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Soil Survey And Land Evaluation Studies Of A Proposed Irrigation Project Site At Ejigbo Dam, Ejigbo, Osun State, Nigeria

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Abstract: *An intensive soil survey and land use evaluation study of a proposed irrigation project site at the Ejigbo Dam in Ejigbo, Osun State, south-west Nigeria, was carried out. The major objective was to identify the soil types to obtain information about their productivity under irrigation. A rigid grid system of survey was adopted. Five soil types were identified on the site along the toposequence from the upper part of the slope to the valley bottom. These are: Plinthic Ustropept; Plinthic Tropustalf; Plinthic Ustropept; Plinthic Tropustalf and Typic Plinthaqualf. A total of about 30.6% of the available 75 hectares of land is a lateritic area due to excavation, construction work (for buildings or road construction). About 22.3% of the land has sandy-loam top soil overlying slightly sticky sandy clay loam with plinthite in the subsoil. Irrigation is possible on these soils because infiltration rates are high enough at the surface. However, the plinthic nature of the subsoil will not allow the use of much water per time as it may result in waterlogging. The native nutrients are not much in concentration and should be boosted over time with fertilizer and/or organic manure application. Crops like yam, cassava, maize, sorghum, upland rice, vegetables like pepper, leaf-vegetables, okra, garden eggs, etc. can be grown on these soils.*

Keywords: *Irrigation, plinthite, dam, soil types.*

I. Introduction

Soil is a very significant factor in crop production. However, it is very heterogenous and this is the cause of differential rates of development and yield on a parcel of land planted to the same type of crop under the same management practices and at the same time. This has been a source of frustration to farmers and researchers in the field of Agriculture. Soil survey minimizes these problems by dividing the landscape into smaller units (mapping units) which are more homogenous within, and more heterogeneous among each other. The mapping units are better managed with less risk and uncertainties than the landscape as a whole, single unit. The Irrigation Project site at Ejigbo Dam, Ejigbo, Osun State, is located within the rain forest zone of south-west Nigeria (Latitude 4^{0}19' E, Longitude 7^{0} 54' N). It is about 75 hectares in size. The characteristics of the soils had not received any attention in terms of actually determining their capability vis-a-vis crop production under irrigation. The objectives of this work therefore are:

1. To conduct a detailed soil survey of the site so as to determine the physico-chemical properties of the soils;
2. To evaluate the suitability of the different soil types for sustainable arable cropping;
3. To evaluate the soil for its suitability for irrigation farming.
4. To suggest management practices that will enhance their productivity under continuous cropping.

II. Materials And Methods

Location

The project area is located in Ejigbo in Osun State of Nigeria, within the rain forest agro-ecological zone of Nigeria. The topographic map and the digital terrain model of the project site are as shown in Figures 1 and 2. The climate of the area is characterized by pronounced wet and dry seasons, moderate temperatures during the wet season and relatively higher temperatures during the dry season. Most arable crops (yam, cassava, vegetables, etc.) are produced in this area throughout the year.

The relative humidity generally rises with increasing rainfall. It is maximum in September and minimum in February/March in the area. The vegetation is characterized by big trees and creepers (the rainforest species). However, the area under study appears to be a secondary forest which has regenerated over a long period of time.

Previous land use

A little portion of the land was under maize and cassava at the time of sampling, while the remaining land was still under natural forestation. A large portion is lateritic due to excavation or other forms of land-moving for various reasons, such as building or other construction work.

Fieldwork

Soil Survey: An existing transect earlier cut by a Land Surveyor served as a base-line for the soil survey. Another transect was cut parallel to this and 100 m away, and another was cut across the two, perpendicular to each transect. A GPS was used to measure the distances while determining the locations at which profiles pits were sited, based on soil physical properties observed.

There were five profile pits from which every identifiable horizon was sampled. Each profile pit measured 1 m x 2 m and up to 1.3 m in depth. The samples were taken to the laboratory for chemical analysis. The observations and recorded characteristics on the field and the chemical characteristics were used to produce a soil map (Figure 3). The horizon characteristics were also described, using the Munsell colour chart where necessary, e. g. for colour. The thickness, texture, structure, consistence (moist and wet), presence of roots, soil faunal activities, accumulations, concretions, ferruginous hardenings, drainage characteristics, mottling, soil moisture state and horizon boundary were all noted.

These observations and notes were made according to the Soil Survey Staff Manual (1992) guidelines for soil profile description. Field provisional classifications were made and these were modified and adopted or changed, as the case may be, after laboratory analysis.

Soil Profile sampling and Laboratory analyses

Soil samples were collected from each horizon of the profiles and the samples were kept in well-labelled plastic containers for subsequent preparation and laboratory analyses.

Soil Permeability/Infiltration

This was determined in-situ by equilibrium infiltration rates. Infiltration of representative soil samples was measured in the field using the double ring infiltrometer method. This method involves the use of two concentric rings (inner- 25 cm diameter ring and outer 55 cm diameter ring) with the outer annular spacing serving as a buffer or guard to ensure the desired vertical in the inner annular space. Both rings were driven into the soil, extending 8 cm below and 22 cm above the soil surface.

Water was applied by ponding under a constant head of 10 cm. Infiltration was continued at each site until equilibrium was attained, usually after 2 – 3 hours.

Chemical analyses

The soil samples brought from the field were air-dried in a room under a ceiling fan for three days. They were sieved with a 2 mm sieve in the laboratory and the fraction greater than 2 mm in diameter was classified as stone/gravel. The samples less than 2mm were used for the physico-chemical analyses, viz: particle size, pH in water and potassium chloride, available phosphorus, exchangeable bases, effective cation exchange capacity (ECEC), exchangeable acidity and the micronutrients. Total nitrogen and organic carbon were determined from the soil sub-samples that were further finely ground to pass through a 0.05 mm sieve. The various methods/procedures used for the analyses are as shown in Table 1.

III. Results And Discussion

Permeability/Infiltration

The results of the soil permeability/infiltration test (Table 2) showed that the soils in the survey area are just fairly permeable. These soils have high initial water intake rates and equilibrium rates in excess of 10 cm/hr. Infiltration is considered to be excessively rapid for Pedon IV where it took less than 2 hours to wet the soil to a depth of 1.5 m. Pedon III is also very highly drained while others have restricted permeability due to their positions on the slope. Pedons I and II are close to a river, hence they have high water tables. Plinthite is prominent in Pedon IV.

All the soils of the project site, except the excavated site for previous construction work, are considered irrigable and drainable with little or no change in irrigation water salt levels. However, it should be noted that infiltration may be adversely affected by reduction in vegetative cover and poor soil management. Sprinkler irrigation is recommended, though this may be expensive.

Soil Classification

The suitability ratings and the area of coverage of the mapping units are as given in Table 3 while the soil textural classes are shown in Table 4. Soil map derived from the survey is shown in Figure 3. Pedons I and

III do not have a clear evidence of any diagnostic horizons; therefore they were classified as Inceptisols. They occur under a temperature regime where the difference between the mean highest and the mean lowest temperature is higher than 5^0C and under an ustic moisture regime. They were therefore classified as Ustropepts. The two pedons are plinthic as is evidenced by the very high gravel contents even on the surfaces. They were therefore classified as Plinthic Ustropept, according to the Soil Survey Staff (1992).

Pedons II, IV and V exhibit argillic horizons in the sub-surfaces as is evidenced by clay budges. This, coupled with the very high base saturations, qualify them as Alfisols and the Ustic moisture regime prevalent in this region qualified them as Ustalfs. Pedons II and IV are less plinthic than pedon V. They are found under a temperature regime where the difference between mean highest and mean lowest temperatures is higher than 5^0C. They were therefore classified as Plinthic Tropustalf (Soil Survey Staff, 1992). Pedon V is exceptionally plinthic, hence it was classified as Plinthustalf and as Typic Plinthaqualf (Soil Survey Staff, 1992) because it met all the definitions of the central concept.

Pedons I and III are very suitable for irrigation project (Table 3) but may be prone to erosion, hence erosion control practices such as cover cropping is recommended. Pedons II and IV are marginally suitable. The presence of sandy surfaces over plinthite could make them prone to erosion and could constitute impedance to root penetration. Both areas should remain under constant vegetative cover. Pedon V is also marginally suitable. The area is highly plinthic and is likely to constitute impedance to roots, nutrient and water penetration as well as to mechanical operations.

3. Soil Physico-chemical Characterization

The results of the physico-chemical characteristics of the horizons were as given in Tables 4 – 7. The soils are generally sandy clay loams (Table 4) and anthropogenic (human activities has a marked effect on their properties). The profiles are well developed and exceeded 130 cm in some cases. Irrigation is quite possible on tese soils, but it will require technical expertise and proper monitoring because there are a lot of stones and gravels, and plinthic horizons very close to the surface. Water application rate must be slow and the quantity should not be much per time to avoid excessive run-off that can pose serious erosion problems and nutrient leaching. The use of organic manures is highly recommended, rather than inorganic fertilizer, as this will result in soil textural and structural improvement, better water infiltration, general soil water movement and reduced risk of soil and water pollution from inorganic fertilizer use.

It appears as if some part of the land had been moved before for some reasons and filled with laterite, as if for construction purposes. Only towards the river is the soil a little less lateritic. This area is not recommended for irrigation as infiltration of water into the soil could pose a serious problem.

(a) <u>Soil reaction (pH)</u>

The soil reaction showed that the soils are moderately acidic to almost neutral, ranging from 5.6-7.0 in water (H_2O) and 4.7-6.0 in Potassium Chloride (KCl) (Table 5). The exchange acidity is also low (0.00-0.08) in all the samples.

The soils are very good for most arable, staple crops of the host community. Plant nutrients would be available to crops at these pH values. The detrimental effects of soil acidity are not envisaged in the near future in these soils.

(b) Plant Nutrients

(i) Nitrogen, Available Phosphorus and Organic Carbon

Most of these are concentrated at the top-soils in all the profiles (Table 6). This is the normal feature of most mineral soils and these soils are no exception. However, they are low in concentration, below the levels required for the production of most arable crops, i.e. the critical levels, Agboola and Ayodele (1987), Metson (1961).

The use of some form of organic manure is advised/ inevitable for good crop production on these soils. This is to supplement the native organic matter, nitrogen and available phosphorus, all of which have high and positive correlations with soil organic matter (Agboola and Corey, 1976). The use of organic manure is recommended also because organic manure improves soil structure and texture, with the attendant benefits of improved aeration, permeability, water-holding capacity, etc., and acts as a slow-release fertilizer. It also enhances cation exchange reactions in soils. The gravelly nature of these soils will require the cohesive ingredients in organic manures to improve the soil aggregation and enhance sustainable crop productivity.

(ii) Exchangeable cations (Ca, Mg, K, Na and ECEC)

These are all moderate in quantity and within ranges that are adequate for arable crop production (Table 5), FAO (1979), Agboola and Obigbesan (1974), Agboola and Corey (1973), Agboola and Ayodele (1987).

(iii) Micronutrients (Zn, Cu, Mn and Fe)

All the micronutrients determined are concentrated in the topsoil of each horizon (Table 7). However, the Mn and Fe contents are very high, especially in Profiles I, II, and III, and may become toxic to plants, based on the levels that plants can tolerate (Sillampa 1972; Adeoye and Agboola, 1985; Sobulo and Osiname, 1981).

IV. Conclusion And Recommendations

Five soil types were identified on the site along the toposequence studied, from the valley bottom to the upper slope. These are: Plinthic Ustropept, Plinthic Tropustalf, Plinthic Ustropept, Plinthic Tropustalf and Typic Plinthaqualf. Two of the pedons (I and III) are very suitable for irrigation project but may be prone to erosion hence, erosion control practices such as planting of cover crops is recommended. The other pedons (II, IV and V) are marginally suitable. The presence of sandy surfaces over plinthite could make them prone to erosion and could constitute impedance to root penetration. The area is highly plinthic which could constitute impedance to root, nutrient and water penetration as well as to mechanical operations. Both areas should remain under constant vegetative cover.

Irrigation is quite possible on these soils and infiltration rates are high enough because of the sandy nature of the topsoils. However, the plinthic nature of the subsoil will not allow the use of much water per time: it may result in waterlogging. The use of cover crops or ensuring a good vegetative cover at all times will make these soils more productive and crop production sustainable.

The native nutrients are not much in concentration and should be boosted over time with organic manure application. However, Manganese and iron could be toxic to plants as they are too high for arable crop production. All the usual crops grown in this area (e.g. yam, cassava, maize, sorghum, upland rice, vegetables (pepper, leaf-vegetables, okra, garden eggs, etc.) can be grown on these soils.

Table 1: Methods for physico-chemical analyses of the soil samples

Soil Property	Method of Determination	Reference
Soil texture	Consecutive hydrometer readings at 40 seconds and 3 hrs of soil-sodium hexametaphosphate suspension.	IITA, 1979
pH (water)	Soil-water mixture at ratio 1:1 (in g:mL) equilibrated for 30 minutes and allowed to stand for 1 hr. pH of suspension measured with pH meter.	IITA, 1979
pH (KCl)	Soil-solution mixture at ratio 1:1 (in g:mL) equilibrated for 30 minutes and allowed to stand for 1 hr. pH of suspension measured with pH meter.	IITA, 1979
Total N	Micro-Kjeldahl digestion of the mixture of 1 g soil (<0.5-mm), Kjeldahl catalyst, and 6-mL conc. sulphuric acid at 370^{o}C for 2 hrs; basification of digest with 10-N sodium hydroxide solution and steam distillation; titration of distillate with 0.02-N hydrochloric acid solution.	IITA, 1979
Organic carbon	Improved Walkey-Black digestion of the mixture of 1 g soil (<0.5-mm), 10-mL of 1-N dichromate solution, and 6-mL conc. sulphuric acid at 130^{o}C for 30 minutes; titration of digest with 0.5-N iron (II) sulphate solution.	IITA, 1979; Heanes, 1984
Avail- P	Equilibration of the mixture of 2-mm sieved soil and Bray-I solution at soil-to-extractant ratio 1:7 (in g:mL) for 5 minutes; colour developed on 1-mL filtered soil extract using Murphy-Riley method; and absorbance measured at 882-□ m wavelength on electrophotometer.	Bray and Kurtz, 1945
Exch. Cations: Ca^{2+}, Mg^{2+}, K^{+}, & Na^{+}	Equilibration of the mixture of 2-mm sieved soil and neutral ammonium acetate solution at soil-to-extractant ratio 1:10 for 2 hrs; concentration measurement of filtered extract on AAS and flame photometer.	IITA, 1979
Exch. Acidity (Al + H)	Equilibration of the mixture of 2-mm sieved soil and 1-N KCl solution at soil-to-extractant ratio 1:10 (in g:mL) for 1 hr; titration of 25-mL extract with 0.05-N NaOH solution.	Anderson and Ingram, 1993; IITA, 1979
Available Fe, Mn, Cu, & Zn	Equilibration of the mixture of 2-mm sieved soil and 0.1-N HCl solution at soil-to-extractant ratio 1:10 (in g:mL) for 45 minutes; concentration measurement of filtered extract on AAS.	IITA, 1979

Table 2: Infiltration classes of the soils of the Ejigbo Dam Site

Pedons	Rate (cm/hr)	Infiltration class
I	15.0	Rapid
II	19.2	Rapid
III	45.4	Very rapid
IV	71.0	Very rapid
V	21.7	Rapid

Table 3: Suitability ratings and area of coverage of the mapping units

Mapping Unit	Name	Area of Coverage (%)	Suitability Rating	Recommendation
I	Plinthic Ustropept	20.0	S_2e	This is very suitable for Irrigation project but may be prone to erosion hence erosion control practices such as cover cropping is recommended.
II	Plinthic Tropustalf	11.6	S_3e	Marginally suitable for irrigation. Sandy surfaces over plinthite, hence prone to erosion and impedance to root penetration. Should also remain under cover.
III	Plinthic Ustropept	14.7	S_2e	Same as I (above)
IV	Plinthic Tropustalf	12.4	S_3e	Same as II (above)
V	Typic Plinthaqualf	10.7	S_3e	Marginally suitable, highly plinthic, impedance to root, nutrient and water penetration as well as to mechanical operations. Should be left for grazing as natural or improved pasture.
VI	Lateritic area	30.6		Unsuitable

Table 4: Soil texture, stone/gravel concentration and textural classification of the soil horizons

		Particle size				
Profile	**Depth (cm)**	**%Sand**	**%Silt**	**%Clay**	**%Stone/ Gravel**	***Textural Class**
I	**0-8**	**65**	**13**	**22**	**17.9**	**s/c/loam**
	8-20	69	7	24	22.5	s/c/loam
	20-45	69	14	17	33.7	s/loam
	45-110	65	11	24	20.9	s/c/loam
	110-130	71	11	18	60.7	s/loam
II	**0-20**	**69**	**11**	**20**	**58.0**	**s/loam**
	20-35	65	11	24	24.0	s/c/loam
	35-60	65	11	24	47.1	s/c/loam
	60-90	71	7	36	20.8	s/clay
	90-135	65	12	23	53.3	s/c/loam
III	**0-5**	**63**	**7**	**30**	**32.9**	**s/c/loam**
	5-10	47	17	36	31.8	s/clay
	10-75	59	11	30	22.6	s/c/loam
	75-130	53	11	36	21.5	s/clay
IV	**0-22**	**63**	**11**	**26**	**18.3**	**s/c/loam**
	22-50	55	7	38	13.0	s/clay
	50-80	37	7	56	53.7	Clay
	80-120	69	11	20	19.6	s/loam
V	**0-8**	**77**	**7**	**16**	**13.0**	**s/loam**
	8-40	71	7	22	71.5	s/c/loam
	40-75	57	9	34	38.7	s/c/loam
	75-120	49	13	38	25.1	s/clay

***s = sandy, c = clay**

Table 5: Chemical properties of the soils of the Ejigbo Dam Site

				-------------------------------cmol+/kg------------------------------					
		pH (1:1)*		Exchangeable cation**				Exch Acidity	ECEC***
Profile Designation	**Depth (cm)**	**Water**	**KCl**	**Ca**	**Mg**	**K**	**Na**		
I	**0-8**	**6.9**	**6.0**	**5.04**	**1.11**	**0.29**	**0.09**	**0.08**	**6.61**
	8-20	6.7	5.6	2.24	0.50	0.18	0.09	0.00	3.01
	20-45	6.6	5.5	2.31	0.49	0.29	0.09	0.08	3.26
	45-110	6.9	5.7	3.50	0.24	0.13	0.08	0.08	4.05
	110-130	7.0	5.7	2.28	0.27	0.19	0.09	0.08	2.90
II	**0-20**	**6.6**	**5.6**	**3.78**	**0.89**	**0.28**	**0.09**	**0.08**	**5.12**
	20-35	6.4	5.2	2.17	0.35	0.21	0.08	0.17	2.98
	35-60	6.7	5.5	2.99	0.37	0.19	0.08	0.17	3.80
	60-90	6.7	5.4	2.10	0.23	0.18	0.09	0.08	2.69
	90-135	6.8	5.5	2.07	0.58	0.28	0.09	0.00	3.02
III	**0-5**	**6.4**	**5.5**	**5.00**	**1.52**	**0.53**	**0.09**	**0.08**	**7.23**
	5-10	5.9	4.9	2.41	0.83	0.33	0.09	0.08	3.74
	10-75	6.6	5.5	2.38	0.55	0.19	0.08	0.00	3.20
	75-130	6.6	5.7	1.63	0.55	0.17	0.09	0.08	2.52

IV	**0-22**	**7.0**	**6.0**	**3.33**	**0.70**	**0.60**	**0.08**	**0.00**	**4.72**
	22-50	6.2	5.4	1.87	0.37	0.18	0.05	0.08	2.55
	50-80	6.6	5.9	2.07	0.56	0.29	0.08	0.08	3.09
	80-120	6.5	6.0	1.93	0.76	0.23	0.09	0.00	3.02
V	**0-8**	**6.6**	**5.5**	**1.39**	**0.46**	**0.29**	**0.09**	**0.08**	**2.31**
	8-40	6.0	4.7	0.74	0.31	0.34	0.09	0.08	1.55
	40-75	5.6	4.7	0.94	0.38	0.19	0.09	0.08	1.68
	75-120	5.8	5.3	1.15	0.41	0.20	0.09	0.08	1.93

*** pH= pH in KCl solution, 1:1 Soil:solution ratio**
****Ca = Calcium, K = Potassium, Mg = Magnesium, Na = Sodium**
*****ECEC = Effective Cation Exchange Capacity**

Table 6: Total nitrogen, organic carbon, C/N and available P of the Ejigbo Dam Site soils

Profile Designation	Depth (cm)	%N*	%C*	C:N Ratio	P* (mg/kg)
I	**0-8**	**2.10**	**0.201**	**10.4**	**1.60**
	8-20	0.75	0.076	9.9	0.54
	20-45	0.75	0.074	10.1	0.41
	45-110	1.01	0.100	10.1	1.07
	110-130	0.68	0.066	10.2	1.18
II	**0-20**	**1.47**	**0.145**	**10.2**	**1.63**
	20-35	0.70	0.067	10.4	0.59
	35-60	0.72	0.070	10.2	0.50
	60-90	0.68	0.068	10.1	0.96
	90-135	0.59	0.058	10.1	0.35
III	**0-5**	**2.52**	**0.251**	**10.0**	**1.34**
	5-10	1.22	0.123	9.9	0.66
	10-75	0.79	0.080	9.9	0.37
	75-130	0.37	0.034	10.9	0.17
IV	**0-22**	**1.11**	**0.110**	**10.1**	**2.23**
	22-50	0.45	0.044	10.2	0.33
	50-80	0.62	0.060	10.3	0.27
	80-120	0.62	0.061	10.2	0.09
V	**0-8**	**0.89**	**0.087**	**10.2**	**1.42**
	8-40	0.45	0.045	9.9	0.62
	40-75	0.45	0.044	10.2	0.21
	75-120	0.42	0.041	10.2	0.07

***C =Organic Carbon, N = Total Nitrogen, P = Phosphorus**

Table 7: Micronutrient content of the soils of Ejigbo Dam Site

		Micronutrient (mg/kg soil)*			
Profile Designation	Depth (cm)	Zn	Cu	Mn	Fe
I	**0-8**	**9.33**	**5.15**	**139.15**	**126.39**
	8-20	1.89	4.28	132.43	127.74
	20-45	1.89	3.41	140.41	79.71
	45-110	2.67	3.41	139.15	164.27
	110-130	2.28	8.64	105.98	89.18
II	**0-20**	**5.81**	**6.03**	**120.26**	**123.01**
	20-35	2.28	7.77	135.37	123.68
	35-60	2.67	8.64	150.06	158.19
	60-90	2.28	5.15	144.39	148.04
	90-135	1.50	6.03	155.52	64.15
III	**0-5**	**58.25**	**23.48**	**128.02**	**137.89**
	5-10	24.20	9.52	100.74	117.60
	10-75	2.28	6.90	145.86	133.15
	75-130	1.50	3.41	139.36	100.01
IV	**0-22**	**6.59**	**8.64**	**188.68**	**127.74**
	22-50	1.89	5.15	167.48	97.98
	50-80	1.11	6.03	90.03	68.89
	80-120	1.50	5.15	67.36	58.74
V	**0-8**	**3.46**	**1.66**	**96.12**	**83.09**
	8-40	1.50	1.66	76.39	77.68
	40-75	0.72	1.66	31.26	48.59
	75-120	1.50	1.66	13.21	37.09

*** Zn = Zinc, Cu = Copper, Mn = Manganese, Fe = Iron**

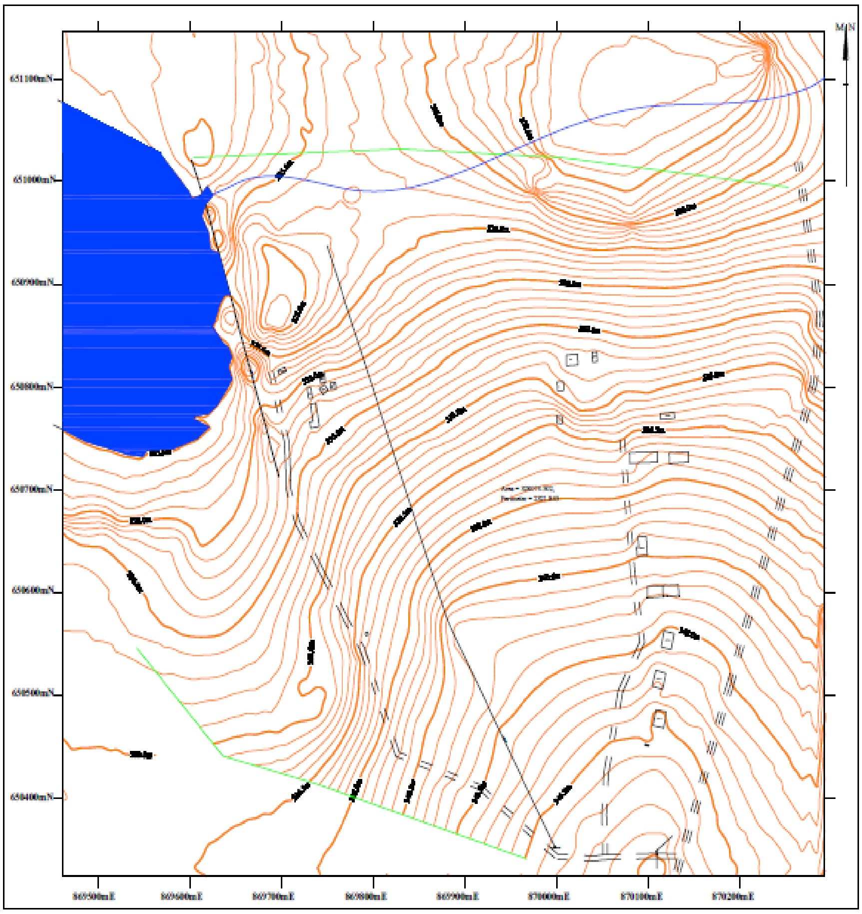

Figure 1: Topographic map of Ejigbo Dam Site (source: OLASAM Nig. Ltd., Nov. 2012, Personal Communication).

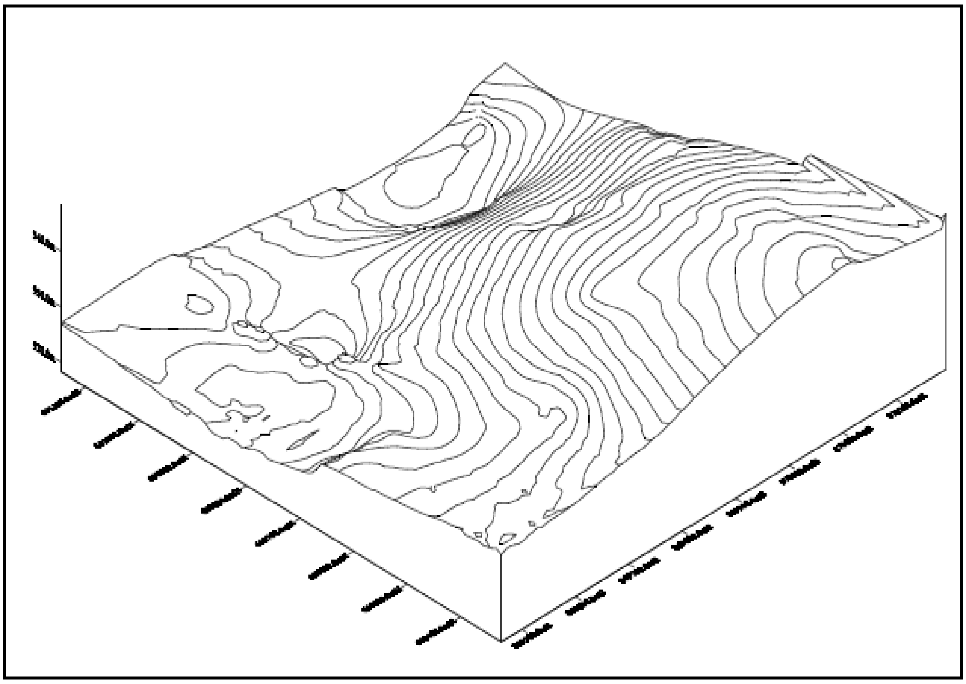

Figure 2: Digital terrain model of Ejigbo Dam Site (source: OLASAM Nig. Ltd., Nov. 2012, Personal Communication).

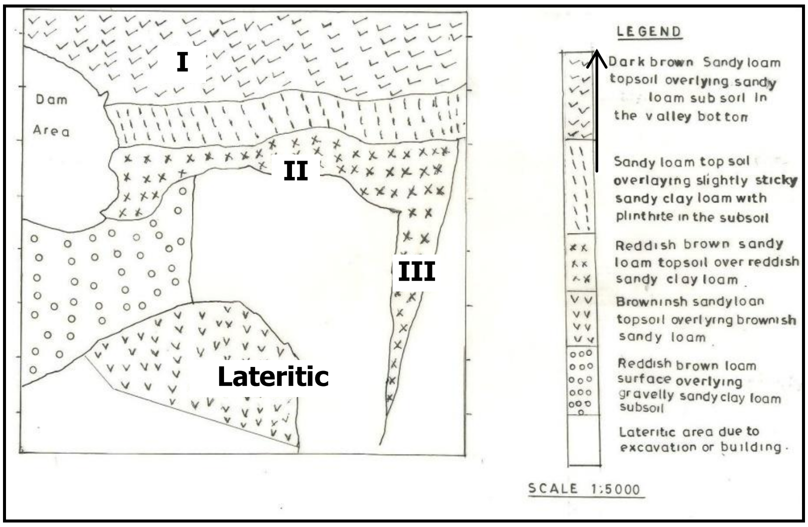

Figure 3: Soil Map of Ejigbo Irrigation Project Site

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