SUBSURFACE WATER QUALITY FROM SAND POINT OF IRRIGATION AND LIVESTOCK-A CASE STUDY OF OYO NORTH AGRICULTURAL DEPARTMENT PROJECT SOUTH WEST NIGERIA

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ABSTRACT

Water quality is one of the basic parameters in agricultural development in any nation for sustainable growth. Subsurface water quality is always present a major challenge considering the fact that there are a lot of pollution associated with its sources. The study was undertaken in Shaki Southwestern Nigeria to assess the current irrigation practice and also to evaluate through a selected but strategic sampling points in the study area the subsurface water quality for irrigated agriculture. Auger sampling - Screw auger was driven into the soil to a depth of 15cm to collect soil samples in the field. Field studies were conducted at the Oyo North Agricultural Development Project, Shaki Sourth Western Nigeria to evaluate the quality of subsurface water resources in relation to irrigation and livestock usage. Based on data from 22 wells, 15 soil samples, seasonal consumption of water for 10 major crops and extensive hydrological analysis of data collated it was established that alkalinity and sodium hazards are low, hence the ground water of the study area is suitable for irrigation. Excessive boron level might restrict the usage of the ground water for certain crops. Maximum values of ECw and SAR is 2.8mmoh/cm and 3.4 respectively. Alkalinity and salinity hazards are low (fit for irrigation). All the water in the study area falls under the classes of $C_1 – S_1$ to $C_4 – S_4$. ECw, TDS, TH values are 8mmoh/cm, 133ppm and 10.10ppm respectively. Concentration of boron in 2/3 of the study area is higher than permissible limit for irrigation. Available water is $31x10^3$ML while irrigation water requirement is $31.4x10^3$ML. About 10,000 HA can be brought under irrigation. Out of the samples of water analyzed 45% exceeded the level of boron stipulated for livestock drinking water.

Keywords: Water, Irrigation, Crop, Subsurface, Quality

1 INTRODUCTION

Water is indispensable for domestic and agricultural activities; with the growing rate of population increase in Nigeria it is becoming difficult to meet the food requirement of the populace. The production of crops along the seasonal rainfall pattern is not helping the situation either. The variability of rainfall, however involves a high risk, particularly in cultivation of second season crop. The risk could however be minimized through careful and well-coordinated development of groundwater source to supplement the rainfall for a second season crop, particularly in the humid tropics with bimodal rainfall [1]. According to food and agricultural organization projections [2]. Irrigated land in Nigeria is expected to reach million hectares by 1990. The figure is expected to increase steadily in the years ahead. The ever-increasing projected irrigated land is supposed to be linked with availability of ground water sources. Before the inventory of groundwater sources of the notable valleys of Sokoto, Kano, Hadeja and Borno province, not much of Nigeria's groundwater potential was known [3, 4] The study however, provides an insight as to the availability of ground water for agricultural development. Shallow groundwater has been noticed in Nigeria at variable yields in fracture and weathered upper strata of the crystalline precambuim shields which covers half of West Africa [4, 5]. In the sedimentary rock formation, abundant water in artesian condition are also available, numerous open wells have been sunk within the formation for water supply and have proved satisfactory [6, 7, 8]. The response of farmers in Bauchi and Kano State of Nigeria to tube well under the National Fadama Development Program (NFDP) for wheat production also attests to the importance of groundwater in food production, [9]. Water quality is one of the basic parameters in agricultural development in any nation for sustainable growth. Subsurface water quality is always present a major challenge considering the fact that there are a lot of pollution associated with its sources. The study is thus undertaken in Shaki Southwestern Nigeria to assess the current irrigation practice and also to evaluate through a selected but strategic sampling points in the study area, the subsurface water quality for irrigated agricultural practices for sustainable farming.

2 MATERIALS AND METHODS

2.1 Study Area

A working arrangement was sought with the authority of the project area (ONADEP). Prior to field investigation and data collection a reconnaissance survey of the project site was undertaken. This was followed with data collection on crop yields, hydrogeology, location of wells, boreholes and extensive soil survey. Irrigation water requirements of major crops grown in the study area were also computed using [10]. The hydrogeological data collected were further subjected to statistical analysis. All data were subsequently analyzed to evaluate the quality and potential of subsurface water for irrigation in the project area.

2.2 Survey of wells and Boreholes

Data on wells and boreholes yields, depth and static water level were collected after which physical inspection of the various location were undertaken. Hydrological data were also collected and careful study of the lithology and description of the rock formation of the study area was carried out using previous studies as a guide [7, 11]. From personal communication with few experience staff of the project area, the water table level is expected to fluctuate by approximately 0.6m and 2m respectively during the wet and dry seasons.

2.3 Crop water requirement

Although field irrigation is not currently undertaken, rainfall crop yield data were collected and compared with standard yield records. Monthly and seasonally consumptive use of major crops in the study area was computed. Effective rainfall was estimated from climatological data and irrigation water requirement computed [12, 13, 14, 15].

2.4 Water Sampling and Analysis

Wells at approximately 3-5km intervals were selected for the purpose of this study. Samples of groundwater were collected after hand pump equipped wells have been operated for thirty minutes. All the water sources come from wells sunk by ONADEP for drinking purpose since no irrigation project is currently being undertaken in the project area. Plastic bottles were thus filled, securely tapered, labeled and transferred to the laboratory for physiochemical analysis. Necessary precaution for conducting water quality tests as prescribed by [16, 17, 18, 19, 20] were followed. The samples were tested for the following parameters; pH, Electric Conductivity (EC_w), Total dissolved solid (TDS), CO_3, HCO_3 Chlorine, Sulphate, Ca^{2+}, Mg^{2+}, Na^+, Boron and sodium adsorption ratio (SAR) which was calculated using the equation 1.

$$\text{SAR adj} = \frac{Na+}{\sqrt{(Ca+Mg)/2}}[1 + (8.4 - \text{pH}) \tag{1}$$

Where TH is Total Hardness.

2.5 Soil Sampling and Analysis

Soil samples in the 0-15 cm profile were collected and analyzed for particle size distribution, bulk density and water retention capacity for the 0-6cm profile. The soils were closely examined using "soils of the western state Savannah (Nigeria)" Volume II, [21, 22, 23]. A total of 15 soil samples were taken with the aid of soil auger and core sampler. The procedures briefly outlined below: Auger sampling - Screw auger was driven into the soil to a depth of 15cm. The auger was gradually and gently withdrawn avoiding any soil droplet. Sampled soil was placed in a polythene bag, labeled and securely tied up for transportation. Core sampling - Core sample 40mm internal diameter was gently driven into the soil using a hammer. The core was scooped out and the end trimmed with a knife. Permeability, of Soil sample were determined using constant head parameter [24, 25] and Bulk density also determined from relatively undisturbed soil sample collected in a 40mm internal diameter core for the determination of bulk density using gravimetric method.

3 RESULTS AND DISCUSSION

3.1 Irrigation Water Need and Potentials

The quantity of water available from subsurface sources as computed is approximately 36 x 10^3 ML per annum, Table 1.

Table 1. Irrigation Land and Subsurface Water Potential

Location	Area (ha)	Subsurface water Potential X103ML
Kishi-Soro-Igboho	3,000	10.8
Garuba-Igbeti-Oguniyi	2,500	9
Itasa-Ijii-Iganna	1,500	5.4
Ago-Are-Sepeteri	3,000	10
	∑10,000	∑36

The seasonal irrigation water requirement (mm) for the major crops grown in the study area are outlined in Table 2. Gross crop water requirement for 10 major crops grown amounts to 3142mm. It is assumed that the irrigable area of ONADEP is close to 10,000 ha. Based on the area, the seasonal irrigation water requirement on volume basis is estimated at 31.42 X 10^6ML. It thus appears that the estimated subsurface water resources (36 X 10^3ML) is capable of only satisfying roughly 12% of irrigation water requirement in the area. These figures are however based on rough estimates. To be able to meet the water requirement of crops grown outside the normal rainfall periods, this analysis has shown that: good water management and irrigation of a few selected economic crops is the only way to justify and expect good returns from an irrigation scheme in the study area. It is clear that surface and subsurface water deficiencies are capable of restricting and probably lowering agricultural activity and production in the study area respectively. Therefore, both surface and subsurface sources will have to be utilized conjunctively. Most of the irrigable areas are found in the basins of the rivers that drain the study area. Relatively flat lands, which are suitable for irrigation, were also sited around.

Table 2. Seasonal Irrigation water requirement of major crops within ONADEP

Crop	Length of growing season (Month)	Evapo-Transpiration ET (mm)	Seasonal consumptive use coefficient K.	Crop consumptive use (mm) KxET	Effective rainfall (mm)	Seasonal irrigation requirement (mm)
Cowpea	3	400	0.85	340	123	217
Vegetables	3	400	0.65	260	123	137
Mellon	3	400	0.85	340	123	217
Maize	4	524	0.75	393	123	269
Rice	4	524	1	524	123	401
Soyabean	4	524	0.75	393	124	270
Groundnut	4.5	587	0.8	470	131	338
Sorghum	5	650	0.7	455	139	316
Cotton	5	650	0.7	455	139	316
Pegion pea	5	790	1.1	869	208	661
						∑3142

Table 3. Estimates of domestic, livestock and agricultural water demand in ONADEP area

Sector	Water demand 1h/d	Total yearly requirement x 103ML
Domestic 1	50	13
Cattle (5per f.f)	50	63
Small ruminants (10 per f.f)	10	3
Poultry (3,500.00)	150/1,000	0.5
Irrigation (10,000)	10,000,000/ha	100
		∑179.50

[1]Based on a population of 700,000.

NB. Population figure was obtained from feasibility report of OYSADP, while figures for calculation from [26]. Kishi, Igboho, Itasa and Ijio.

It is possible to bring an estimated 10,000 ha of land in the study area under surface irrigation. This figure would have been higher except for the undulating and rocky nature of parts of the study area. Areas between the boundaries of Kwara State viz. Kishi to Igbetti (along the forest reserves) have slopes of up to 2.4% and are generally considered as being suitable for irrigation [27]. Between Iwere-Ile, Sepeteria and Ago-Are, there is relatively flat and fertile land which is also suitable for irrigation. In general, the land slope of the potentially irrigable areas ranges between 2 - 6%. In Table 4 is detailed physical characteristics of the surface soil in fifteen locations spread across the project area. The soils range from sandy, clay, loam to sandy loam textures based on USDA classification. Apparently, the sandy nature of the top soil will preclude any intensive land leveling. A method of irrigation which will minimize the disturbance of the surface soil as much as possible is required. The variation in soil type, texture and hydraulic conductivity will undoubtedly influence ground water level and storage in the respective locations [28, 29, 30].

Table 4. Some Physical Prosperities of the Surface soil (0 - 15cm)

Sample no.	Location	Particles size distribution Sand	Clay	Silt	Classification (USDA)	Bulk Density (g/cm^3)	Hydraulic Conductivity (cm/hr)
01.	Kishi	58	24	18	Sandy clay loam	1.5	1.42
02.	Ogboro	76	16	8	Sandy clay loam	2.8	1.55
03.	Igboho	54	23	23	Sandy clay loam	1.4	1.17
04.	Igbetti	56	25	14	Sandy clay loam	1.6	0.98
05.	Ago-Are	65	22	4	Sandy clay loam	1.8	1.18
06.	Shaki	81	15	6	Sandy clay loam	1.3	1.65
07.	Irawo-lle	77	19	6	Sandy clay loam	1.7	1.23
08.	Isme-lle	73	19	6	Sandy clay loam	1.2	1.65
09.	Llero	79	15	7	Sandy clay loam	1.7	1.23
10.	Iganna	71	22	7	Sandy clay loam	1.6	0.94
11.	Itasa	81	13	6	Sandy loam	1.2	2.17
12.	Idioko-lle	88	9	3	Sandy loam	1.0	4.78
13.	Ofiki	79	15	6	Sandy loam	1.1	6.96
14.	Oke-Iho	67	3	30	Sandy clay loam	1.9	1.32
15.	Soro	73	22	5	Sandy clay loam	1.8	1.12

3.2 Water Quality for Irrigation and Livestock

The evaluation of water quality is necessary in the planning, design and operation of irrigation systems to ensure that no deleterious salts or compounds occur in the irrigation water. Over twenty (20) wells in the project area have been examined. In addition, extensive physiochemical analysis of twenty-two (22) samples from different locations was carried out. In table 5 is the detailed range and mean values of the parameters tested.

Table 5. Overall Characteristics of Groundwater in ONADEP Area

Parameter	Range	Mean (n = 22)
Conductivity (mmhos/cm)	0.16 -2.80	0.53
Cl^-	36 -152	87.00
HCO_3	117 - 433	203
SO_4^{2-}	0.5 - 2.7	1.4
Total Hardness	3 – 1090	191
Mg^{2+}	0.7 - 9.2	3.3
($Na^+ + K^+$)	10 – 290	37
SAR (Adji)	0.4 - 3.4	1.3
Boron	0.3 - 10.0	3.2
Ph	6.5 – 8	7.2
Total dissolved (solids)	102 – 1330	400

Although the bicarbonate ion is the major detectable anion, its concentration is low (average of 203mg/l). This value is not expected to cause any serious problem with respect to indirect sodium hazard [31, 32, 33, 34]. The range of values of the compounds tested has also enabled the classification [14, 35, 36, 37]. In this classification which in essence assesses the suitability of the water for irrigation, the two most important parameters are the sodium adsorption ratio, SAR and Electrical Conductivity EC_w (see Table 6). Results show that roughly 50% of the samples examined fall under class C2-S1, viz. medium salinity hazard and low sodium hazard. All the samples examined were fit for irrigation for all levels of exchangeable sodium.

Table 6. Classification of wells water based on sodium adsorption ratio (SAR) and electrical conductivity (EC_w). (may be deleted after inserting fig 2a&2b see word KISHI)

Sample No	Location	Sodium adsorption ratio, SAR	Electrical conductivity mmhos/cm	Classification U.S Sal. Lab. (1984)
1	Kishi west	2.60	1.20	C3-S1
2	Adeyo-yin	1.40	0.38	C2-S1
3	Kishi (ONADEP)	0.64	0.33	C2-S1
4	Soro-Igboho	0.98	0.28	C2-S1
5	Igboho	2.70	2.80	C2-S1
6	Garubu	1.80	0.70	C2-S1
7	Igbetti	1.70	0.48	C2-S1
8	Shaki	0.63	0.23	C2-S1
9	Ogboro	1.20	0.68	C2-S1
10	Tede	1.02	0.33	C2-S1
11	Ago-Are	0.43	0.16	C1-S1
12	Aha	3.40	0.98	C2-S1
13	Ago-Amadu	0.43	0.34	C2-S1
14	Irawo-Iho	0.70	0.85	C3-S1
15	Itasa	0.60	0.65	C2-S1
16	Iganna	1.90	1.44	C3-S1
17	Oke-Iho	0.43	0.48	C2-S1
18	Ilero	0.63	0.18	C1-S1
19	Ilua	3.40	0.95	C3-S1
20	Iwere-Ile	0.62	0.45	C2-S1
21	Idiko-Ile	0.99	0.22	C2-S1
22	Isime-Ile	0.75	0.21	C1-S1

Only three (3) out of all the samples (Ago- Are, Ilero and Isime - Ile fall in the class C1-S1, (Table 6). Although a mean electrical conductivity of 0.53mmhos/cm was recorded, three (3) locations namely Igboho, Kishi West and Iganna recorded especially high value of conductivity. Using the data from physio-chemical analysis of well water, sensitive crops can be irrigated in most cases, while crops with moderate salt tolerance can only be cultivated around Irawo-Ille, Aha and Ilua. In these locations leaching may be required coupled with good irrigation water management to achieve good results. About 60% of the water samples fall under C1-S1 and C2-S1. These categories could be utilized without special cultural practices for salinity control. A broad scale difference in the physiochemical characteristic of groundwater in the study area is notable for only one district location, namely, Igboho. Sodium hazard and conductivity measurement reveal that the groundwater is totally unfit for irrigation under ordinary condition and requires highly permeable soil and adequate drainage. Irrigation water must be provided in excess to meet the leaching requirements of salt tolerant crops. Sodium adsorption ration (SAR) was also computed using the data obtained from physiochemical analysis of water samples. This parameter is also useful in assessing suitability of groundwater for irrigation. The minimum and maximum values of calculated SAR were 0.34 and 3.40 respectively. This figure in general implies low sodium (alkalinity) hazards [29, 38]. Total hardness value ranges from 3mg/l to 1090mg/l. General, 60% of the samples tested could be classified as soft to moderately hard water (Table 7). There are no significant differences between pH values. All samples are within the normal range, 6.5 to 8.4. The chloride concentration in a number of locations exceeds 100mg/l. The maximum permissible level of chloride concentration in water meant for irrigation is about 142mg/l [39, 40]. This limit has not been exceeded in all the samples tested. For irrigation water, the maximum limit of total dissolved solid is 4,000ppm [41, 42, 43, 44]. Groundwater concentration of total dissolved solid in the study area ranges from 102mg/l to 1330mg/l. This value does not pose corrosion and encrustation problems. Small amount of boron is essential for plant growth but excessive concentration causes reduction in yield of crops. The formation of the study being a basement complex contains appreciable quantity of boron, (see table5). High levels of boron in the waters of Oke-Iho, Idioko-ille and

Kishi West are established. In 60% of the sample's boron level exceeds the permissible criteria of 2ppm [45, 46, 47].

Table 7. Classification of water samples by total hardness in ONADEP (Replace with PIE Chart)

Total hardness (expressed as CaCO3)	No. of Samples	%
Soft (0 – 60ppm)	7	32
Moderately hard (61-120ppm)	6	27
Hard (121-180ppm)	1	5
Very hard (>180ppm)	8	36

The physio-chemical and bacteriological analysis of wells in the study area was conducted, courtesy of Oyo State Water Corporation. The silica content ranges from 16-40mg/l. This relatively low value will not cause damage to pumps. The level of pollution of wells as indicated by the data obtained is not severe. Nevertheless, well protection is still very necessary especially where they are used to irrigate vegetables. Based on the results from physiochemical analysis, wells in the study area with possible exception of Igboho, Iganna and Kishi west are excellent for livestock. Permissible criterial for TDS in livestock drinking water is 10,000ppm [48, 49]. Values obtained from analysis are not up to half the limit. The use of wells for livestock may however have limitation due to boron content. About 45% of the samples tested had boron level exceeding the stipulated limit of 5mg/l for livestock usage. These analyses although based on spot samples sometimes representing a wide geographical area are nevertheless useful in providing information capable of influencing decision on whether to embark on irrigation project in the study area or not.

4 CONCLUSIONS

The study conducted, evaluated the subsurface water quality/resources of ONADEP in relation to irrigation and livestock water quality. Various standard methods and techniques were employed during the study. Estimated groundwater flow in the area is about 36 x 10^3ML per annum. This value cannot fully satisfy the water demand of the area (Agricultural, domestic and livestock). PH values ranges from 6.5 to 8.0 with mean value of 7.2 which indicate alkalinity and good for irrigation. EC_w, TDS, and SAR mean values of 0.53mmhos/cm, 191mg/l and 1.30 respectively all falls within the FAO standard limit for irrigation water quality. There will be no problem of salinity/sodium hazard. Boron content values ranges from 0.3mg/l to 10mg/l in groundwater of the study area and in more than 60 percent of the samples exceeds the FAO standard of 5.0mg/l. This may limit the usage for livestock purposes in some areas. There are no wide variations in ground water quality for irrigation in ONEDAP. It appears that only about 10,000 ha of land can conveniently be irrigated due to topography and soil texture, (sandy, clay, loam and sandy loam).

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