Evaluation of the Impact of Gurara Dam on Soil Quality within the Catchment in Kaduna State Nigeria

Abugu, Nkechinyere Anthonia
Geography Department Nasarawa State University Keffi

Yero Ahmed Bello
Geography Department Nasarawa State University Keffi

Nwaokocha Chuhukwuemeka Andrew
Zoology Department Nasarawa State University Keffi

Inemesit Innocent Udofot
Geography Department Nasarawa State University Keffi

Abstract

This study evaluates Gurara dam impact on soil quality within the catchment. Its objectives were to assess the soil quality of Gurara dam catchment area and compare the quality of soil in the EIA baseline data with the present soil quality. The result of this research work was gathered through laboratory analysis of soil samples collected within Gurara dam catchment. Data collected were analsysed using mean, range coefficient of variance and student't' test. This study found that soil nutrient has reduce due to erosion caused by dam, The concentration load of soil nutrients such as nitrate, sulphate, phosphate and chloride ranged from 3.4mg/kg – 5.9mg/kg; 8.95mg/kg – 80.1mg/kg; 0.4mg/kg – 0.8mg/kg; and 18mg/kg – 23mg/kg for these parameters respectively; there is a significant difference in soil quality in terms of nitrate, sulphate, phosphate, chloride and organic matter but not for pH, temperature and electrical conductivity between present soil samples and EIA baseline data. Thus this study recommended among other things the implementation of the environmental management plan listed in the EIA.

Keywords: Gurara Dam, Soil Quality, Heavy Metals, Soil Nutrient, Evaluation, Impact and EIA

1. Introduction

The objectives of this study *were to assess the soil quality of Gurara dam catchment area and compare the quality of soil in the EIA baseline data with the present soil quality.* The period of economic growth after the Second World War prompted rise in the global dam construction rate in quest for comfort and the satisfaction of human. Dam constructions have been seen as means of meeting up water and energy requirement of ever increasing population. However, like many other development projects dam comes with many environmental challenges include both limited to soil degradation. On this note, environmental impact assessment (EIA) concept in Nigeria and globally is recognized as a tool for achieving sustainable development and its main objective is to ensure that potential environmental impacts are foreseen at the appropriate stage of project design and addressed before any decision is taken on the project. Despite this application of EIA on dam projects, soil degradation of dam surroundings manifest as a consequence of alteration of hydrological conditions caused by the installation and operation of the irrigation scheme. The construction of a dam itself can contribute to the degradation of its catchment. For example, extraction of cooking fuel by the labour force and improved access to the forests, both during and after dam construction, degrades catchment forest thereby exposing the soil to erosion. The construction of roads and other infrastructure and the enhanced activities in the area also put an additional pressure on the soil (Federal Ministry of Water Resources, 2015; Ogunkunle *et al,* 2015). Dam construction, reservoir impoundment and operation enhance flood and erosion. Consequently alter the soil quality of the catchment area. Several studies portrays soil contamination and loss of soil fertility due to dam construction, operation and related activities (Nwafor, 2006; UNEP,2007; Salami and Sule,2010; Ujoh *et al*, 2012; Deshmukh, 2012; Dukiya, 2013) .

Studies have identified two main impacts of dams and reservoirs on soil quality. Firstly, salinization may occur in arid conditions in relation to irrigation, mainly due to the maintenance of a high groundwater level when evaporation and evapotranspiration are strong (Cause, 2001 cited in Wildi, 2010). In addition, contamination of soil in the floodplain by reworked contaminated reservoir sediments during floods may be expected. "This mechanism is linked to the accumulation of contaminants in reservoirs" (Jüstrich *et al*., 2006 cited in Wildi, 2010).

Although the use of dam is diverse and significant, there is a growing awareness on the environmental consequences of dam, thus, this research intends to contribute on the ongoing- debate on environmental impact of dam by evaluating the extent to which Gurara dam has affected the soil quality of the catchment area.

1.1 Material and methods

This research used both primary and secondary sources of data but mainly primary sources. Primary sources of data include random sampling of soil, observation and photographing of striking features. While secondary data was gathered through review of existing literature and the Gurara EIA report. The baseline soil quality in the EIA report was collected for comparison with present study soil quality. Series of field works were carried with the help of assistants and experts for primary data collection. Samples of soil were collected from EIA sample points for proper comparison of variations. Soil sampling was carried out at ten (10) locations across the entire study area (Table 1).

These ten sampling points were purposively selected from the EIA report due to outstanding degradation going on in these locations. The sampling points were also spatially selected to capture variability in environmental setting. Sampling points maintained exact point of the EIA sample points for proper comparison of variation resulting after the dam construction. Ten soil samples were collected at 0-15 cm for the top-soils and 15-30 for sub-soil using auger. Soil samples for physico-chemical analyses were collected in polyethylene bags. In order to eliminate micro/macro variability and to ensure that representative soil samples collected on the field were properly analysed. Soil samples were subjected to laboratory test for the following physical and chemical properties: P^H, temperature, electrical conductivity (EC), soil nutrients (nitrate, sulphate, phosphate and chloride), and organic matter content and the results were compared with the Federal Ministry of Environment FMEnv standard and the EIA baseline data (Table 2).

1.1.1Results and Discussion

Table 3 present the soil quality of the catchment area

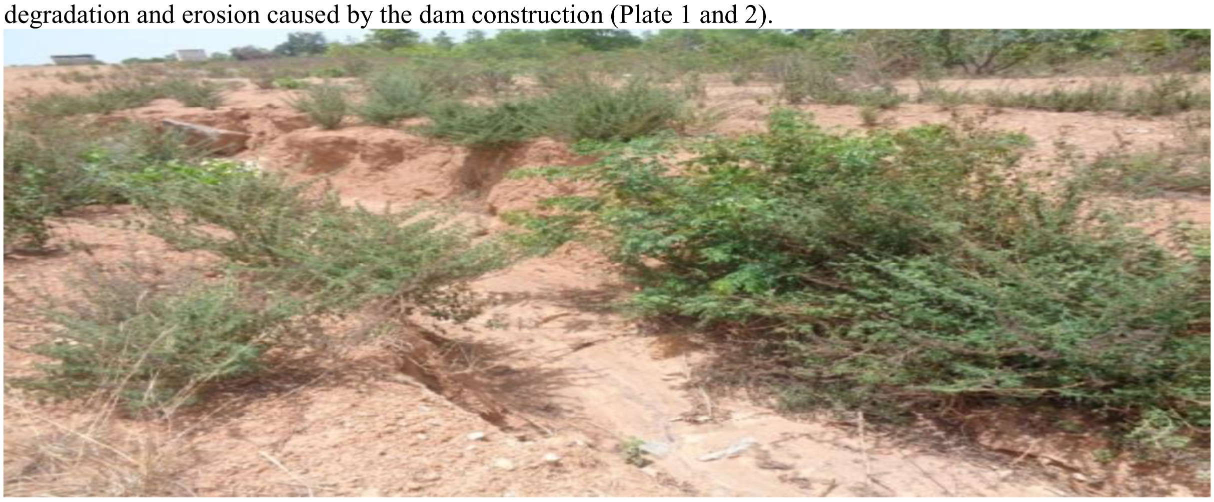
Soil Quality of the Catchment Area Compared With the Federal Ministry of Environment (Fmenv) Standard

pH

The soil pH values range from 6.0 – 6.8 are slightly acidic. Though this values fall within the Federal Ministry of Environment recommended range of 6 - 9 for crop production.“Soil pH is a measure of the alkalinity or acidity of the soil. A pH value of 7 is neutral, values below 7 are defined as acidic and those above are alkaline. The most important effect of pH on the soil is on ion solubility, which in turn affects microbial and plant growth. A pH range of 6.0 – 6.8 is ideal for most crops because it coincides with optimum solubility of the most important plant nutrients” (Ogunkunle *et al*, 2015). Some minor elements (e.g iron) and most heavy metals are more soluble at lower pH. The soils have low EC ranging from 38µS/cm - 85µS/cm and by inference low salinity with values below FMEnv threshold (250 µS/cm). “Soil salinity is a measure of the total soluble salts present and is determined by measuring the EC of the soil sample. High levels of soluble salts in the root zone may affect water and nutrient uptake and adversely affect plant growth. Plants are susceptible to salinity in their germination and seeding stage. Soil Electrical Conductivity (EC) is the ability of the soil to conduct electrical current measured in µS/cm” (Wildi, 2010).

Soil Nutrients – Nitrate, Sulphate, Phosphate, Chloride

The concentration load of soil nutrients such as nitrate, sulphate, phosphate and chloride were observed to be low. Concentration values ranged from 3.4mg/kg – 5.9mg/kg; 8.95mg/kg – 80.1mg/kg; 0.4mg/kg – 0.8mg/kg; and 18mg/kg – 23mg/kg for these parameters respectively. Concentration levels for phosphate, sulphate, nitrate, chloride and sulphide were all below FMEnv acceptable limits. The low soil nutrients are attributed to land degradation and erosion caused by the dam construction (Plate 1 and 2).



Source: Field Study (2016)
Plate 1: Soil Erosion at upstream of the Study Area.

Source: Field Study (2016)
Plate 2: Soil Erosion and Land Degradation at the pipeline rout of the Study Area.

Organic Matter

The soil organic matter content ranged from 2.10% - 7.40% with values below 3% in soils sampled from Farm 3 and Engineers Camp/Farmhouse. The percentages of organic matter in the soils were low due to deforestation for the dam construction which exposed the soil to erosion(Plate 3) .

Source: Field Study (2016)
Plate 3: Soil Exposed to Erosion during Site Clearing at the construction site.

The Present Soil Quality Compared With the EIA Baseline Data.

The mean, variance and standard deviation for EIA baseline data and the present study soil quality results are shown in table 4 and 5. respectively, while table 6 shows the coefficient of variance (CV) and the student 't' test at 95% confidence level for the two data set (soil quality in EIA and the present study soil quality).

Table 6 shows that soil quality parameters such as pH, temperature and electrical conductivity have low coefficient of variance 7.54%, 3.12%, and 8.76%, respectively. This means that there is insignificant change in these parameters (pH, temperature and electrical conductivity) between present soil samples and EIA baseline data. However, parameters such as nitrate, sulphate, phosphate, chloride and organic matter have high coefficient of variance which indicate significant change in these parameters between present soil samples and EIA baseline data.

Moreover, the student t test results correspond with the coefficient of variance of these parameters as follows: the calculated t values 0.13, 0.66, 0.77 for pH, temperature and electrical conductivity are lower than their critical value of 1.89 while the calculated't' values of 2.82, 1.97, 2.17, 1.93 and 1.91 for nitrate, sulphate, phosphate, chloride and organic matter respectively are greater than their critical 't' value of 1.89 at 95% confidence level. Therefore, Ho is rejected for pH, temperature and electrical conductivity but accepted for nitrate, sulphate, phosphate, chloride and organic matter. Thus, there is a significant difference in soil quality in terms of nitrate, sulphate, phosphate, chloride and org-anic matter but not for pH, temperature and electrical conductivity between present soil samples and EIA baseline data. Then it can be deduced that there is a reduction in soil nutrients (nitrate, sulphate, phosphate, chloride) and organic matter in the present study soil samples than the EIA baseline data. This is because the mean nitrate, sulphate, phosphate, chloride and organic matter are higher in the EIA baseline data than the present data (Table 4 and 5).

1.1.2 Conclusions

Soil nutrient were observed to be lower than Federal Ministry of Environment standard and differ significantly between the EIA baseline and present study soil samples .It was concluded that the Grurara dam have significantly affect the soil quality of the catchment area.

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Table 1. Sampling locations in the project area for soil studies

S/N	Sampling location	Northing	Easting	Elevation (m)
1	Gurara dam	090 38.360’	0070 45.813’	632.9
2	Dam spillway	090 38.694’	0070 44.773’	629.6
3	Confluence point downstream	090 38.113’	0070 44.312’	605
4	Maintenance engineering workshop	090 38.865’	0070 44.450’	615.2
5	Mobile sprinkler farm	090 36.996’	0070 42.994’	603.1
6	Drip irrigation farm	090 36.991’	0070 43.060’	601.8
7	Surface irrigation farm	090 36.709’	0070 42.955’	600.8
8	Centre pivot farm	090 36.188’	0070 42.687’	577.7
9	Fixed sprinkler farm	090 36.212’	0070 43.500’	578.3
10	Engr camp/ farm house	090 35. 294’	0070 32.513’	538.0

Table 2: EIA Baseline Physical and Chemical Properties of Soil in the Study Area

Sampling Location	Northing	Easting	Elevation (m)	Temperature	pH	Conductivity(EC)	Nitrate	Sulphate	Phosphate	Chloride	OM
East of Gurara Dam	090 38.360’	090 38.360’	632.9	28.8	6.9	58	15.3	51.1	1.9	35	9.3
Dam Spillway	090 38.694	0070 44.773’	629.6	28.7	6.4	50	17.3	82.1	1.89	29	16.6
Confluence Point Downstream	090 38.113	0070 44.312’	605	31.2	6.6	47	16.9	8.85	0.87	37	17.4
Maintenance Engineering Workshop	090 38.865’	0070 44.450’	615.2	29.6	6.1	46	15.1	50.6	1.97	44	16.8
Mobile Sprinkler Farm	090 36.991	0070 42.994’	601.8	29.8	6.8	36	15.3	35.5	1.07	49	12.6
Drip Irrigation Farm	090 36.709’	0070 43.060’	600.8	28.9	6.7	58	15.2	10.8	2.46	58	16.5
Surface Irrigation Farm	090 36.188	0070 42.687’	577.7	30.1	6.5	87	142	10.9	2.17	74	12.1
Centre Pivot Farm	090 36.212’	0070 43.500’	578.3	30.6	6.7	49	15.3	43.6	1.87	65	12.1
Fixed Sprinkler Farm	090 35. 294’	0070 43.500’	538	29.6	6.4	42	14.3	30.5	1.15	30	14.1
Engr Camp/ Farm House	090 37.991	0070 41.687’	650	28.5	6.8	48	14.5	11.3	1.74	32	15.7
Average				29.58	6.59	52.1	28.12	33.525	1.709	45.3	14.32

Table 3: The Present Physical and chemical Properties of Soil in the Study Area

Sampling Location	pH	Conductivity(EC)	Nitrate	Sulphate	Phosphate	Chloride	OM
East of Gurara Dam	6.9	58	5.3	51.1	1.1	25	6.3
Dam Spillway	6.4	50	6.3	82.1	1.09	19	6.6
Confluence Point Downstream	6.6	47	6.9	8.85	0.7	28	7.4
Maintenance Engineering Workshop	6.1	46	5.7	50.6	1.67	26	6.8
Mobile Sprinkler Farm	6.8	36	5	35.5	1.07	29	2.6
Drip Irrigation Farm	6.7	58	5.1	10.8	1.46	28	6.5
Surface Irrigation Farm	6.5	87	4.8	10.9	1.17	51	2.1
Centre Pivot Farm	6.7	49	5.3	43.6	1.07	24	2.1
Fixed Sprinkler Farm	6.4	42	4.7	30.5	1.15	19	4.1
Engr Camp/ Farm House	6.8	48	4.4	11.3	1.34	21	5.7
Average	6.59	52.1	5.35	33.525	1.182	27	

Table 4: The mean, variance and standard deviation for present soil quality.

Parameters	Mean	Variance	Std Dev
pH	6.4	0.14	0.02
Temperature	29.7	0.30	0.42
Electrical Conductivity	52.1	13.92	193.76
Nitrate	5.35	15.91	253.13
Sulphate	33.53	5.84	32.12
Phosphate	1.18	1.25	1.56
Chloride	27	11.60	134.65
Organic matter	5.02	1.87	2.84

Table 5: The mean, variance and standard deviation for EIA baseline soil quality.

Parameters	Mean	Variance	Std Dev.
pH	6.6	0.24	0.06
Temperature	29.7	0.65	0.42
Electrical Conductivity	53.9	13.44	180.63
Nitrate	28.12	14.11	199.09
Sulphate	33.525	4.83	23.34
Phosphate	1.709	1.46	2.13
Chloride	45.3	7.23	52.23
Organic matter	5.02	2.23	4.97

Table 6: Coefficient of Variance and Student't' test Result Comparing Soil Quality Parameters Between EIA and the present soil quality.

Parameters	Coefficient of Variance (%)	Calculated 't" Value	Critical 't'
pH	7.54	0.13	1.89
Temperature	3.12	0.66	1.89
Electrical Conductivity	8.76	0.77	1.89
Nitrate	65.34	2.82	1.89
Sulphate	50.37	1.97	1.89
Phosphate	58.26	2.17	1.89
Chloride	61.59	1.93	1.89
Organic matter	55.19	1.91	1.89