellow. The infiltration of Oxysols is fast and good due to the sandy component and the special characteristics of the clay.

With the increasing of the erosion in the depth and with the flattening of the relief, an accumulation of ground water appears. The ground water lies on the deep eroded layer of the soil. As the erosion continues, a layer of kaulinitic clay might appear at times, preventing infiltration and causing water to accumulate above it.

In the water saturated layers reduction of the Fe^{3+} occurs to create Fe^{2+}. This form of iron has a tendency to rise up towards the more ventilated layer. It is repercipitated there to form a secondary compound named Plintite. At first, this iron compound appears in concretions but it is finally able to fill the spaces between the concentrations and a continuous layer of Laterite or Plintite is formed. This layer might harden irreversibly after drying. This kind of layer does not develop under forest cover, but only, where the forest disappears exposing the surface to sunshine which dries it causing a hard layer of Laterite or Plintite to form. Above this hard layer, yellow or red soil appears. If this soil is washed away, the hard layer is exposed

Soil Phases Table				
Soil type	**Relative area (%)**	**Area (ha)**	**Soil phases**	**Coding**
Alluvium of the Gurara river	4.0	284.5	C1, D3, T0	**Alr**
total	4.0	284.5		
Alluvium of secondary streams	2.7	193.0	C1, D2, T0	**Als1**
	2.6	183.9	C1, D2, T1	**Als2**
total	5.3	376.9		
Red Laterite	2.8	193.9	C3, D2, T0	**L1**
	19.3	1,358.5	C3, D2, T1	**L2**
	8.5	599.2	C3, D2, T2	**L3**
	2.6	180.2	C3, D2, T3	**L4**
total	33.1	2,331.9		
Weathered Laterite	8.4	589.9	C2, D1, T0	**WL1**
	28.6	2,018.0	C2, D1, T1	**WL2**
	6.6	466.3	C2, D1, T2	**WL3**
	0.7	51.4	C2, D1, T3	**WL4**
total	44.3	3,125.5		
Yellow Brown soils	1.4	102.1	C1, D0, T0	Y1
	7.9	558.4	C1, D0, T1	Y2
	3.1	215.4	C1, D0, T2	Y3
	0.8	53.1	C1, D0, T3	Y4
total	13.2	929.0		
Total area	100%	7,047.8		

Table No. 5 Soil Phases

4.5 Soil units' description

General:

The boundaries between each of the soil units are based on geomorphic features. The landscape units which reflect geomorphic conditions greatly influence the formation and distribution of the soil types. The land units follow the distribution into two main appearances: upland and lowland.

The different slopes have been mapped by five categories: 0-2%, 2-4%, 4-6%, 6-8%, 8% and above. This soil survey does not include the bare rocks and the slopes above 8% that were diagnosed as non arable.

	Soil type	Relative area (%)	Area (ha)	Coding
Low land	**Alluvium of the Gurara river**	4.0	284.5	**Alr**
	Alluvium of secondary streams	5.3	377	**Als1**
				Als2
Up land	**Red Laterite**	33.2	2,331.8	**L1**
				L2
				L3
				L4
	Weathered Laterite	44.3	3,125.5	**WL1**
				WL2
				WL3
				WL4
	Yellow Brown soils	13.2	929	**Y1**
				Y2
				Y3
				Y4
	Total area	100%	7,047.8	

Table No. 6
Soil units - upland, lowland.

Yellow brown soil

Total area 929 hectare

The area's rate 13.2 %

Position: This soil unit appears as one block in the western part of the project's area. It is characterized by multiple rock exposures which stick out of the ground, and by a large settlement in its south-western end (Jere). Practically all of the units area is cultivated by field crops.

General description: Light brown soils, relatively light (Sandy Loam – Loamy Sand) in the topsoil's horizon, and medium in the subsoil (Sandy Clay Loam - Loam-Clay Loam). The soil's structure is stable, horizon A reaches 40-60 cm and a clay accumulation starts underneath it. This soil unit is characterized by an initial and light development of a Laterite horizon, or by the total absence of one.The soil is well drained. The presence of a laterite horizon, or a clay accumulation in the depth of the ground might slow the drainage in the depth.

Occurrences:

There are four occurrences in this unit according to the slope:

Y1 :T0 ,C1,D0 - 102 hectare: a plateau near the Gurara River, over a steep terrace.

Y2: T1, ,C1,D0 - 558 hectare: a slight slope, over most of the unit's areas.

Y3: T2,C1,D0 – 215 hectare: a moderate slope. An irrigation limitation, low level of erosion and compaction.

Y4: T3,C1,D0– 53 hectare: moderate slope.

Yellow brown soil - soil characteristics Summary

	Soil characteristics	Specific description
1.	Texture:	Sandy Loam – Sandy Clay Loam
2.	Drainage:	Well
3.	Soil reaction:	Neutral
4.	Calcium carbonate content:	None
5.	Salinity problem:	None
6.	Natural fertility:	Low
7.	Water holding capacity:	Moderate
8.	Infiltration:	Well
9.	Water requirement	Moderate

Table No. 7 Yellow brown soil - soil characteristics Summary

Typical soil Laboratory test for each soil type																
Y - yalC ydnaS hsiwolleY																
NO.	**Sample**	**saturation**	**EC**	**pH**	**Na**	**Ca+Mg**	**Cl**	**$_3$NO**	**SAR**	**N**	**P**	**K**	Sand	Clay	Silt	Type Soil
			(dS/m)		(meq/l)	(meq/l)	(meq/l)	(meq/l)	(meq/l)$^{0.5}$	**N-NO3**	**Olsen**	**CaCl**				
		(%)								(mg/Kg)	(mg/Kg)	(mg/Kg)	**%**	**%**	**%**	
95	0-10	37.2	0.53	7.01	0.38	5.76	0.39	0.52	0.22	2.7	41.0	31.5	73	12	15	Sandy loam
	10-70	40.8	0.17	5.76	0.33	1.44	0.25	0.37	0.38	2.1	28.8	15.1	54	30	16	Sandy clay loam
	70-125	34.8	0.09	7.56	0.19	0.72	0.11	0.06	0.31	0.3	23.8	10.9	67	16	17	Sandy loam

Table No. 8 Laboratory tests – Yellowish sandy clay

Picture No. 29
Exposed profile of Yellow – brown soil in a typical digging point

Recommendations:

These soils, together with the alluvial areas are the most suitable for agricultural cultivation. This unit is almost entirely cultivated due to: The absence of a laterite horizon, or, at least its minor presence, the comfortable texture and structure, and the good drainage.

The soil is suitable for a broad range of crops, the irrigation method will be adjusted to the surface and the degree of the slope. Particular attention should be paid to the steep slope strips, in which a different cultivation and irrigation system will be required.

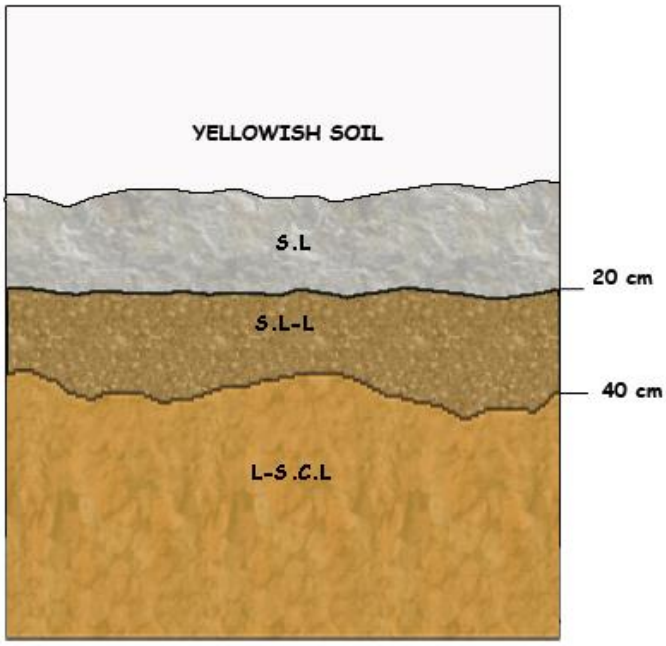


Illustration No. 2
A typical profile of Yellow – brown soil, with its characteristic light sandy upper horizon A, descending gradually to horizon B which contains a higher rate of clay.

Red Laterite

Total area 2,332 hectare

The area's rate 33 %

Position: The unit appears as a large block on both sides of the western river which flows to the Gurara, in the central part of the project's area, and two smaller blocks in the eastern part of the area.
Most of the area is uncultivated, and is densely covered in natural trees and bushes.

General description: Brown reddish soils, light to medium texture in the topsoil's upper horizon (Sandy Loam - Sandy clay loam - Clay loam) and medium to heavy in the lower subsoil's horizon (Sandy Clay Loam - Clay Loam – Clay).
The soil is characterized by the development of a hard laterite horizon. The laterite horizon may appear in different depths and different levels of development, ranging from the presence of different concretions and concentrations, to the appearance of a hard and continuous layer of laterite. The depth in which the laterite appearance occurs may vary too, and it could range between an occurrence on the surface to an occurrence within a range of a few tens of centimeters. in places with a considerable slope the laterite might be exposed on the surface.
The soil's structure is very compacted, it must be noted that the compacted structure also appears in soils of relatively light texture; this seems to be due to the combination of the presence of the hard laterite, which causes an over compaction of the soil, and a high content of clay in the soil's depth.
The soil is somewhat poorly drained.

Occurrences:

L1: T0,C3,D2 194 hectare: plateaus on the watershed line between the rivers.
L2: T1,C3,D2 1358 hectare
L3: T2,C3,D2 600 hectare: moderate slope.
L4: T3,E2,C3,D2 180 hectare

Red Laterite - soil characteristics Summary

	Soil characteristics	Specific description
1.	Texture:	Sandy Loam – Sandy Clay Loam
2.	Drainage:	Somewhat poorly drained
3.	Soil reaction:	Neutral.
4.	Calcium carbonate content:	None.
5.	Salinity problem:	None.
6.	Natural fertility:	Low.
7.	Water holding capacity:	Moderate to high.
8.	Infiltration:	Moderate to imperfect.
9.	Water requirement	Moderate to low.

Table No. 9 Red laterite - soil characteristics Summary

Picture No. 30
Exposed profile of Red Laterite soil in a typical digging point

Recommendations:

There are serious limitations to agricultural cultivation of these soils. The restrictions are:

The presence of hard iron concentrations in the soil profile, and sometimes iron layers (laterite) within the range of tens of centimeters in varying depths.

The laterite presence causes an excessive compaction, impermeability, hard structure, lack in ventilation and poor drainage of the soil profile.

These soils require deep plowing in order to break the laterite layer and to improve the soil structure.

Most of this unit's soils are covered in dense vegetation. Clearing the vegetation is required as it will achieve the drying of the soil and will accelerate the lateralization process.

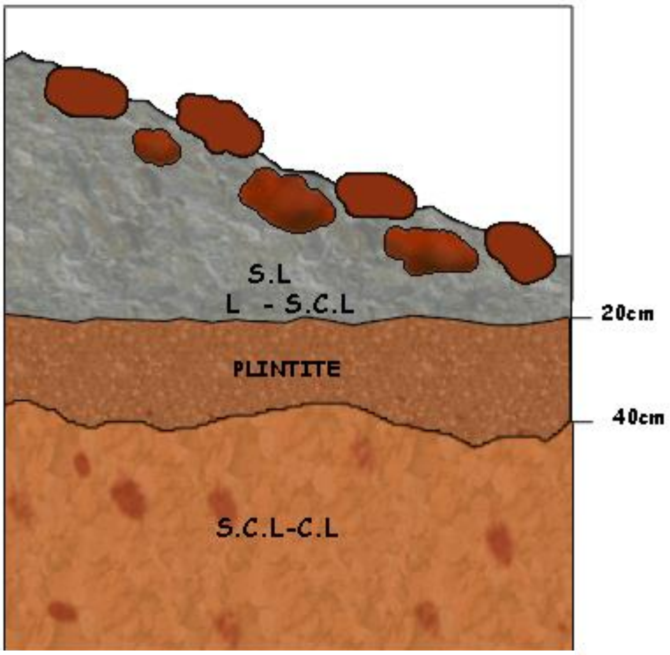


Illustration No. 3
A typical horizon of lateritic soil found in a slope. Pieces of plintite are exposed and can be seen over the surface.

Typical soil Laboratory test for each soil type

L - etiretaL deR

NO.	Sample	saturation	EC	pH	Na	Ca+Mg	Cl	$_{3}$NO	SAR	N	P	K	Sand	Clay	Silt	Soil Type
			(dS/m)		(meq/l)	(meq/l)	(meq/l)	(meq/l)	$(meq/l)^{0.5}$	N-NO3	Olsen	CaCl				
		(%)								(mg/Kg)	(mg/Kg)	(mg/Kg)	%	%	%	
136	0-20	37.1	0.52	5.47	0.64	5.40	0.28	0.66	0.39	3.4	32.4	31.5	64	16	20	Sandy loam
	20-50	47.4	0.32	5.47	0.51	2.88	0.14	0.47	0.42	3.1	32.2	34.2	52	26	22	Sandy clay loam
	50-140	54.5	0.12	6.50	0.46	0.72	0.06	0.15	0.76	1.1	19.8	39.7	57	22	21	Sandy clay loam

Table No. 10 Laboratory tests – Red Laterite

Weathered Laterite

Total area 3,125.5 hectare

The area's rate 44.3%

Position: The unit appears as two large blocks in the eastern and the western parts of the project. The unit's area is cultivated in alternating patches, and is partially covered in dense vegetation.

General description:

Light brown to brown reddish soils, light to medium texture in the topsoil's upper horizon (Sandy Loam -Sandy Clay Loam), and medium texture in the subsoil's lower horizon (Sandy Clay Loam - Clay Loam).

These soils are characterized by initial developments of iron concretions and soft laterite. The laterite occurrences may be in different developmental levels but they rarely reach the forming of hard laterite. The depth of the laterite's appearance varies, starting from the surface to a depth of a few tens of centimeters.

The soil in the depths is compacted, in accordance to the extent of the laterite's occurrence and the level of its development. The high clay rate contributes to the excessive compaction in the deep layers as well.

The drainage is moderately well drained according to the appearance of the impermeable layers in the depth of the soil.

Occurrences:

WL1: T0,D1,C2 590 hectare: plateaus on the watershed line between the rivers.

WL_2: T1, D1,C2 2018 hectare

WL_3: T2,E1, D1,C2 - 466 hectare

WL_4: T3,E2, D1,C2 - 51 hectare

Weathered Laterite - soil characteristics Summary

	Soil characteristics	Specific description
1.	Texture:	Sandy Loam – Sandy Clay Loam
2.	Drainage:	Well to moderately well.
3.	Soil reaction:	Neutral.
4.	Calcium carbonate content:	None.
5.	Salinity problem:	None.
6.	Natural fertility:	Low.
7.	Water holding capacity:	Moderate.
8.	Infiltration:	Well to moderate.
9.	Water requirement	Medium.

Table No. 11 Weathered Laterite - soil characteristics Summary

Picture No.31
Exposed profile of Weathered Laterite
soil in a typical digging point

Recommendations:

The soils are suitable for cultivation. Attention must be given to the laterite layer in the soil's depth, to its compactness, and its position in the Soil Profile. In places that will be recognized as problematic, deep plowing (60-90 cm) will be necessary in order to crumble the laterite layer, to improve the soil structure, the permeability and drainage.

Typical soil Laboratory test for each soil type																
LW - etiretaL drehtehW																
NO.	Sample	saturation	EC	pH	Na	Ca+Mg	Cl	$_3$NO	SAR	N	P	K	Sand	Clay	Silt	Type Soil
			(dS/m)		(meq/l)	(meq/l)	(meq/l)	(meq/l)	$(meq/l)^{0.5}$	N-NO3	Olsen	CaCl				
		(%)								(mg/Kg)	(mg/Kg)	(mg/Kg)	%	%	%	
26	0-20	31.9	0.75	5.57	0.42	9.36	0.03	0.44	0.19	1.9	28.6	15.5	66	12	22	Sandy Loam
	20-50	44.1	0.30	6.44	0.39	3.60	0.00	0.47	0.29	2.9	6.8	19.6	51	28	21	Sandy Clay Loam
	50-120	43.6	0.12	6.46	0.28	1.08	0.00	0.10	0.38	0.6	16.4	16.9	38	36	26	Clay Loam

Table No. 12 Laboratory tests – Weathered Latrite

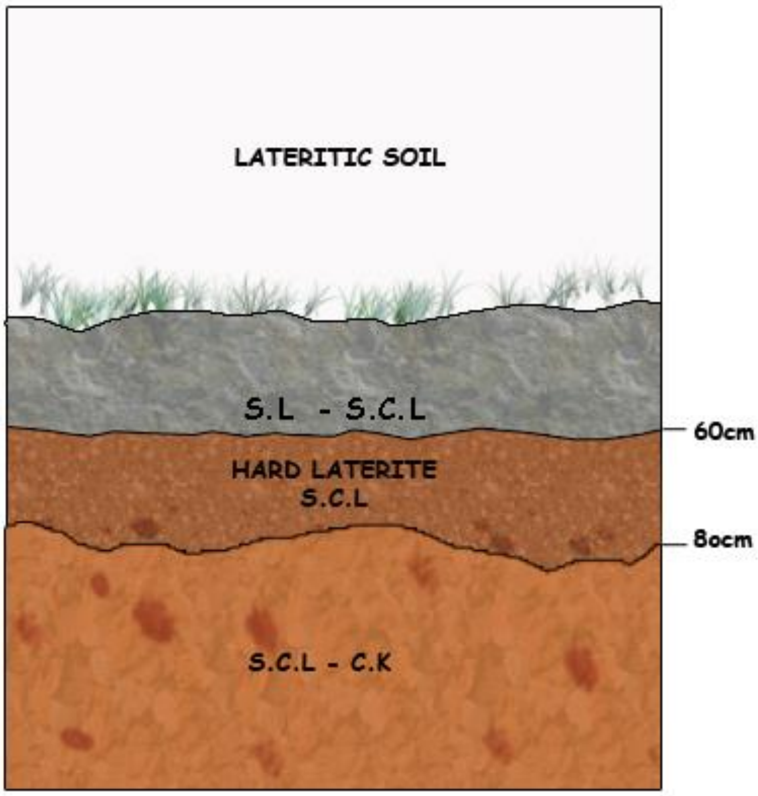


Illustration No. 4
Weathered lateritic soil

Alluvium Gurara River

Total area 284.5 hectare.

The area's rate 4% of the entire projects area.

Position: The alluvial area occurs in the flood plain of the Gurara River, and lies in a strip of 13,000 meters from the waterfront to the feet of the hills. The area is flat and is almost entirely cultivated.

General description: Typical alluvial soils, of a dark grey color and a relatively heavy texture, lie along the profile, but there is a possibility that coarse grained layers will appear along the profile in accordance with the conditions of the flow and sedimentation that occurred in the area.

The soil's structure is stable, and there is no presence of iron concretions or laterite developments in the alluvial soils. The soil is compact due to a high content of clay.

The drainage is poor, due to the heavy texture and the presence of ground water close to the surface.

Occurrences: There is only one occurrence in this unit:

Alr: T0,C1,D3 – 285 hectare

`

Alluvium of Gurara River - soil characteristics Summary

	Soil characteristics	Specific description
1.	Texture:	Heavy texture along the profile, appearance of coarse texture might occur in the layers.
2.	Drainage:	Imperfect to Poor.
3.	Soil reaction:	Neutral to lightly positive.
4.	Calcium carbonate content:	None.
5.	Salinity problem:	No salinity problems at this stage, but such a problem is probable in the future due to the poor drainage and accumulation of salts.
6.	Natural fertility:	Low to medium.
7.	Water holding capacity:	High.
8.	Infiltration:	Imperfect.
9.	Water requirement	Low.

Table No. 13 Alluvium of Gurara River - soil characteristics Summary

Picture No. 32
An exposed profile of alluvium Gurara River soil in a typical digging point (ground water appear close to soil surface)

Recommendations:

Heavy and medium alluvial soils along the river. Drainage and flooding problems might occur, due to heavy soil texture, constant presence of ground water, and seasonal flooding of the river over short distances. There is high variation in the soil texture in nearby areas as well. Ground water may appear close to the surface even in the dry season. A long term salinity problem might occur. Nonetheless, these soils are the best suited for agriculture, the moderate slope enables varied methods of irrigation, including flooding.

Typical soil Laboratory test for each soil type

Alluvium river Alr

NO.	Sample	saturation (%)	EC (dS/m)	pH	Na (meq/l)	Ca+Mg (meq/l)	Cl (meq/l)	$_3$NO (meq/l)	SAR (meq/l)$^{0.5}$	N N-NO3 (mg/Kg)	P Olsen (mg/Kg)	K CaCl (mg/Kg)	Sand %	Clay %	Silt %	Type Soil
9 river	9 5-40	43.3	0.19	6.16	0.31	2.52	0.03	0.18	0.27	1.1	6.4	17.8	62	17	21	Sandy Loam
	9 40-90	69.9	0.11	6.84	0.29	1.08	0.08	0.16	0.39	1.6	12.8	16.4	24	35	41	Clay Loam
193 Levee	0-20	55.5	0.77	7.39	1.00	7.20	0.71	0.71	0.53	5.5	24.0	21.9	52	12	36	Loam
	20-90	42.6	0.45	5.52	0.60	3.96	0.56	0.29	0.43	1.7	32.4	12.3	65	13	22	Sandy loam
	19 90-190	60.1	0.95	7.47	3.70	7.20	3.39	0.34	1.95	2.8	33.2	17.8	24	36	40	Clay loam

Table No. 14 Laboratory tests – Alluvium River

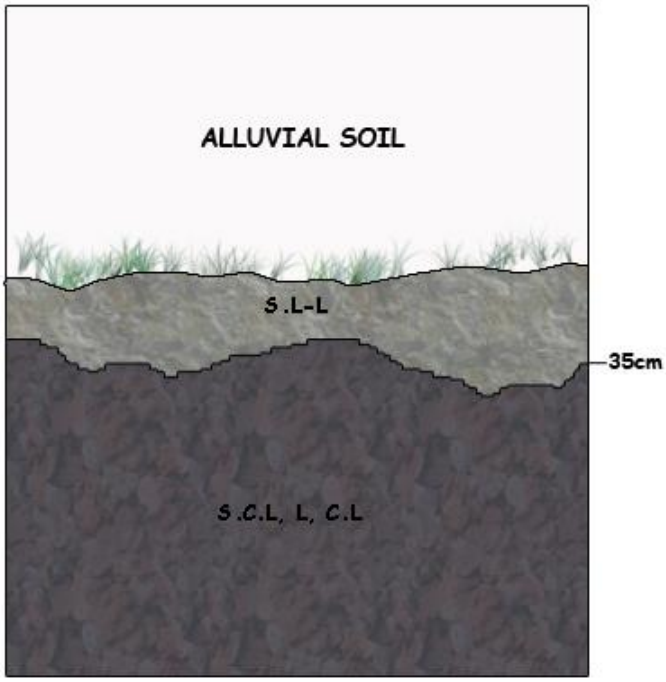


Illustration No. 5 Alluvial soil

The clay rate in these soils is relatively high in comparison to the other soil types in the area, therefore the G.E.C rate, and the soil fertility will be higher.

Alluvium of Secondary Rivers

Total area 377 hectare.

The area's rate 5.3% of the project's area.

Position: The alluvial area occurs in the flood plain of the secondary rivers flowing to the Gurara River, within the projects area. The area is flat or slightly sloped along the river's rout, and it is almost entirely cultivated.

General description: Typical alluvial soils, of a dark grey color**.** and a relatively heavy texture lie along the profile, but there is a possibility that coarse grained layers will appear along the profile in accordance to the conditions of the flow and sedimentation that occurred in the area.

The soil's structure is stable, and there is no presence of iron concretions or laterite developments in the alluvial soils. The soil is compact due to a high content of clay.

The drainage is medium to poor- accordingly to the slope.

Occurrences:

Als_1: T0,EO,C1,D2 – 193 hectare: flat topography 0-2%, comfortable structure, slightly compact and with drainage problems.

Als_2: T1,EO,C1,D2 - 184 hectare. Slightly sloped soils, comfortable structure, slightly compacted with medium drainage conditions.

ALS- Alluvium of Secondary Rivers

Soil characteristics Summary

	Soil characteristics	Specific description
1.	Texture:	Medium - Heavy texture along the profile, appearance of coarse texture might occur in the layers.
2.	Drainage:	Medium to Poor.
3.	Soil reaction:	Neutral to lightly positive.
4.	Calcium carbonate content:	None.
5.	Salinity problem:	No salinity problems at this stage, but such a problem is probable in the future due to the poor drainage and accumulation of salts.
6.	Natural fertility:	Low to medium.
7.	Water holding capacity:	High.
8.	Infiltration:	Imperfect.
9.	Water requirement	Low.

Table No. 15 ALS- Alluvium of Secondary Rivers - soil characteristics Summary

Recommendations:

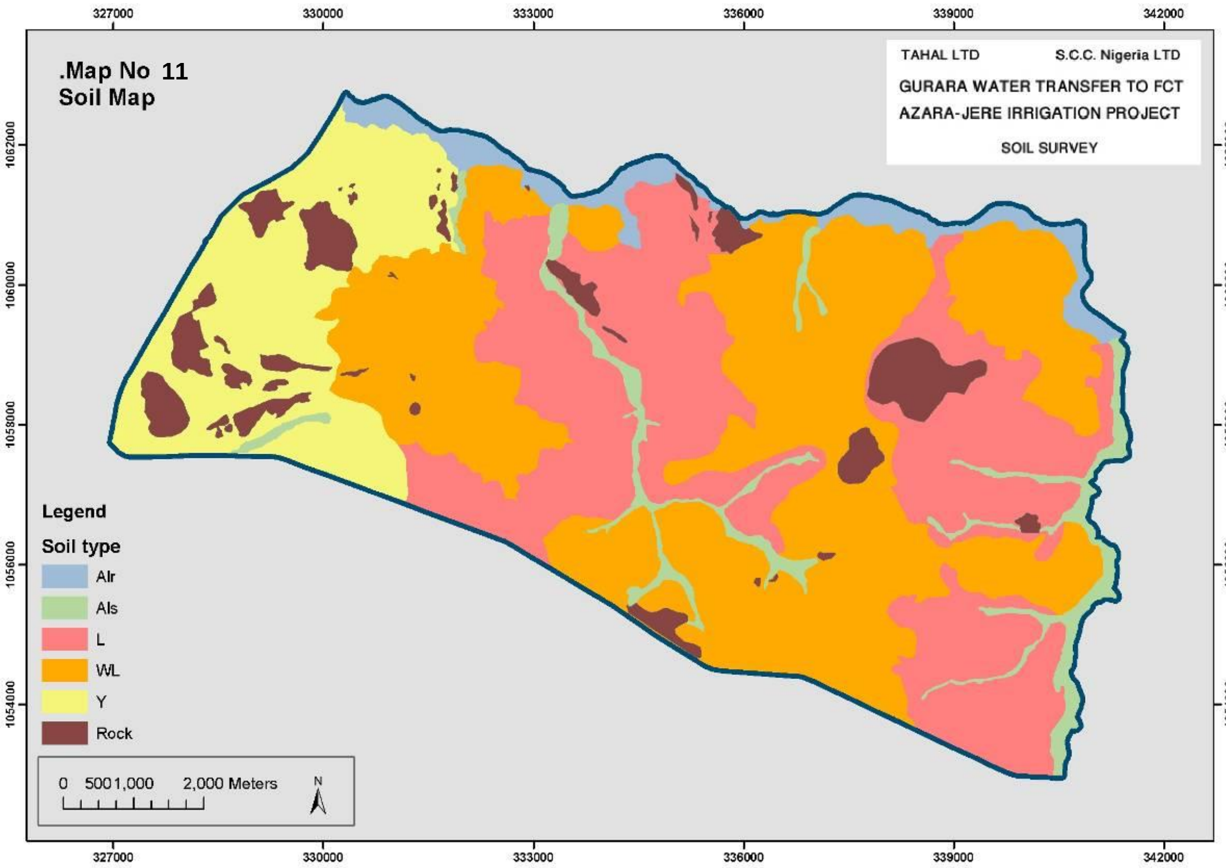
Varied alluvial soils lie along the secondary rivers. Drainage problems might occur. Ground water may appear close to the surface. There might be a salinity problem in the long term.

Even so, these soils are well suited for agriculture only near the Gurara River. The moderate slope in part of the units enables varied methods of irrigation, including furrow irrigation. One must discern between the soil's moderate slope, 0-2% near the Gurara River, and their steeper slope 2-4% found higher up the river. The drainage conditions will be better, and the flooding hazard smaller, in the higher parts of the river.

Picture No. 33
Exposed profile of alluvium secondary river soil in a typical digging point

Typical soil Laboratory test for each soil type																
Alluvium stream - Als																
NO.	**Sample**	**saturation**	**EC**	**pH**	**Na**	**Ca+Mg**	**Cl**	**$_3$NO**	**SAR**	**N**	**P**	**K**	Sand	Clay	Silt	Soil Type
			(dS/m)		(meq/l)	(meq/l)	(meq/l)	(meq/l)	$(meq/l)^{0.5}$	**N-NO3**	**Olsen**	**CaCl**				
		(%)								(mg/Kg)	(mg/Kg)	(mg/Kg)	**%**	**%**	**%**	
148	0-30	39.0	0.87	5.90	0.47	9.00	0.62	1.19	0.22	6.5	42.2	65.7	78	6	16	Loamy sand
	30-150	25.5	0.16	7.15	0.50	1.08	0.34	0.24	0.67	0.9	42.6	34.2	60	16	24	Sandy loam

Table No. 16 Laboratory tests – alluvial streams - ALS


.Map No 11
Soil Map
TAHAL LTD
S.C.C. Nigeria LTD
GURARA WATER TRANSFER TO FCT
AZARA-JERE IRRIGATION PROJECT
SOIL SURVEY
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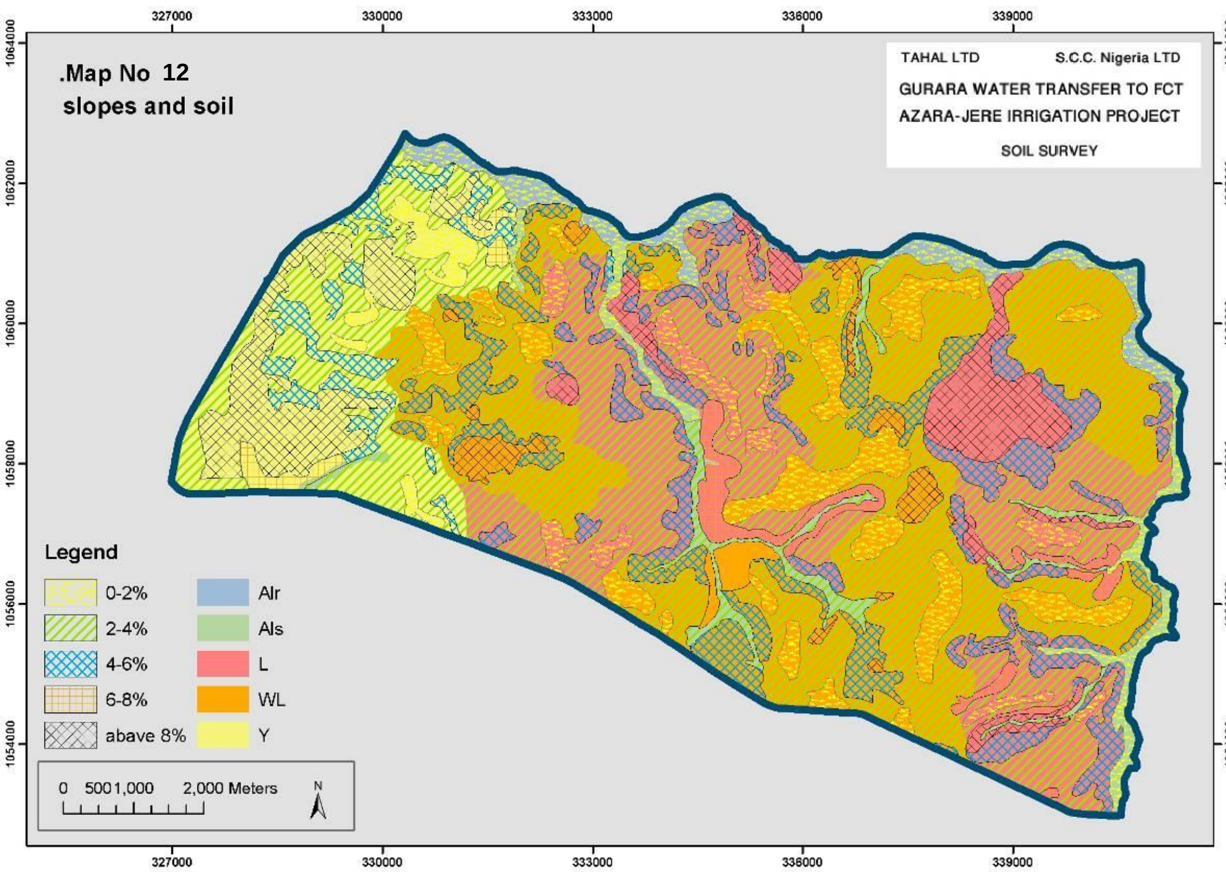
.Map No 12
slopes and soil
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S.C.C. Nigeria LTD
GURARA WATER TRANSFER TO FCT
AZARA-JERE IRRIGATION PROJECT
SOIL SURVEY
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4.6 Soil phases

Each of the soil types has different characteristics. These characteristics will have an influence on the soil's suitability for management and to various cultivation conditions. These characteristics are:

- The slope level
- The drainage level
- The laterite appearance in the soil's depth

The soil appearances are as follows:

T stands for topography.

This measure has 5 categories:

T_0 – 0-2% flat to almost flat .appears in the plateaus of the hills and in the alluvial sector adjacent to the river and the secondary streams.

T_1 – 2-4% appears in the moderate slopes of the hills descending to the Gurara river and to the secondary streams .

T_2– 4-6% local slopes adjacent to the secondary streams.

T_3 – 6-8% local slopes adjacent to the secondary streams..

T_4 – 8% slope and above. This category includes bare rocks, it is not suitable for cultivation and it was excluded from the map.

D stands for drainage.

This measure has 4 categories:

D_0 somewhat excessively drained. Water is removed from the soil rapidly. Many of these soils have little horizon differentiation and are sandy and very porous.

D_1: well drained, water is removed from the soil readily but not rapidly. Well drained soils commonly retain optimum amounts of moisture for plant growth after rains or additions of irrigation water.

D_2 moderately well drained. Water is removed from the soil somewhat slowly, so that the profile is whet for a small but significant part of the time. Moderately well drained soils commonly have a slowly permeable layer within or immediately beneath the solum, a relatively high water table, additions of water through seepage, or some combination of these conditions.

D_3 imperfectly drained. Water removed from the soil slowly enough to keep it wet for significant periods but not all the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile, a high water table, additions through seepage, or a combination of these conditions.

E stands for erosion.

This measure has 3 categories:

E_0 – no significant erosion. These soils are flat or almost flat. No erosion hazard.

E_1 – soils with minor slope (4%-6%), slight erosion hazard.

E_2 – soils with moderate slope, adjacent to secondary streams, hazard of local erosion.

C stands for compaction and stony appearance.

This measure has 3 categories:

C_1 - slightly compacted. These soils appear mostly in the alluvial sector or soils with no Laterite appearance in the yellowish brown soils on the western side of the project.

C_2 - moderately compacted soils. Soils with some compaction problems. These soil has a soft lateritic layer and initial development of iron concretions.

C_3 – compacted soils. These soils contain hard iron concretions and sometimes an iron layer.

Recommendations summary:

The soils that appear in the projects area are laterites in varying levels of development. The prominent agricultural qualities of these soils are:
a low level of fertility, a rapid leaching of nutrition elements, a low water retension, and the presence of hard iron horizons in the soil's profile and on the surface.

The general recommendations are:

1. Addition of lime to the soil - liming, permanently, in order to improve the soil structure and the basic fertility level.
2. Addition of organic fertilizers, in order to improve the soil structure and the natural fertility.
3. Deep plowing in places in which a hard lateritic (plintite) horizon has formed.
4. Constant supervision over the levels of metal presence, especially aluminum, which can, in high amounts, become toxic to plants.
5. Follow up on the levels of nutrition elements, N.P.K, and determining the required fertilizer rations according to the area's conditions.

5. Land capability

5.1 Capability subclasses

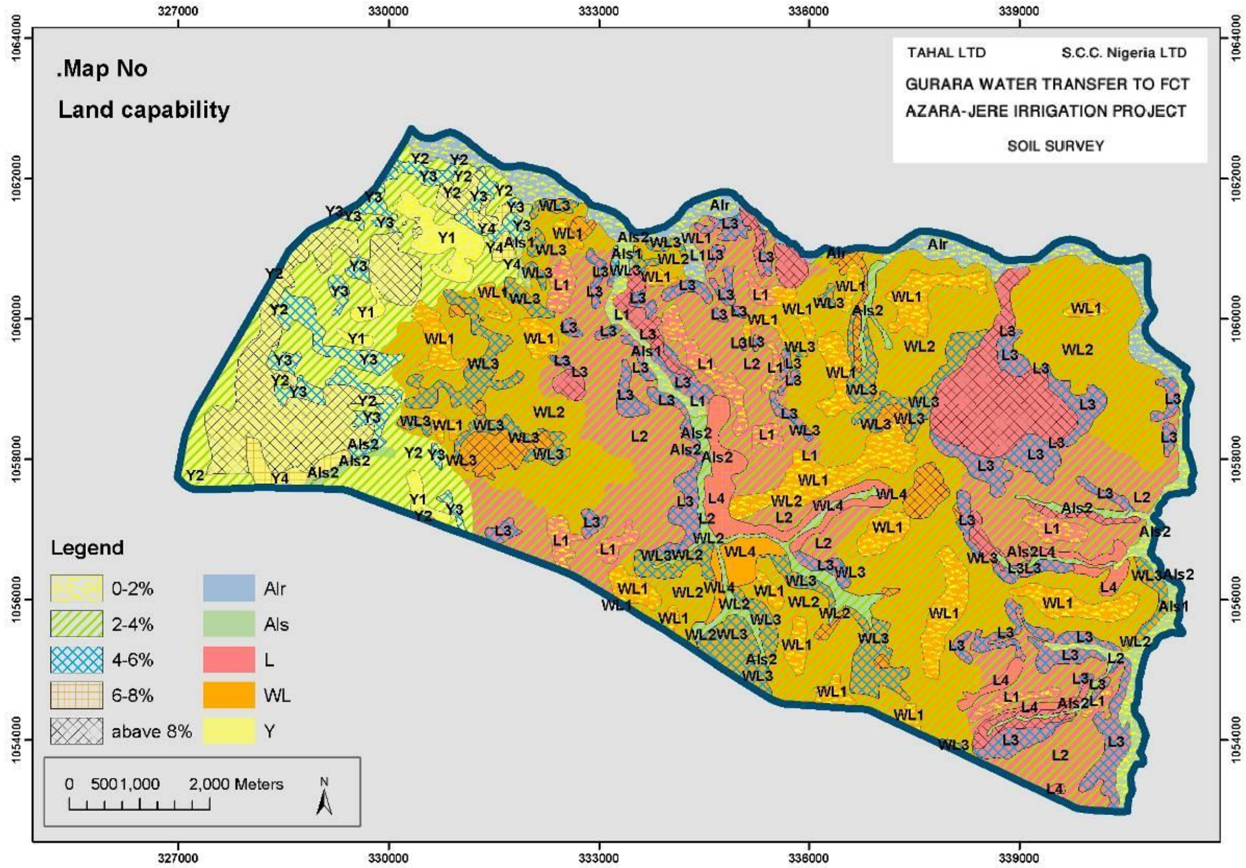
Subclasses are groups of capability units which have the same major conservation problem such as:

E - Erosion and runoff.

D - Excess water.

C – Soil and Root-Zone limitations.

The capability subclass provides information as to the kind of conservation problem or limitations involved. The class and subclass together provide the map user information about both the degree of limitation and kind of problem involved for broad program planning, conservation need studies, and similar purposes.



6. Land classification for irrigation criteria

The soil characteristics and land classifications for irrigation adapted in this study are based on the USBR manual Vol 5."Irrigation Land Use" and "Land Classification for Irrigation"

Land Classification for Irrigation, establishes the extent and degree of suitability of land to sustained irrigation, according to its characteristics and limitations.

This system distinguishes and classifies the land for irrigation purposes according to three basic factors:

Soil, Topography and Drainage.

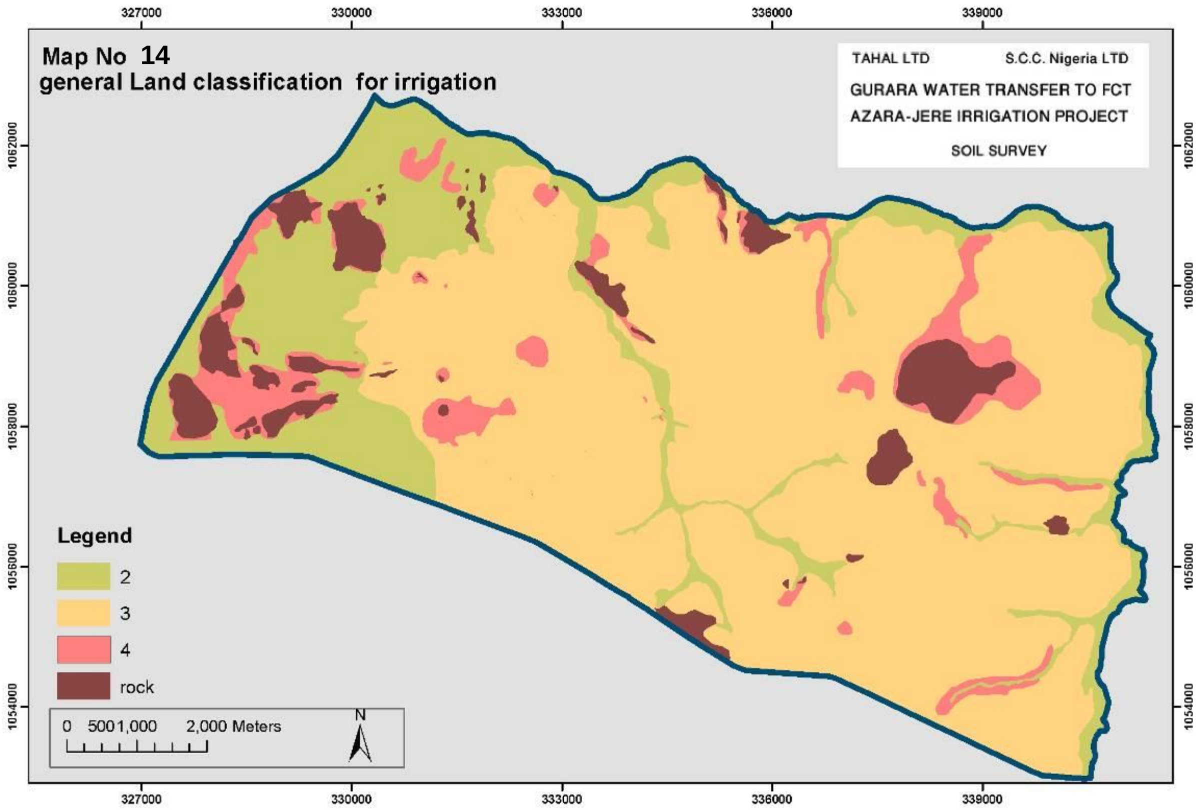
The system also takes economic factors such as present land use, land productivity, land development cost, water requirement and drainage into consideration.

This system of land classification for irrigation groups the soils into 6 basic land classes, decreasing in suitability for irrigation from class 1 to class 6 according to the severity of the limitations.

Those 6 classes are further divided into subclasses according to the degree of deficiencies of the soil – s, topography – t, and drainage – d.

The interaction of these deficiencies or their cumulative effect may justify placing the particular land in a lower class.

6.1 Land classification for irrigation criteria in the Gurara project area



In the Gurara project the soils where classified into four major groups by their suitability for irrigation and by agricultural adequacy.

Primary division

Class 2: Arable, Moderately suitable for irrigation, adaptable to a narrower range of crops. Intermediate payment capacity.

Class 3: Arable, Marginally suitable for irrigation, deficiencies in soil, topography or drainage properties. Adequate payment capacity.

Class 4: Limited Arable/ Special Use. Suitable for very limited range of crops. Range in payment capacity

Class 6: Non arable land.

These classes are further divided into subclasses:

Secondary division

Class 2d: Alluvial soils of the main Gurara River and the secondary rivers in the projects area. This subclass contains alluvial fertile soils with drainage limitations (d). The soils in this subclass are seasonally flooded and may contain high ground water even in the dry season. These soils are fully cultivated.

Class 2s: Yellow brown soils with compaction limitations. These soil are located in the western part of the project. The soil has generally light, sandy loam – loamy sand, on the upper horizon and medium, sandy clay loam – loam – clay loam, underneath it. These soils have an initial and light development of a Laterite horizon, or total absence of one. The soil in this subclass is almost fully cultivated due to the comfortable structure and good drainage.

Class 2st: Yellow brown soils with compaction and topography limitations. The soil has generally light, sandy loam – loamy sand, on the upper horizon and medium, sandy clay loam – loam – clay loam, underneath it. These soils have an initial and light development of a Laterite horizon, or total absence of one.

Class 3s: Weathered Laterite soils with compaction limitations. Light brown to brown reddish soils, light to medium in the topsoil's upper horizon Sandy Loam -Sandy Clay Loam, and medium texture in the subsoil's lower horizon Sandy Clay Loam - Clay Loam.

Class 3st: Weathered Laterite soils with compaction and topography limitations. Light brown to brown reddish soils, light to medium in the topsoil's upper horizon Sandy Loam -Sandy Clay Loam, and medium in the subsoil's lower horizon Sandy Clay Loam - Clay Loam. The slope of these soils is 6%-8%.

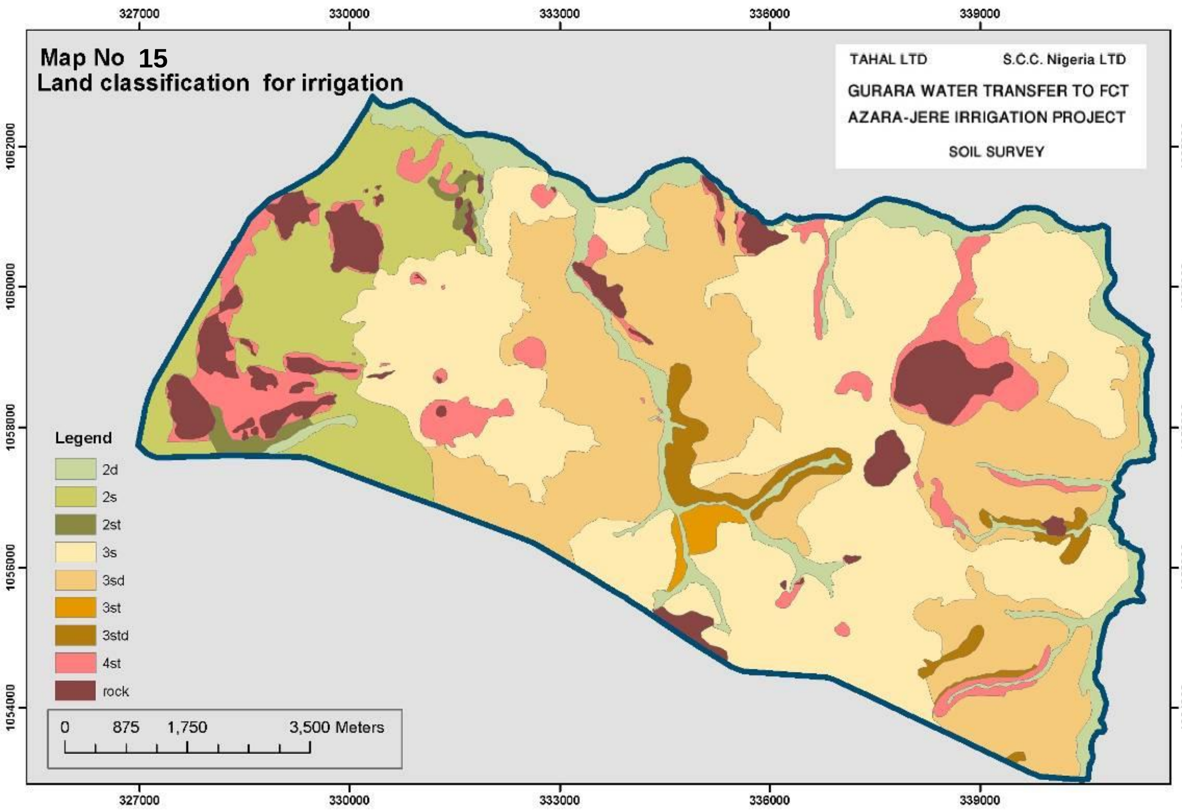
Class 3sd: Red Laterite soils with compaction and drainage limitations. Brown reddish soils, light to medium in the topsoil's upper horizon Sandy Loam - Sandy clay loam - Clay loam, and medium to heavy in the lower subsoil's horizon Sandy Clay Loam - Clay Loam - Clay.
The soil is characterized by the development of a hard laterite horizon.

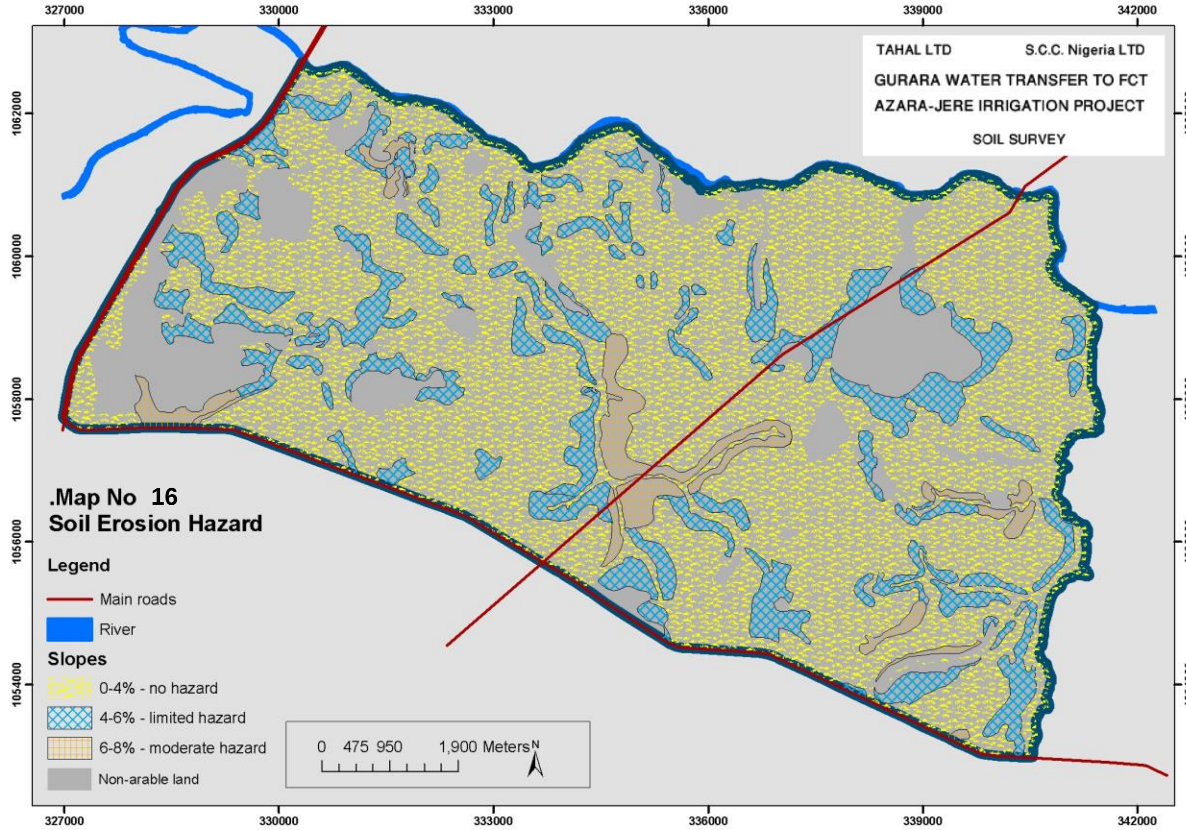
Class 3std: Red Laterite soils with compaction, topography and drainage limitations. Brown reddish soils, light to medium texture in the topsoil's upper horizon Sandy

Loam - Sandy clay loam - Clay loam, and medium to heavy in the lower subsoil's horizon Sandy Clay Loam - Clay Loam - Clay. The slope of these soils is 6%-8%.
The soil is characterized by the development of a hard laterite horizon.

Class 4st: Soil with topography limitations. This sub class contains different soils, all with significant topography limitation. The slope of these soils is 8%-10%. These soils are often in the boundaries of rock exposures.

Class 6: Non arable land. This subclass contains exposed rocks, high slopes of above 10%, and large settlements.





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GURARA WATER TRANSFER TO FCT
AZARA-JERE IRRIGATION PROJECT
SOIL SURVEY
.Map No 16
Soil Erosion Hazard
Legend
Main roads
River
Slopes
0-4% - no hazard
4-6% - limited hazard
6-8% - moderate hazard
Non-arable land
0 475 950 1,900 Meters
N

Annexes

Annex 1

Soil Analysis Methods

1. SP - Saturation Percentage
   Measurement of the percentage of humidity in soil paste.
   Regents: None.
   Equipment: Analytical scale, Oven.

2. Ec - Electrical conductivity
   Method: Measurement of the conductivity level in soil extract (water).
   Regents: None.
   Equipment: Electrical conductivity meter.

3. pH - Acidity/Basicity
   Method: Measurement of the pH level in soil extract (water).
   Regents: None.
   Equipment: pH meter.

4. NO_3 - Nitrate
   Method: Measurement of the Nitrate level in soil extract (water).
   Regents: None.
   Equipment: Ion selective Nitrate electrode.

5. P - Phosphorus
   Method: Olsen. Measurement of the phosphorus level in soil.
   Regents: $NaHCO_3$, H_2SO_4, Merck reagents: PO_4-1, PO_4-2.
   Equipment: Spectro-Photometer.

6. K - Potassium
   Method: Measurement of the Potassium level in soil.
   Regents: $CaCl_2$.
   Equipment: Flame-Photometer.

7. Ca+Mg - Calcium and Magnesium
   Method: Measurement of the Ca+Mg level in soil extract (water).
   Regents: Merck reagents: H-1K, H-2K.
   Equipment: Spectro-Photometer.

8. Na - Sodium
   Method: Measurement of the Sodium level in soil extract (water).
   Regents: None.
   Equipment: Flame-Photometer.

9. Cl - Chloride
   Method: Measurement of the chloride level in soil extract (water).
   Regents: None.
   Equipment: Ion selective chloride electrode.

10. SAR - Sodium Absorption Ratio
    Method: Calculation of Ca+Mg and Sodium levels.
    Regents: None.
    Equipment: None.

11. Soil texture - Sand, Clay and Silt percentage
    Method: Measurement of the Sand, Clay and Silt percentage in soil.
    Regents: $NaPO_3$.
    Equipment: Blender, Hydrometer.

12. Calcite - $CaCo_3$
    Method: Measurement of the $CaCo_3$ level in soil.
    Regents: HCl.
    Equipment: Calci-meter.

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Illustration list

Maps:

Tables:

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Illustration No. 1 Cross Section

Illustration No. 2 A typical profile of Yellow – brown soil, with its characteristic light sandy upper horizon A, descending gradually to horizon B which contains a higher rate of clay.

Illustration No. 3 A typical horizon of lateritic soil found in a slope. Pieces of plintite are exposed and can be seen over the surface.

Illustration No. 4 Weathered lateritic soil

Illustration No. 5 Alluvial soil

Pictures:

Picture No. 1

Rock surfaces are exposed in certain areas, beyond the wide mapped rock surfaces. The rocks appear as rock plates and large chunks. The surrounding soil is deep and is not affected by stoniness.

Picture No. 2

Rock surfaces and large rocks piled along their edges.

Picture No. 3

The Gurara River. Sandy material accumulation on the northern bank.

Picture No. 4

A characteristic view of a tributary flowing to the Gurara River. The tributary's surrounding are usually covered with dense vegetation. Some of the tributaries are cultivated, while water flows in others throughout the year.

Pictures No.5-7

Various settlement forms.

Picture No. 8

Papaya trees are scattered between the agricultural plots.

Picture No. 9

Banana plantations are scattered between the cultivated areas

Picture No. 10

A characteristic view of the Gurara River. Mango and banana trees can be observed on the river banks.

Picture No. 11

A large mango tree on the levee near the river.

Picture No. 12

A watermelon crop.

Picture No. 13

Furrow irrigation near the Gurara River

Picture No.14

A watermelon and cassava field near the banks of the Gurara River raised furrows, irrigated by flooding

Picture No. 15

Pumping water from the Gurara River with a hose, and drawing them to the fields for irrigation purposes.

Picture No. 16

Intensive agriculture in the west of the area

Picture No.17

An agricultural farm in the central part of the area.

Picture No.18

Cultivation plots are burnt, as part of a routine farming method of pruning and burning, in order to prepare the soil for cultivation. At the far end of the area banana trees can be seen.

Picture No. 19

Supervised burning as part of the area's preparation for cultivation.

Picture No. 20

A dense grove in the central part of the area. The appearance of hard laterite stones on the surface can be observed (in the left corner).

Pictures No. 21, 22

A yam crop, the yam is one of the most common crops in the area

Picture No. 23

Millet - a common crop in the project's area.

Pictures No.24

Guinea Comm- a common crop in the project's area

Picture No. 25

Lumps of hard metallic laterite, appear as hard stones tightly pressed to the surface, creating an impermeable cover. This situation is common in steep areas where the laterite is exposed. A close view of the rock allows us to discern between the rock's different shades, as a result of different oxidation and reduction situations.

Picture No. 26

Rounded iron concretions in a characteristic horizon of lateritic soil.

Picture No. 27

Rounded iron concretions in a characteristic horizon of lateritic

Picture No. 28

Iron manganese concretions, in a soil chunk going through a lateritization process

Picture No. 29

Exposed profile of Yellow – brown soil in a typical digging point

Picture No. 30

Exposed profile of Red Laterite soil in a typical digging point

Picture No. 31

Exposed profile of Weathered Laterite soil in a typical digging point

Picture No. 32

An exposed profile of alluvium Gurara River soil in a typical digging point (ground water appear close to soil surface)

Picture No. 33

Exposed profile of alluvium secondary river soil in a typical digging point