JOURNAL OF
ENVIRONMENTAL HYDROLOGY

The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com

VOLUME 13 2005

EVALUATING THE QUANTITY AND QUALITY OF GROUNDWATER FOR IRRIGATION IN THE BASEMENT COMPLEX OF ILE-IFE, NIGERIA

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The objective of this study was to evaluate the groundwater yield and quality in relation to the irrigation requirements of common field crops grown on a small-scale basis in Ile-Ife, Nigeria. Quantitative and qualitative analyses of well water samples were carried out to determine their suitabilities for irrigation. Qualitative analysis showed that water from most of the wells is within a low electrical conductance (EC) range of 100-250 μmhos/cm. Several wells have ECs of up to 750 μmhos/cm. The groundwater yield in the basement complex areas is 70 m^3/day on average. However a yield of 98 m^3/day has been achieved in a well in this area. The yield capacity of the wells showed that the average irrigable crop area is 0.5 hectares. As small as the irrigable area from an individual well may seem, it can be profitable to grow small vegetables. There is opportunity for a farmer with small holdings and some capital to purchase a low horse power pump and a few pipes to irrigate his land.

INTRODUCTION

Where to find adequate quantities of good quality water has been an important consideration for many generations. Livestock and crop producers, irrigators, homesteaders and municipalities require large quantities of good quality water. In recent years there has been increasing interest in irrigation in southwestern Nigeria. A water supply of 5 gallons per minute (gpm) (without a storage) is usually adequate to supply a farmstead including the home and livestock. Sprinkler irrigating cropland requires water supply rates as high as 10 gpm per acre, while drip irrigation requires 3 to 7 gpm per acre (Jarrett, 2002). In Nigeria, over 50 percent of the accessible and renewable fresh water resources are said to be committed already (Musa, 1997). This means that even in Nigeria, competition for water may soon become as serious as it is in some other parts of the world.

The total amount of groundwater within the depth of 0.6 km of the land surface is more than 60 times the total water in all freshwater lakes and more than 3,000 times the average volume in all rivers and streams in the world (Nace, 1964). The quality of water supply for irrigation is very essential and should be critically examined. In India for instance, extensive areas of land in the arid and semiarid regions have gone out of cultivation due to the rise of the water table and the accumulation of salt (Michael, 1999).

Irrigation water is supplied to supplement the water available from rainfall and the contribution to soil moisture from groundwater. In many areas of the world the amount and timing of rainfall are not adequate to meet the moisture requirements of crops, hence, the need to supplement with irrigation. Current large irrigation projects have been made possible only by the application of modern power sources to deep well pumps and by the storage of large quantities of water in reservoirs.

Efficient and economical utilization of groundwater through wells depends on the design of wells to best suit the characteristics of the water bearing formations. Flow of groundwater into the wells is influenced by the physical characteristics of the water bearing formations, the number and extent of these formations, the elements of well design and the methods used for constructing and developing the wells (Michael, 1999).

The Ife region is underlain by crystalline basement complex rocks, which cover about 50% of the total land areas of Nigeria (Hubbard, 1968). Rocks found in these areas are pre-Cambrian in age and lie within the zone of Pan African reaction (Rahaman, 1975). The common rock types present in Ife town are undifferentiated schists with gneiss, banded gneiss, pegmatite and quartzite. The undifferentiated schists with gneiss dominate most parts of the northern and western parts of Ife town. Eastern Ife is occupied by schist pegmatite and the southern part by granite gneiss, banded gneiss and schist pegmatite (Bashiru, 1981). The schist complex consists of amphibolite, amphibolite schists, pelitic schists, quartzite, gneiss, pegmatite and other rock units which show amphibolites facies grade of metamorphosis (Jones and Hockey, 1964). These geological units make up the aquifer materials in Ile-Ife town, Nigeria.

There has been very little work done on the study of groundwater exploitation in Ile-Ife area of southwestern Nigeria, partly due to the traditional belief that the basement complex wells are not good sources of groundwater and in part due to the belief that surface sources of water could supply all necessary amounts of water needed in the area (Ayoade, 1975). Investigation has shown that with high rainfall and low surface runoff that is typical of the basement complex area, a high rate of recharge in the over burden crystalline rock is expected (Azeez, 1972). Although the basement area has poor water yields when compared with sedimentary aquifers, it could be adequately used for irrigation. The traditional belief that the basement complex has poor water yields can be explained as due to poor well drilling, construction and development which in turn lead to poor well performance (Bashiru, 1981).

Presently, there is little information on groundwater exploitation, aquifer performance and utilization of the groundwater in the basement complex especially in Ile-Ife town for irrigation. Also there is virtually no information on the quantity and quality of groundwater for irrigation in the basement complex of Ife-Ife. This study is aimed at obtaining more direct information from wells, and together with the existing data, determining the quantity and quality of groundwater available for irrigation in the basement complex. This information along with the water requirement of common field crops grown in the area will help to estimate the area of each crop that can be grown.

THE STUDY AREA

The study area (Ile - Ife, 7^o 31' N and 4^o 33'E) has a mean annual rainfall of about 1500 mm and monthly relative humidity as high as 90%. The average minimum and maximum air temperature are 20^oC and 32^oC, respectively. Southwestern Nigeria has two distinct seasons, the dry season and the rainy season. In the rainy season, the rainfall is high (about 1500mm) and is adequate for the production of most crops grown in the area. However, towards the end of the rainy season (transition period), the rainfall becomes erratic and reduces to about 500mm. In the dry season, there is very little rainfall (less than 100mm). The average evapotranspiration rate during the rainy season for major crops ranges from 200mm - 500mm and from 250mm - 600mm in the dry season. Thus, there is need for supplemental irrigation during the transition period and full irrigation during the dry season in order to have three cropping seasons for the grains and pulses like maize, rice, cowpea, vegetables and to have good yield for annual crops like cocoyam, and cassava.

The study area has sandy clay loam soils (ultisols) and covers an area of 447,034 ha in the southwestern part of Nigeria. The soil is well drained and the parent rock from which it was formed includes fine-grained biotite, gneiss and schist.

FIELD INVESTIGATION

Groundwater Quantity Determination

Before testing the wells for yield, the static water level was determined. After the initial water level of the wells had been determined, the wells were tested for yield by pumping at a maximum rate until the water level in the well stabilized. The depth of the water was then noted. The difference in depth is the drawdown, and the discharge-drawdown ratio is an estimate of the specific capacity of the well. The discharge of the wells when the level of water had been stabilized was measured. The yield capacity of the wells in m^3/day was determined by measuring the volume of water collected by the calibrated bucket per unit time. The yield capacity was determined using Equation 1.

$$\text{Yield Capacity} = \frac{\text{Discharge x 1000}}{60 \text{ x } 60 \text{ x } 24} \tag{1}$$

Groundwater Quality Determination

The water samples were collected with rubber collectors, which draw water from the wells on the site. The water samples collected were stored in rubber containers prior to testing to prevent samples from getting contaminated with dissolved ions as is usually the case with metallic containers. Ten samples were collected across the town and tested for the presence of major cations including potassium, sodium, calcium and magnesium, major anions such as carbonate, sulfate and chloride and minor radicals. The results were evaluated with reference to the possible hazards they could constitute to farm crops.

Sodium (Na^+) and potassium (K^+) ions were tested by using a flame photometer while magnesium (Mg++) and calcium (Ca^{++}) ions were tested using atomic absorption spectrophotometer. The anions Cl^-, SO_4^- and CO_3^-, were determined by using laboratory techniques such as gravimetry and precipitation. The salinity of the water samples, which is the measure of the total salt concentration, was measured with the electrical conductivity meter. The sodium adsorption ratio (SAR), which is one of the most reliable indices used in expressing or determining the exchangeable sodium in the soil was calculated using Equation 2 (Michael, 1999):

$$SAR = \frac{Na^+}{\sqrt{(Ca^{++} + Mg^{++})/2}} \tag{2}$$

The bicarbonates of the water were determined by laboratory tests of precipitation of soluble calcium and magnesium from the water samples to obtain carbonate by using Equation 3:

$$2HCO_3 + Ca^{++} = CaCO_3 + H_2O + CO_2 \tag{3}$$

Magnesium content of the water samples in milligrams/liter *(mg/l)* or parts per million (ppm) was calculated by multiplying the ion concentration in *meq/l* by the atomic weight of the ion. Thus, the magnesium content of the water samples was calculated using Equation 4 below:

$$Mg\ (ppm) = Mg^{++}\ (meq/l) \times 24.3 \tag{4}$$

Chlorine content was determined using a simple laboratory test. The results of each constituent after test were compared with the standards.

Seasonal Irrigation Requirements and Crop Area

The total volume of water needed during an irrigation season (year) for a given crop grown at the specified location was estimated using Equation 5.

$$SIR_{j,k} = 100\left(\frac{(ET_s)_{j,k} - (P_e)_{j,k}}{E_i}\right) \tag{5}$$

where

$SIR_{j,k}$ = seasonal irrigation requirement for crop j during year k, mm

$(ET_s)_{j,k}$ = total seasonal evapotranspiration for crop j during year k, mm

$(P_e)_{j,k}$ = annual effective precipitation from crop j during year k, mm

E_i = irrigation efficiency, percent

Equation 5 is based on the assumption that the initial and final soil moisture levels for the irrigation season are identical and that there are sufficient deep percolation losses to provide the leaching requirement. The seasonal irrigation requirements of twelve commonly grown crops in the study area were estimated.

The Et_s for a crop was computed using an adjusted Blaney-Criddle equation developed by Fapohunda and Ude (1992). This method provides adequate accuracy, is easy to use, requires data that are normally readily available, and requires less computing time than other sophisticated methods. The adjusted Blaney-Criddle Equation is given as Equation 6 below:

$$ET = (2.50 + 0.027R_b)K_{SCS}K_tP(0.46T_C + 8.13) \tag{6}$$

where

T_c = mean monthly temperature in ^oC

R_b = monthly relative humidity in %

K_{scs} = correlation coefficient for annual crops

The climatological data used for estimating evapotranspiration in the study area were extracted from the records of the meteorological station on the Teaching and Research farm of the Obafemi Awolowo University, Ile - Ife. The total volume of water needed to irrigate the farm during a given year was calculated using Equation 7:

$$(SIV)_k = K\sum_{j=1}^{n}(SIR_{j,k})A_j \tag{7}$$

where

$(SIV)_k$ = seasonal irrigation volume for farm during year k, m^3

K = 10.0 when SIV is in m^3, SIR is in mm and A is in hectares

A = area of crop j, hectares

The yield capacity of wells determines the amount of water available for use in this study. Hence, the yield capacity of wells constitutes the total volume $(SIV)_k$ of water available for use in irrigation. The area of crop j (A_j) that can be irrigated with the available water can then be estimated by rearranging Equation 7 as follows:

$$A_j = \frac{SIV_k}{K\sum_{j=1}^{n}(SIR_{j,k})} \tag{8}$$

where SIV_k = seasonal well discharge in m^3. Other terms are as previously defined.

RESULTS AND DISCUSSION

Analysis of Water Yield

Table 1 shows the different values of the static water level and yield capacity of the wells in the study area. From the table, the average yield from the basement complex is 70.05 m^3/day. Also from the table, it can be shown that the potential yield of the underlying aquifers varies although all the wells in the study area are located in the same basement complex of Ile-Ife. Some of the wells, especially in the southern part of the study area, have very high yield capacity and low static water levels. This may be due to the fact that the southern part of the study area is occupied by a colluvium over weathered schist of intermediate crystalline Pre-Cambrian Basement Complex rocks (Bashiru, 1981) which generally have a higher yield than the sedimentary rock of uniform lithology with varying clayey and sandy contents which occupies the other parts of the study area. This implies that

Table 1. Static Water Level and Yield Capacity of Wells

Sample No	Static water level (m)	Yield capacity (m^3/day)
1	10.6	65.5
2	4.6	78.5
3	6.7	52.4
4	2.4	98.2
5	3.7	65.5
6	12.2	78.5
7	7.6	58.9
8	7.0	72.0
9	1.5	78.5
10	4.6	52.4

the southern part of the study area has better water yields for irrigation purposes than the northern part of the town.

Table 2 gives the calculated values of irrigation requirement and hectares of common crops in the basement complex of Ile-Ife. From the table, it can be seen that the early maize crop requires less irrigation water than the late crop. This is because the period of the year during which early maize is grown is a period of high effective rainfall that substitutes for most of the evapotranspiration that occurs during that period. Cassava requires more water than cocoyam although both have the same period of maturity. In both cases, the types that mature in 12 months were considered. The type of yam that was investigated is the one that matures in 10 months and requires a reasonable amount of irrigation water within its growing season. From the table, the most economical crops in terms of water requirement and irrigation water needs are the small vegetables. Ewedu (*colhoru oliterus*) and okro (*Albernoschus esculentus*) belong to this class of economical crops.

Table 2. Irrigation Requirement and Area of Common Crops in the Basement Complex of Ile-Ife

Crops	Seasonal ET (mm)	Seasonal Effective Rainfall (mm)	Irrigation Requirement (mm)	Crop acreage (ha)	Water supply rate m^3/day
Amaranthus	1759.7	655.2	1104.5	0.52	136.7
Beans	1135.6	368.5	767.1	0.75	95.8
Cocoyam	8669.5	1472.1	7197.4	0.32	76.8
Cassava	8821.0	1472.1	7348.9	0.31	75.9
Ewedu	610.3	303.2	307.2	0.94	48.1
Early Maize	2214.7	574.4	1640.3	0.35	63.8
Late Maize	2161.5	505.1	16456.4	0.35	64.4
Okro	925.7	403.4	522.3	0.73	63.5
Pepper	1568.4	408.9	1159.5	0.50	96.6
Spinach	1429.3	206.0	1223.3	0.46	93.7
Tomato	1364.9	403.4	961.5	0.40	64.1
Yam	7718.4	1059.9	6658.5	0.29	64.3

From the table, the average crop area is 0.5 hectares. This value shows that the discharge from the wells in this basement complex area can irrigate on the average a small home garden of 0.5 hectare. However, an area of as much as 0.94 hectare is possible with a small vegetable crop like Ewedu (*colhorus oliterus*). Okro (*Albemoschus esculentus*), which belongs to the same class as Ewedu, also has an area of 0.73 hectare, while 0.75 hectare of land planted with bean crop could be irrigated conveniently with the discharge from a well in the basement complex of Ile-Ife.

Therefore, small vegetables are the most economical in terms of water requirement and irrigation water needs. They consume less water and have more crop area than all other crops considered in this study. Most leguminous plants would also do well in any irrigated farm in the Ile-Ife basement complex that has well water as its source. The leguminous plants are good moisture conservators; hence, they consume relatively less water than most other crops and thus, relatively more land can be planted with the same amount of irrigation water.

Analysis of Water Quality

The results of water sample analysis from the wells in the study area are shown in Table 3. The quality of the water samples viz-a-viz irrigation is discussed in terms of salinity hazard, sodium hazard and bicarbonate hazard. These three criteria then show the suitability of water from Ife town and its environs for irrigation purposes.

From Table 2 and the qualitative analysis, most of the wells are within the low electrical conductance (EC) limit of 100-250 µmhos /cm. Two of the wells considered have ECs of 250-750

Table 3. Results of Chemical Analysis of Groundwater Samples from Ile-Ife Town

Sample No	EC µmhos/ cm at 25^{o}C	Total dissolved solids	pH	Na^+ ppm	K^+ ppm	Ca^{++} ppm	Mg^{++} ppm	Cl^-	HCO^-_3	SO_4	SAR
1	75	44.15	6.2	14.6	11.5	6.4	2.7	27.9	58.9	0.5	1.212
2	784	466.00	7.0	66.9	143.8	47.2	26.8	178.6	252.8	4.0	1.967
3	24	16.44	5.3	23.3	4.6	0.8	1.6	9.3	26.4	3.5	3.42
4	20	12.75	5.5	1.7	1.15	1.2	0.6	37.5	12.2	0.75	0.326
5	112	68.34	6.7	13.0	32.7	1.4	4.9	8.9	100.6	11.0	0.826
6	660	415.00	6.0	74.4	73.5	17.4	12.4	202.8	110.4	-	3.29
7	842	380.62	6.5	13.5	13.1	10.0	16.3	167.8	95.7	1.0	0.607
8	233	80.50	5.6	30.7	33.5	14.0	19.7	125.0	162.6	-	1.225
9	424	195.80	7.1	22.8	33.0	12.0	19.2	100.5	120.2	1.0	0.938
10	75	57.60	6.0	23.3	30.0	13.0	3.4	75.4	104.3	2.0	1.466

µmhos/cm. In general, the sodium hazard was considered low because the observed sodium adsorption ratio for the wells lies between 0.3 and 3.42, while the salinity hazard varies from low to medium and these levels are considered good for irrigation purposes.

CONCLUSION

This paper has highlighted the quality and quantity of well water for irrigation in the basement complex of Ile-Ife in southwestern Nigeria. On the average, the groundwater yield in the basement complex in this area is 70.05 m^3/day while yield as much as 98.24 m^3/day has been achieved on a well located in the southern part of the study area. From the qualitative analysis, water from most of the wells are within the low electrical conductance (EC) limit of 0-250 μmhos/cm while some of the wells have electrical conductance limit of 250-750 μmhos/cm and two of the wells have ECs higher than 750 μmhos/cm.

A quick examination of the groundwater parameters and the crop water requirements indicate that the supply can meet the demand, at least on a small-scale irrigation project in the areas underlain by the basement complex with Ile-Ife as a case example. As small as the area irrigated for the twelve commonly grown crops in this area may seem, the small size offers unique opportunity for a farmer with small holdings and some capital to purchase a low horse power pump and a few pipes to irrigate his land.

ACKNOWLEDGMENT

The authors wish to acknowledge the comments of Dr. Kenneth O. Adekalu of the Department of Agricultural Engineering on the draft paper and also members of the University Research Committee (URC), Obafemi Awolowo University, Ile-Ife Nigeria.

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