Assessment of the Environmental and Social Impacts of Gurara and Azara/Jere Irrigation Projects in Nigeria

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Abstract

It has been clearly established that development of dams and associated user facilities (such as irrigation, water transfer and hydro-power infrastructure, aqua-culture, etc.) significantly impact the quality of the physical environment and established social networks of host communities. It is therefore, necessary that a holistic and sustainable approach is adopted in the process of planning these projects. This study reviewed the environmental and social impact status of the Gurara and Azara/Jere Irrigation Projects in the Upper Niger River Basin in Kaduna State, North-West Nigeria. The study focused on investigating key environmental and social attributes including soil quality, water quality, air quality and noise level, vegetation (landuse) cover analysis, health status, socio-economic and livelihood appraisal, and social characteristics of host communities using various approaches such as laboratory analysis, in-situ assessment, key informant interviews, and document analysis. The findings of the study reveal a range of risks which include pollution of water and soil as well as vulnerability to floods and erosion, and loss of livelihoods. Generally, the outcome of this study serves to advance the importance of assessing environmental impacts from anthropogenic activities, as well as measurement and intervention to relevant criteria/conditions. Among others, the study suggests periodic monitoring and assessment of key environmental and social risks components and the resolution of land related compensation issues at the project sites.

Keywords: Environmental impact, social impacts, irrigation, River Basin Development Authorities (RBDAs) & ESMP.

Introduction

It is clear that natural resource development and exploitation is critical to economic advancement of nations. However useful, it is equally important to recognize the fact that resource development and exploitation significantly alters the physical environment (air, soil, water, vegetation, terrestrial and aquatic ecosystems, etc.) which collectively aggravates the impacts of climate change and also dislocates the socially and economically established networks of host communities (Kumar *et al*, 2019; Singh *et al*., 2020). Therefore, it is necessary that a holistic and sustainable approach is adopted in the process of natural resources development and management. Thus, in recent times, questions of sustainability contextual (the difference in environmental quality vis-à-vis physical developments) and measures put in place to mitigate or prevent further degradation has been growing, assuming even greater international and cross-disciplinary dimensions as the scale and ramifications of these issues escalate. These discussions are best reflected in the sustainable development goals (SDGs) and other relevant international sustainability instruments such as the Kyoto Protocol, the Clean Development Mechanism (CDM), the United Nations Framework Convention on Climate

Change (UNFCCC), the World Bank Environmental and Social Guidelines, the International Standards Organization (ISO) suite of Environmental Management Systems (EMS), etc.

Ideally, climate change is triggered by both natural and anthropogenic actions. In recent decades (indeed since the Industrial Revolution) however, the rate of climate change and environmental degradation have been at record high levels with human activities accounting for a significant percentage of these changes. Already it is established by Denman *et al* (2007) that globally, human related activities account for 38% of total emissions. It is necessary to state that the general climate change mirrored implications of the existing and proposed developments at the RBDAs are viewed in 4 dimensions, with the physical aspects culminating into sub-regional climate change effects. These dimensions are:

i. Development effects - defined as the deformation and alteration of ground mass and terrestrial ecology such that can create effects such as horizontal and vertical movements, curvature and strains in the case of the former, and extinction of species in the case of the latter;

ii. Development impacts – defined as the physical changes to the ground that are caused, for example, by erosion and rapid runoff, and exposure and disruption in the food chain;

iii. Environmental consequences - identified, for example, as a loss of soil structure and nutrients, destabilization of ecosystem pattern and bio-diversity, significant alteration in micro-climatic parameters, and surface/sub-surface water flow alteration, and possible contamination largely envisaged from the various agricultural activities to be carried out at the project sites at the RBDA; and,

iv. Socio-economic and health related consequences - identified, for example, as impacts on workers of the proposed major and related (irrigation, power, etc.) infrastructure, and the neighbouring communities who may collectively be viewed as 'stakeholders' due to the unique identity of the proposed developments as a critical but delicate infrastructure/asset at RBDAs. The fully developed projects may likely stimulate economic activity around and within the respective RBDAs generally, and may also serve as a powerful magnet for related businesses and even criminality, all of which will need to be planned for and against, so to speak. In addition, health related consequences may also arise as a major cause for consideration especially the possibility of the proliferation of respiratory tract infections and vector-based and zoonosis diseases (VBZDs). Ground/surface water pollution (if mitigative steps are not implemented) may also be a cause for concern.

Prior to the promulgation of Nigeria's EIA Decree 86 of 1992 (currently known and cited as EIA Act, Cap. E12, Laws of the Federation of Nigeria, 2004), all physical developments were carried out provided a cost-benefit analysis (CBA) was conducted, without consideration for the environmental and social impacts/risks on host environments and communities. The Act mandates an EIA to be carried out on new projects likely to exert any form of impacts on the Nigerian environment, by providing guidelines for developments which EIA is deemed mandatory. The Federal Ministry of Environment (FME) procedural and sectoral guidelines provide detailed stages for which an EIA study/process must adopt including the categorization of projects into I, II and III. Category I projects require a full EIA; Category II projects may or may not require a full EIA; while Category III projects do not require an EIA (Federal Government of Nigeria, 1992). The EIA Act No. 86, Section 3 (1) of 1992 states, inter alia:

> *"In identifying the Environmental Impact Assessment process in this Decree, the relevant environmental issues shall be identified and studied before commencing or embarking on any project or activity covering the provisions of*

this Decree or covered by the Agency or likely to have environmental impact on the Nigerian environment".

Additionally, in 1991, the then Federal Ministry of Environment, Housing & Urban Development released "National Interim Guidelines and Standards for Industrial Effluents, Gaseous Emissions and Hazardous Waste Management". These provisions were separately listed as:

S.1.8. National Environmental Protection (Effluent Limitation) Regulation;

S.1.9. National Environmental Protection (Pollution Abatement in Industries and Facilities Generating Waste) Regulation; and,

S.1.15. National Environmental Protection (Management of Solid and Hazardous Wastes) Regulation.

Regarding the existing dams/projects and proposed projects development (irrigation schemes, power generation, agricultural production and processing, fisheries, etc.), the EIA Act mandates the conduct of a full ESIA (irrespective of location and project life span) before construction works are allowed to commence. In essence, a full ESIA must be conducted for the proposed projects to be developed for the additional components that would be improved upon across the RBDAs. However, for projects that EIAs were conducted before commencement, an EA is to be mandatorily conducted in accordance and according to the environmental statement/commitment stipulated in the environmental management plan (EMP).

In order to ensure that EIA's are properly conducted, the FME also issued a National EIA Procedure (Figure 1) indicating the steps to be followed through the EIA process up to approval after which project implementation would commence. This is mandatory in order to ensure that projects requiring EIA are executed with maximum consideration for the environment.

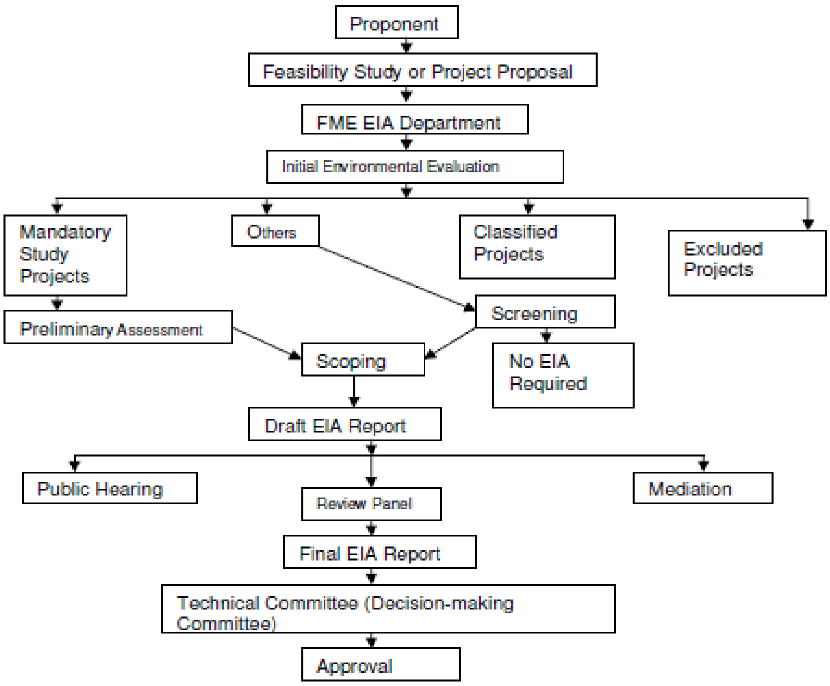

Figure 1. EIA Process in Nigeria

Source: Federal Ministry of Environment, https://ead.gov.ng/eia-process-flowchart/

Collectively, these guidelines are contained within the EIA Act, Cap. E12, Laws of the Federation of Nigeria, 2004 and are therefore, deemed relevant for adoption during the implementation phase of the proposed expansion and upgrading of the projects for the 4 pilot RBDAs.

The National Irrigation/Drainage Policy & Strategy (NIDPS) was published in 2015 by the FMWR actively supported by the Food and Agriculture Organization (FAO) of the United Nations. The NIDPS provides a synoptic background on the current status and contributions of irrigation to Nigeria's economy, eventually x-raying 7 broad emerging issues of population expansion, conflicts, low productivity and low return on investments, environmental imbalances, underutilization of water and land resources, low regulation capacity, and low user inclusiveness (Federal Ministry of Water Resources, 2015). Of particular interest to this study are 2 of the 8 policy objectives: (a) socio-economic and cultural inclusion; and (b) Improved capacity for sustainable data generation, management and use. These objectives are closely followed and guided by 7 main principles, viz:

- Responsive ownership;
- Demand-driven performance and productivity;
- Environmental responsibility;
- Integrated resource management and sustainability;
- Gender sensitivity and participation;
- Decentralization and subsidiarity; and,
- Right of access to and use of land and water resources.

These policy provisions are to be implemented via 8 clearly defined strategies which include: (a) environmental (improve environmental management and governance, and promote all-inclusive land and water management systems), and (b) social (provide more access to and inclusion in management of land & water resources for vulnerable groups, and promote specialization along the irrigation value chain) considerations in the proposed rationalization of irrigation in Nigeria. Given these policy provisions, guiding principles and implementation strategies, the NIDPS will be actively considered and incorporated into the irrigation components of this RBDAs partial commercialization programme.

Considering the life span, scale and footprint of existing and proposed infrastructure for the various projects (irrigation of thousands of hectares of plantations, processing of farm yields, hydro-power generation, fisheries, municipal water usage, etc.) at the 4 RBDAs reviewed, it is instructive to also note the possibility of injecting various forms of pollutants into the environment from the range of envisaged activities across the focus RBDAs as production becomes highly rationalized through operational efficiency. This study is therefore, a response and contribution to these current sustainability discourse as it illuminates parallels between past and current environmental and social risks/impacts resulting from irrigation projects development at selected river basins across Nigeria, and also reveal contradictions, misrepresentations, or potential long-term environmental and social damages that might result from neglect of internationally prescribed environmental and social principles and best practices outlined as socially acceptable yardsticks put in place to ensure that past, present and future human activities do not impact negatively on the environment and population of host communities. It is against this background that this study examined the environmental and social impacts of the Gurara and Azara/Jere irrigation projects in Nigeria.

Description of Study Area

The Gurara irrigation project and Azara / Jere irrigation project are both located at the Upper Niger River Basin in Kaduna State, North-West Nigeria. The Basin has an area of about 1226.385 km^2. The Gurara Irrigation Project is situated near Jere town in Kaduna State, within Kachia Local Government Area. This project was designed to support agricultural transformation by providing irrigation to 12,000 hectares of farmland, facilitating the production of crops like rice, maize, and melons. The project's infrastructure includes a dam on the Gurara River, water distribution systems, and various types of irrigation systems such as pivot irrigation and drippers (Daily Trust, ND).

Geographically, the Gurara Dam is positioned at 9°05’N, 7°30’E, and the Gurara River flows southwards, passing through Niger State and the Federal Capital Territory (FCT) before merging with the River Niger in Kogi State (Fig. 2). The area experiences a tropical climate with a rainy season from April to early November and a dry season from late November to March. The vegetation is characterized by derived-Guinea Savannah grassland mixed with remnants of tropical forest.

Azara-Jere Irrigation Project

The Azara-Jere Irrigation Project is also located in Kaduna State, downstream from the Gurara Dam. This project aims to irrigate 6,000 hectares of farmland and is part of the broader initiative to utilize the Gurara Dam's resources for multiple purposes, including hydroelectric power generation and water supply to the FCT. The area around the project shares similar climatic conditions and vegetation types with the Gurara project.

The Gurara multi-purpose dam was designed to generate hydro-electricity, municipal water supply (for Abuja by recharging the Usuma dam), aqua-culture, tourism and irrigation of 19,000Ha of land. Completed in 2007, the currently irrigable area is 12,000Ha (2,000Ha slightly downstream of the dam and 10,000Ha in Jere, about 40km away from the dam site). Full compensation has been paid for the dam reservoir area and the irrigation area to over 30 affected communities which include Maje, Attara, Akama, Chinka, etc. The reservoir capacity is 880MCM, hydropower generation installed capacity of 30MW, water level at 65m, dam crest length is 3.5km and sprinkler, pivot and drip irrigation infrastructure. The major concerns expressed by the dam workers were the issue of sprinkler vandalization by herdsmen, absence of agricultural extension services, and insecurity of farm equipment.

Both projects highlight the potential for significant agricultural productivity and economic development, though they have faced challenges in terms of infrastructure maintenance and effective utilization. Efforts are ongoing to enhance the security and functionality of these projects through public-private partnerships and investments in ancillary developments.

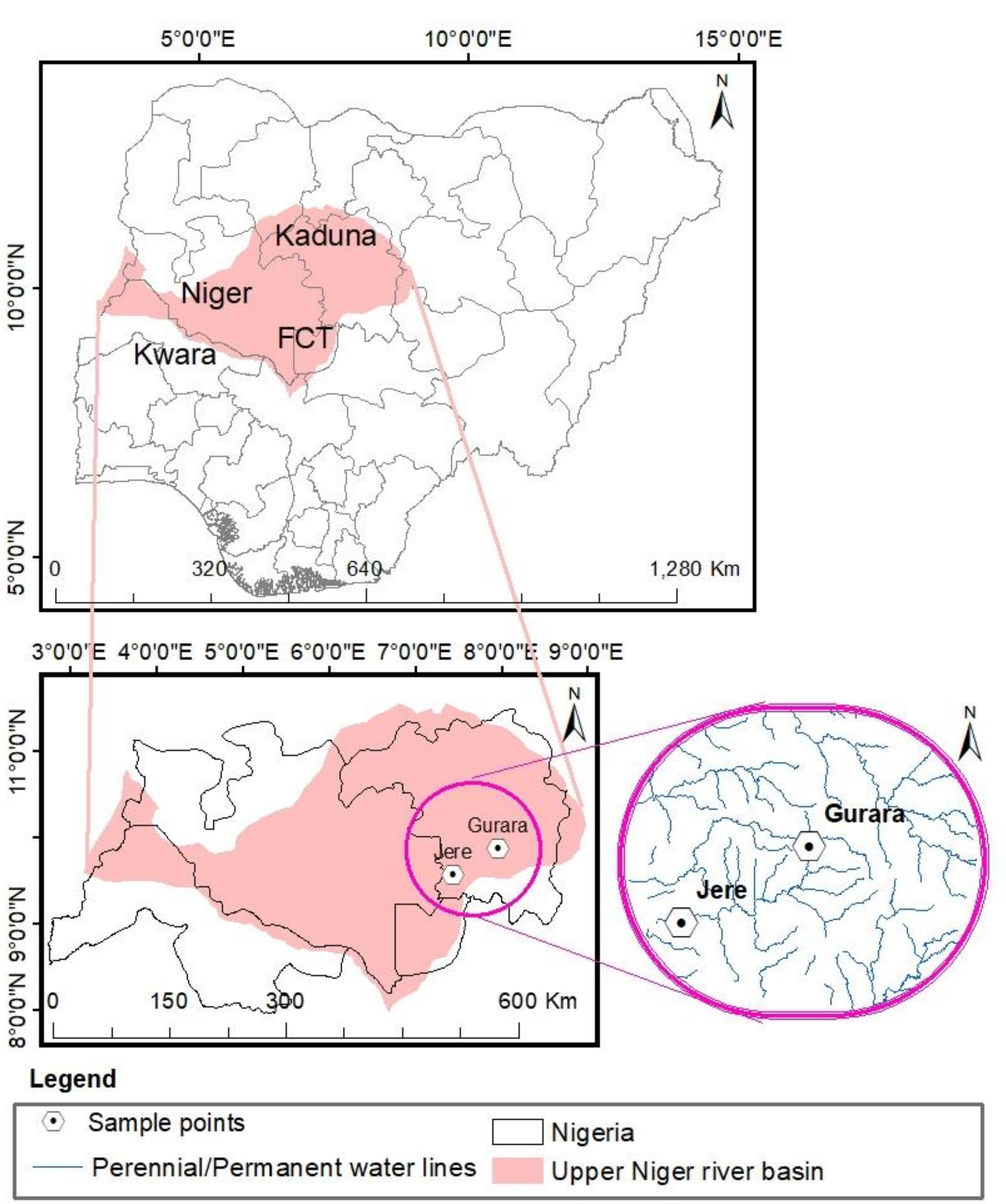

Fig. 2. Map of the study area

Plate 1(a) Sprinkler irrigation in progress at Gurara; and (b) CPIS in progress at Azara/Jere Irrigation Scheme

Materials and Methods

The objectives of the sampling activities are to: a) establish the existing state of the environment; and, b) evaluate the sensitivities of various environmental components to the existing (and planned) projects. Sampling activities were conducted based on the sampling plan evolved during the field survey of the RBDAs projects sites. The field activities generally aimed at gathering information to cover the following environmental and social attributes:

i. Soil quality assessment;
ii. Water quality assessment;
iii. Air quality & noise level assessment;
iv. Vegetation (landuse) cover analysis;
v. Availability of social facilities;
vi. Health assessment;
vii. Socio-economic and livelihood appraisal; and,
viii. Social characteristics of host communities.

Samples Collection, Laboratory Analysis and In-situ Assessment

Various methods were adopted during samples and data collection as each environmental and social component required unique methodology for sample and data collection and analyses. It is important to note clearly that the methodology adopted for this study is at variance with the one to be employed during an environmental audit which is expected to be repetitive across seasons (for the physical/environmental components).

A total of 10 water samples were collected at the irrigation project sites from a combination of surface, and underground water sources, at different locations including the dam reservoir, main irrigation canal, creek/natural canal, hand-dug wells for irrigation, isolated ponds, boreholes and wells at host communities, river channels downstream of reservoir. For soil samples, a total of 10 samples were collected within the RBDA for laboratory analyses, while a minimum of 14 and maximum of 21 locations for 7 days at each project site were sampled for air quality and noise level assessment.

Samples of water and soil were analysed for concentration of heavy metals, physical and chemical elements, biological contaminants, and oxides at the laboratory, while water temperature, EC and pH, air quality and noise levels were assessed on-site (in-situ). For the physical/environmental baseline data documentation, the Irrigation Water Quality Tool (IWQT) proposed by Bortolini *et al* (2018) was adopted (but modified to suit local conditions) for soil and water analysis. Therefore, the focus is on:

i. Agronomic quality (toxicity) indicators (pH, Sodium, EC and other physico-chemical parameters);
ii. Hygiene and health quality (sanitary risk) indicators (microbial count); and,
iii. Irrigation systems Management quality indicators (some heavy metals and chemical parameters).

Water Samples Laboratory Analysis

The water samples were tested for 24 parameters (Table 2) which include physico-chemical, heavy metals and biological parameters. These parameters are selected by way of modification of the Irrigation Water Quality Tool (IWQT) proposed by Bortolini *et al* (2018).

Table 2. Parameters tested in water samples at all 4 pilot RBDAs project sites

Category	Parameters
Physical/Chemical Parameters	pH Conductivity Temperature Dissolved Oxygen Total Dissolved Solids (DSS) Total Suspended Solids (TSS) Turbidity Total Hardness Chemical Oxygen Demand (COD)
Heavy Metal	Calcium Sodium Potassium Magnesium Copper Chromium Manganese Lead Zinc Iron

Biological Parameters	Total Coliform Count Faecal Coliform Count Biochemical Oxygen Demand (BOD) Thermo Tolerant Coliform (or E.coli) Faecal Streptococcus Clostridium Perfringens Spore

The sampling points for water samples collection were geo-referenced using a hand-held GPS equipment, and subsequently mapped. Water samples were collected by simple dip method using sterilized sample holding containers, and transported in a preservation box to the laboratory for analysis.

Soil Samples Laboratory Analysis

Soil analyses were conducted to determine the content of oxides, heavy metals and soil physical & biological parameters. Collectively, a total of 33 (8 for heavy metals, 17 for oxides, and 8 for physical and biological) parameters were tested per sample (Table 3). The detailed soil analysis procedure is presented in Appendix I. The Irrigation Water Quality Tool (IWQT) proposed by Bortolini *et al* (2018) was adopted, modified and applied to soil quality parameters selection for this study.

Table 3. Parameters analysed in soil samples

Category	**Parameters**
Heavy metals	Iron Lead Calcium Chromium Magnesium Manganese Zinc Copper
Oxides	SiO_2 TiO_2 Al_2O_3 Fe_2O_3 P_2O_5 SO_3 CaO

	MgO Na_2O K_2O MnO V_2O5 Cr_2O_3 NiO CuO BaO LOI
Physical & Biological	Ph Conductivity Bacteria Count Organic Carbon Organic Matter Moisture Content Temperature Cation Exchange Capacity (CEC)

Air quality and noise level in-situ assessment

For the air quality and noise levels assessment, samples were taken at a total of 18, 14, 16 and 15 locations at the project's locations over a period of 7 days at the site. On the whole, 11 air quality parameters and noise level (Table 4) were measured and assessed (mornings and late afternoons) and average values for each parameter obtained. Details of the equipment used for the air quality assessment are provided as follows: 10µm particulate monitor unit mg/m^3 model HD 1000 manufactured by Environmental Devices USA; Gas sensor model EEX IA IIC T3-T4 manufactured by CROWNCO GASMAN for HCN. For CH_3 (Flammable) EX IA S IIC T3-T4; for CO_2 (TOXIC) EEX IA IIC T3-T4; for NH_3 (TOXIC) EEX IA IIC T3-T4; for SO_2 (TOXIC) EEX IA IIC T3-T4; for CO (TOXIC) also NO_2 (TOXIC); all manufactured by same company. For temperature, the equipment used was the IN- and OUT-DOOR THERMOMETER manufactured by RION China.

Table 4. Air Quality and Noise Levels Parameters assessed

S/No.	Parameters
1.	Particulate Matter (PM_{10}) (mm/m^3)
2.	Noise (dB)
3.	Humidity (%)
4.	T^0C
5.	CO (ppm)
6.	CO_2 (ppm)
7.	NO_2 (ppm)
8.	NH_3 (ppm)
9	CH_3 (Flammable) (ppm)
10.	HCN (ppm)
11.	SO_2

Vegetation and Land Cover Analysis & Mapping

The mapping of relevant aspects of the basin was carried out using Google earth images and GPS point/locational data. The following basin-wide maps were generated during the course of the study: flow accumulation, DEM/DTM, topographical map, locational maps for dams and cultural features, landuse/cover map, NDVI and maps showing the locations of sampling.

Health Status Assessment

The Rapid Assessment Procedure (RAP) formed the core design adopted for the investigation of the health status of the communities surrounding the studied project sites. The appraisal was carried out to extract information from key informants and medical records from the primary healthcare centres (PHCs) and General Hospitals servicing the host communities. The focus on health-based effects is borne out of the correlation scientifically established between the prevalence of certain diseases (vector borne and zoonotic diseases [VBZDs], respiratory tract infections, water borne diseases, etc.) and other related dam/irrigation infrastructure. Key Informant Interviews (KIIs) with health workers, and medical records (January to April 2019) at a total of 8 healthcare facilities (3 General Hospitals, 4 PHCs and 1 Missionary Clinic) at 3 project sites were used for the health appraisal while a telephone interview was conducted with the Medical Doctor on duty at the time Dr. Arome Okeme at Katari which is about 100km away from the Gurara dam site but the closest working health facility.

Key Informant Interviews (KIIs)

KIIs were conducted to interview some select key stakeholders (Traditional, Religious and Community Leaders, Leaders of the Water Users' Association, farmers, and residents at host communities) and the Project Managers at each of the irrigation projects. The KII aimed at gathering thoughts and information about the surrounding communities regarding on-going economic and livelihood activities and health conditions at the dams and irrigation projects sites, as well as the availability of facilities such as schools and healthcare centres, etc., while issues regarding land acquisition, resettlement and compensation were also interrogated at all project locations. Given that this is basically a rapid assessment, an expansive Stakeholders' forum/engagement was not conducted. However, this is expected to be conducted in the event that a full ESIA is required or during the full environmental audit phase (after full project design and feasibility but certainly before project commencement as required by law) which will be monitored by the FME and other relevant authorities.

For the KIIs, the Open Data Kit App (https://opendatakit.org/), an open-source data collection platform used by mobile hand-held devices running the Android Operating Systems, was used for administering the structured questionnaire used for the KIIs. Combined with the Formhub (https://formhub.org/) data aggregation tool, the data collection process was automated such that survey data was aggregated in digital format in real-time to an internet-based secure server, and viewed on a PC running a local instance of the Formhub software. This allowed for remote ability to view, analyze and report on data collected in the field on a geo-referenced base map, in real-time, irrespective of location of data analyst.

Result of the Findings

The results from laboratory and field analyses of various parameters were subjected to descriptive statistical analysis and analysis of variance (ANOVA) to ascertain the statistical significance of the degree of variation between the results of the various locations of each sample type (water, air and soil). This same analysis is applied to land cover data generated from land cover change detection, NDVI and LST. Furthermore, the mean values of results generated from soil, water and air/noise sampling were compared to acceptable /prescribed/recommended levels and standards by WHO, FAO, Nigeria's Federal Ministry of Environment and other well-researched and documented sources in the literature. The outcome provided the basis for flagging areas requiring immediate or future attention in projects design and conceptualization.

Water Quality Results

Irrigation water, irrespective of source, contains appreciable quantities of chemical substances in solution that may reduce crop yield and deteriorate soil fertility. In addition to the dissolved salts which have been the major problem for centuries, irrigation water carries substances derived from its natural environment or from the waste products of man's activities (domestic and industrial effluents). These substances may vary in a wide range, but mainly consist of dirt and suspended solids (SS) resulting into the emitters' blockages in micro-irrigation systems and bacteria populations and coliforms harmful to the humans and the animals. Basically, certain water elements have a higher potential to disrupt crop productivity. It is therefore, essential to understand the quantum of occurrence of these elements in water sources around irrigation project sites (Brady & Weil, 2002; Seid & Genanew, 2013). The water samples taken from 10 points at the Gurara and Azara/Jere irrigation sites consist of a number of sources including the dam reservoir, River Gurara downstream of reservoir, and other streams at the 2 sites.

Physico-chemical: The mean values of the laboratory analysis results indicate that TDS and hardness all occur below permissible limit (BPL) while EC, Na and K occur above permissible limit (APL). Given that the mean value of sodium is recorded APL, the implication is that both soil and plants would be adversely affected as sodium once deposited from irrigation water, sodium becomes relatively impermeable to air and water (Husien *et al*., 2017). All water samples recorded pH values below 6.5 (Table 5), an indication of high acidic concentration. It is important to note that for EC, TDS, TSS, COD and BOD, the limit adopted is for irrigation purpose while all other limits are adopted for drinking water as provided by WHO (2012) guidelines for drinking water. This is considered relevant as it was observed during field work that most of the communities around dams actually use reservoir water for drinking and other domestic uses.

Table 5. Concentration of Physico-chemical parameters in water samples at Gurara & Azara/Jere Irrigation Projects

Samples	Chemical Parameters (Mg/L)									
	pH	**EC**	**DO**	**Hardness**	**COD**	**BOD**	**Na**	**K**	**TDS**	**TSS**
A	6.0	53.9	7.8	15.6	0.8	13.1	0.7	0.5	1.0	Trace
B	5.8	91.8	9.2	13.2	1.4	15.4	1.5	0.5	2.0	0.1
C	5.8	50.1	6.9	15.6	1.0	13.6	0.9	0.4	2.0	Trace
D	6.2	184.4	5.7	21.6	0.9	12.8	2.0	0.7	1.0	Trace
E	5.9	50.5	7.3	16.8	0.8	19.2	1.0	0.3	1.0	Trace
F	5.6	49.3	8.1	16.8	1.1	12.4	0.8	0.4	1.0	Trace
G	6.0	56.2	6.9	22.8	1.1	11.6	0.8	0.3	1.0	Trace
H	5.9	92.4	7.7	37.2	0.7	10.8	1.1	0.2	1.0	Trace
I	6.3	187.4	9.7	31.2	1.1	18.8	1.8	0.7	3.0	0.2
J	6.3	74.5	7.5	32.4	0.8	12.2	1.0	0.3	2.0	0.2
Min	**5.60**	**49.30**	**5.70**	**13.20**	**0.70**	**10.80**	**0.70**	**0.20**	**1.0**	**0.00**
Max	**6.30**	**187.40**	**9.70**	**37.20**	**1.40**	**19.20**	**2.0**	**0.70**	**3.0**	**0.02**
Mean	**5.980**	**89.0500**	**7.680**	**22.320**	**0.970**	**13.99**	**1.160**	**0.430**	**1.50**	**0.50**
SD	**0.22998**	**53.63741**	**1.14969**	**8.41332**	**0.21108**	**2.91069**	**0.45019**	**0.17029**	**0.70711**	**0.08498**
Limit	**6.5-8.5**	**0.7-3.0**	**NP**	**50-200**	**250mg/L**	**100ppm**	**0.05**	**0.012**	**450-2000**	**30mg/L**
Status	**OPR**	**APL**	**NA**	**BPL**	**BPL**	**BPL**	**APL**	**APL**	**BPL**	**BPL**

Source: Lab. Analysis results

Heavy metals: Heavy metals are basically non-degradable elements that are harmful to human, plant and animal populations. Their occurrence is largely associated with anthropogenic activities including certain agricultural practices such as use of certain synthetic fertilisers, pesticides and herbicides, etc. The heavy metals from water samples at Gurara and Azara/Jere irrigation sites exhibit varying concentration. Out of the 8 heavy metals assessed, 5 reveal concentrations APL while chromium and copper occur BPL. Lead was not recorded in any of the water samples (Table 6). With regards to heavy metal, the most polluted water sample is 'H' taken from Azara stream in Farm 1 at Azara/Jere Irrigation Project site. The permissible limits adopted for heavy metals are those prescribed by WHO (2012) guidelines for drinking water.

Table 6. Heavy metals concentration in water samples at Gurara & Azara/Jere Irrigation Projects

Samples	**Heavy Metals Parameters (Mg/L)**							
	Ca	**Cu**	**Cr**	**Fe**	**Mg**	**Mn**	**Pb**	**Zn**
A	922.3881	0.0412	ND	0.4514	58.6896	0.1504	ND	0.0862
B	817.3134	0.0230	0.0902	0.2532	59.2691	0.3154	ND	0.0138
C	764.1791	0.0266	ND	0.0073	59.0455	0.2964	ND	0.0411
D	873.4328	0.0085	0.0773	0.1064	59.0000	0.0876	ND	0.0170
E	891.9403	0.0569	ND	0.4698	56.6779	0.1051	ND	0.0933
F	728.9552	0.0642	0.0193	0.0954	50.7216	0.0102	ND	0.0652
G	796.4179	0.0787	0.0258	0.3523	50.2125	0.0832	ND	0.0704
H	963.5821	0.0787	0.0451	0.3120	52.6753	0.0993	ND	0.0925
I	633.4328	0.0763	0.0902	0.1211	58.8965	0.4263	ND	0.0684
J	779.7015	0.0751	0.0021	0.2055	49.3267	0.3752	ND	0.0510
Min	**633.43**	**0.01**	**0.00**	**0.01**	**0.00**	**0.01**	**0.00**	**0.01**
Max	**963.58**	**0.08**	**0.09**	**0.47**	**59.27**	**0.43**	**0.00**	**0.09**
Mean	**817.1343**	**0.0529**	**0.0350**	**0.2374**	**49.5618**	**0.1949**	**0.00**	**0.0599**
SD	**98.57160**	**0.02627**	**0.03811**	**0.15763**	**17.87331**	**0.14459**	**0.00**	**0.02883**
Limits	**0.01**	**0.02**	**0.05**	**0.1**	**0.05**	**0.1**	**0.01**	**0.01**
Status	**APL**	**BPL**	**BPL**	**APL**	**APL**	**APL**	**BPL**	**APL**

Source: Lab. Analysis results

Microbial Count: The microbial count analyses revealed that the Faecal coliform, Faecal Streptococus and Clostridium Perfringens Spore were not present in all the 10 samples taken from the Gurara and Azara/Jere Irrigation Project environment. However, there are relatively high microbial counts for Total Coliform Count (TCC), Thermo Tolerant Count (TTC) and Bacterial Count. Again, Sample H records the highest TCC as shown in Table 7 and 8 (cattle were also sighted grazing around the harvested fields), while Sample E (taken from an irrigation chamber at the Gurara Irrigation site, a source of water also used by community members for consumption) records the highest aerobic and anaerobic bacterial count (Table 9).

Table 7. Microbial Enumeration in Water samples at Gurara & Azara/Jere Irrigation Projects [**Total Coliform Count (TCC)]**

Sample	**Number of tubes giving positive reaction out of**			**MPN Coliform**
	3 of 10ml	**3 of 1ml**	**3 of 0.1ml**	
A	2	1	1	**20**
B	2	1	1	**20**
C	2	2	0	**21**
D	1	1	0	**8**
E	2	0	0	**9**
F	2	1	1	**20**
G	1	1	0	**8**
H	3	3	2	**1100**
I	3	2	2	**210**
J	3	2	1	**150**

Source: Lab. Analysis results

Table 8. Thermo tolerant coliforms (TTC)

Sample	**Number of tubes giving positive reaction out of**			**MPN Coliform**
	3 of 10ml	**3 of 1ml**	**3 of 0.1ml**	
A	2	1	0	**15**
B	1	0	0	**4**
C	1	1	0	**8**
D	1	0	0	**4**
E	0	0	0	**0**
F	0	0	0	**0**
G	0	0	0	**0**
H	2	0	0	**9**
I	2	1	1	**20**
J	2	1	0	**15**

Source: Lab. Analysis results

Table 9. Bacterial count (Viable counts/Total plate count)

Sample Code	Aerobic x 10^5		Anaerobic x 10^5	
	Plate counts	Standard cfu/ml	Plate counts	Standard cfu/ml
A	09	**9 x 10^5**	08	**8 x 10^5**
B	06	**6 x 10^5**	03	**3 x 10^5**
C	15	**1.5 x 10^6**	05	**5 x 10^5**
D	07	**7 x 10^5**	05	**5 x 10^5**
E	67	**6.7 x 10^6**	16	**1.6 x 10^6**
F	05	**5 x 10^5**	03	**3 x 10^5**
G	13	**1.3 x 10^6**	06	**6 x 10^5**
H	12	**1.2 x 10^6**	04	**4 x 10^5**
I	14	**1.4 x 10^6**	03	**3 x 10^5**
J	19	**1.9 x 10^6**	04	**4 x 10^5**

Source: Lab. Analysis results

Soil Quality Results

Generally, soil quality is the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, maintain the quality of air and water environments, and promote plant, animal, and human health. In the literature, soil 'quality' and soil 'health' are often used interchangeably. However, soil health is most often used to emphasize the linkage between soil and human or animal health, and the idea that soil works as an organism or system, while soil quality is used as the more technical term (Ujoh, 2013). Generally, soil contaminants (chemical, heavy metals and microbial) exert toxic effect on soil micro-organisms resulting in the alteration of the diversity, population size and overall activities of the soil microbial communities (Ashraf & Ali, 2007). So, it is crucial to understand the quality of soils when proposing investments into irrigation agriculture. For instance, it is instrumental to know that cation exchange capacity (CEC) is an estimate of the capacity of soil to hold or adsorb positively charged nutrients known as cations majorly calcium (Ca2+), potassium (K+), sodium (Na+), magnesium (Mg2+), etc. Also, it is equally important to know that CEC is primarily influenced by soil type, pH levels and amounts of organic matter, hence, the higher the CEC, the more the clay and organic matter content present in the soil, ultimately determining the quality of support for plants, animals and humans. Similarly, Soil pH which is probably the most commonly measured soil chemical property indicates acidity or alkalinity of the soil. It is also an excellent indicator of a soil's suitability for plant growth which in turn affects the availability of nutrients to the crop. However, crops vary in their acidity tolerance, growing best in a narrow pH range, while the desirable pH range for optimum plant growth also varies among crops (Adejumobi *et al*., 2014). The result of laboratory analysis of soil samples taken at Gurara and Azara/Jere irrigation project sites are presented in Tables 10, 11, 12 and 13.

Physico-chemical: The chemical composition of the soil samples show that the mean value of Organic carbon occurs APL while organic matter is found to occur below required level (BRL) for optimal plant growth. Although sodium is not a plant nutrient, nonetheless it does play a role in soil health. High levels of sodium indicate salinity problems or sodicity problems such as poor soil structure while excess sodium can also reduce the uptake of other nutrients by plants. In Photosynthesis, potassium regulates the opening and closing of stomata, and therefore regulates CO_2 uptake. Also, sodium soils are relatively impermeable to air and water, making both soils and plants adversely affected (Husien *et al*., 2017). All of these respective roles played by these elements indicate that there is need to document the quantum of each element/mineral in soils to confirm adequacy for irrigation or otherwise develop solutions to remedy the identified issues to the extent that irrigation agriculture becomes a viable investment.

Heavy Metals: For heavy metals, 8 parameters were assessed out of which 4 each were APL and BPL (Table 11). The 4 heavy metals with APL amounts are calcium, copper, manganese and zinc. Although calcium helps in soil amendment by maintaining chemical balance in the soil, reduction of soil salinity, and improvement of water penetration, nonetheless excess calcium in soil results in reduced uptake of other cation nutrients. Excess copper is highly toxic for the growth and health of some crops including tubers like sweet potato. In excess amount, copper can inhibit the uptake of iron therefore, stunt plant growth. The occurrence of copper in soils is primarily influenced by pH and organic matter. Manganese is an essential plant mineral nutrient, playing a key role in several physiological processes, particularly photosynthesis. Its deficiency is a widespread problem, most often occurring in sandy soils, organic soils with a pH above 6 and heavily weathered, tropical soils. However, in excess amount, manganese can reduce plant growth and inhibit phosphorous uptake. Its availability in soil is influenced by pH and organic matter. Zinc is a key constituent of many enzymes and proteins. It plays an important role in a wide range of processes, such as growth hormone production and internode elongation. Severe damage to the roots at high zinc concentration may cause general yellowing and wilting. High levels of zinc inhibit the uptake of iron, and it is common to find symptoms of severe iron deficiency induced by zinc toxicity. These 4 excess occurrences (in calcium, copper, manganese and zinc) and accompanying effects combine to form the heavy metals deficiencies in the soils around the Gurara and Azara/Jere Irrigation Project sites. Lead is not detected in any of the 10 soil samples while chromium, iron and magnesium are found occurring below the excess threshold limit in soils.

Table 10. Concentration of Physico-chemical parameters in Soil samples at Gurara & Azara/Jere Irrigation Projects

Samples	pH	EC	Organic Carbon	Organic Matter	Na	K	CEC	Moisture
A	5.6	47.3	0.16	0.28	0.30	0.31	19.6	1.0
B	5.7	43.0	0.28	0.48	0.52	0.38	22.6	1.5
C	5.8	110.5	0.14	0.24	0.39	0.28	19.2	1.5
D	5.8	42.9	0.32	0.55	0.52	0.56	21.6	2.5
E	5.7	40.1	0.14	0.24	1.61	2.51	32.2	2.5
F	5.8	124.7	0.06	0.10	1.70	2.46	31.4	1.5
G	5.5	57.9	0.28	0.48	0.30	0.46	20.4	1.5
H	5.7	60.2	0.34	0.59	0.65	0.64	24.2	2.5
I	5.5	53.5	0.12	0.21	0.43	0.31	23.4	2.5
J	5.8	58.6	0.12	0.21	1.70	0.44	27.8	2.0
Min	**5.50**	**40.10**	**0.06**	**0.10**	**0.30**	**0.28**	**19.20**	**1.0**
Max	**5.80**	**124.70**	**0.34**	**0.59**	**1.70**	**2.51**	**32.20**	**2.50**
Mean	**5.690**	**63.870**	**0.196**	**0.3380**	**0.8120**	**0.835**	**24.240**	**1.900**
SD	**0.1197**	**29.390**	**0.09879**	**0.1702**	**0.60175**	**0.87704**	**4.70631**	**0.568**
Limits	**5.5 – 7**	**1.0 -3.0**	**1.0 – 3.0**	**>3.4**	**NP**	**150-250ppm**	**NP**	**NP**
Status	**WPL**	**APL**	**BPL**	**BRL**	**NA**	**BPL**	**NA**	**NA**

Source: Lab. Analysis results

Oxides: Generally, geological formations also influence the presence of some oxides in the soil, however the quantities are usually trace. Higher concentrations (such as the levels recorded in some of the samples analysed) are driven largely by pollutants from anthropogenic (industrial and other human) activities. The oxides results (Table 12) shows that FeO_3, CaO, MgO, Ca_2O and K_2O occur APL in soils for agricultural purposes as stipulated by Bohn *et al.*, (2001). Permissible limit for the rest of oxides assessed were not found.

Table 11. Heavy metals concentration in Soil samples at Gurara & Azara/Jere Irrigation Projects

Samples	Heavy Metals Parameters (Mg/kg)							
	Ca	**Cu**	**Cr**	**Fe**	**Mg**	**Mn**	**Pb**	**Zn**
A	1020.2985	0.1042	0.1481	1.3469	61.6905	3.7449	ND	0.1399

B	2177.9104	0.1502	0.1825	1.9157	60.2583	1.4439	ND	0.1957
C	1173.1343	0.3682	0.2662	1.4423	62.4521	5.1305	ND	0.2099
D	1614.9254	0.2350	0.1095	1.5524	63.7973	4.6428	ND	0.1340
E	1004.7761	0.1199	0.1975	1.4460	65.2378	1.5637	ND	0.1384
F	1166.5672	0.1441	0.1395	1.6699	65.2088	1.1198	ND	0.1819
G	1156.4179	0.1223	0.1975	1.5231	60.8833	1.0556	ND	0.1040
H	1012.5373	0.1490	0.2920	1.4974	62.3859	1.1125	ND	0.1281
I	1007.1642	0.1054	0.1202	1.5010	64.1657	1.7651	ND	0.1929
J	812.5373	0.1211	0.1868	1.3102	62.0175	4.3829	ND	0.1427
Min	**812.54**	**0.10**	**0.11**	**1.31**	**60.26**	**1.06**	**0.00**	**0.10**
Max	**2177.91**	**0.37**	**0.29**	**1.92**	**65.24**	**5.13**	**0.00**	**0.21**
Mean	**1214.6269**	**0.1619**	**0.1840**	**1.520**	**62.8097**	**2.5962**	**0.00**	**0.1568**
SD	**397.62232**	**0.08168**	**0.05933**	**0.17207**	**1.7280**	**1.66541**	**0.00**	**0.03531**
Limits	**1,000**	**0.05**	**100**	**6.3**	**100**	**0.01**	**0.01**	**0.05**
Status	**APL**	**APL**	**BPL**	**BPL**	**BPL**	**APL**	**BPL**	**APL**

Source: Lab. Analysis results

Bacterial Count: Generally, the numbers and kinds of microorganisms present in any given soil depend on any one or a combination of the following environmental factors: amount and type of nutrients available, available moisture, degree of aeration, pH, temperature, etc. (Ogunmwonyi *et al.*, 2008). Soil bacteria play pivotal roles in various biochemical cycles and are responsible for the recycling of organic compounds (Wall & Virginia, 1999). Bacteria make up the most abundant group of microorganisms in the soil ($3.0 \times 10^8 – 5.0 \times 10^8$) per gram of soil (Ogunmwonyi et al., 2008). The total bacterial count (TBC) from the soil samples taken at Gurara and Azara/Jere irrigation site (Table 13) shows presence of bacteria in all except samples A and B (taken at Dam toe and at the Drip irrigation farm, respectively) while the highest presence is recorded at Samples C and D, taken from the Sprinkler and Surface irrigation fields, respectively.

Table 12. Oxides concentration in Soil samples at Gurara & Azara/Jere Irrigation Projects

Samples	Oxides (Mg/kg)										Statistical Analyses					
	A	B	C	D	E	F	G	H	I	K	Min	Max	Mean	SD	Limit	Status
SiO_2	86.90	86.80	84.82	85.22	84.78	86.60	86.85	84.74	86.72	86.00	**84.74**	**86.90**	**85.943**	**0.94840**	**NP**	**NA**
TiO_2	0.28	0.24	0.17	0.18	0.16	0.20	0.26	0.15	0.22	0.19	**0.15**	**0.28**	**0.2050**	**0.04378**	**NP**	**NA**
Al_2O_3	2.86	2.80	3.70	3.80	3.68	2.50	2.84	3.65	2.67	3.86	**2.50**	**3.86**	**3.2360**	**0.54177**	**NP**	**NA**
FeO_3	0.97	0.92	0.85	0.87	0.82	0.88	0.95	0.80	0.90	0.90	**0.80**	**0.97**	**0.8860**	**0.05379**	**0.577**	**APL**
P_2O_5	0.14	0.08	0.18	0.19	0.17	0.02	0.10	0.15	0.05	0.20	**0.02**	**0.20**	**0.1280**	**0.06233**	**NP**	**NA**
SO_3	0.027	0.024	0.010	0.011	0.009	0.021	0.026	0.008	0.023	0.013	**0.01**	**0.03**	**0.0175**	**0.00821**	**NP**	**NA**
CaO	1.53	1.08	1.40	1.42	1.37	0.38	1.20	1.35	0.85	1.46	**0.38**	**1.53**	**1.2040**	**0.35362**	**0.25**	**APL**
MgO	1.10	1.02	0.91	0.93	0.88	0.99	1.06	0.86	1.00	0.96	**0.86**	**1.10**	**0.9710**	**0.07767**	**0.25**	**APL**
Na_2O	0.55	0.50	0.44	0.45	0.42	0.47	0.53	0.40	0.48	0.47	**0.40**	**0.55**	**0.4710**	**0.04677**	**0.15**	**APL**
MnO	0.15	0.13	0.09	0.10	0.07	0.11	0.14	0.06	0.12	0.12	**0.06**	**0.15**	**0.1090**	**0.02923**	**NP**	**NA**
V_2O_5	0.24	0.21	0.28	0.30	0.27	0.11	0.22	0.25	0.18	0.32	**0.18**	**11.00**	**1.3270**	**3.39901**	**NP**	**NA**
CrO_3	0.092	0.087	0.048	0.050	0.046	0.084	0.090	0.044	0.085	0.054	**0.04**	**0.09**	**0.0676**	**0.02064**	**NP**	**NA**
NiO	0.43	0.39	0.29	0.32	0.26	0.37	0.41	0.24	0.38	0.35	**0.24**	**0.43**	**0.344**	**0.06433**	**NP**	**NA**
CuO	5.9	5.6	4.7	5.0	4.5	5.3	5.7	4.3	5.5	5.2	**4.30**	**5.90**	**5.1700**	**0.53552**	**NP**	**NA**
BaO	4.22	4.18	4.30	4.50	4.10	3.21	4.20	4.00	4.15	4.80	**3.21**	**11.38**	**4.8240**	**2.32838**	**NP**	**NA**
LOI	11.67	11.40	11.93	12.00	11.88	11.30	11.55	11.75	11.38	12.15	**0.14**	**12.15**	**10.577**	**3.67689**	**NP**	**NA**
K_2O	0.25	0.16	0.30	0.34	0.28	0.12	0.20	0.26	0.14	0.40	**0.12**	**4.80**	**0.7110**	**1.43909**	**0.15**	**APL**

Table 13. Bacteria count in Soil samples at Gurara and Azara/Jere Irrigation Projects

Sample	**Plate counts**	**Standard cfu/ml**
A	INC	**INC**
B	INC	**INC**
C	288	**2.88×10^7**
D	192	**1.92×10^7**
E	112	**1.12×10^7**
F	76	**7.6×10^6**
G	88	**8.8×10^6**
H	96	**9.6×10^6**
I	108	**1.08×10^7**
J	104	**1.04×10^7**

Air Quality & Noise Levels Assessment Results (Gurara & Azara/Jere)

Up to one-fifth of the total disease burden in developing countries may be associated with environmental risk factors. While the disease burden in poor countries is about twice that of richer countries, the disease burden from environmental risk is 10 times greater in developing countries. Poor people are most affected by environmental conditions such as unsafe drinking water, poor air quality and exposure to dangerous substances (e.g. pesticides, mercury from illegal mining, etc.). Research has shown that people are aware of how poor environmental conditions affect both their wellbeing and their ability to move out of poverty. Although it may be argued that the existing and proposed projects at the 4 RBDAs are located in largely non-populated locations, it is nevertheless, expected that these projects (along with the multiplier effect of the full value change) would attract increased population eventually as businesses and workers converge. There is therefore, the risk of exposure to air-borne pollutants and eventual risk of diseases such as pneumonia and chronic respiratory disease and there is emerging evidence that it may also increase the risk of TB, low birth weight and cataract, amongst several other diseases.

The air quality readings for the study area (Table 14) reveal varying results. The mean values for PM_{10} (Particulate matter), CO (carbon monoxide) NO_2 (Nitrogen dioxide), CH_3 (Acetone) and HCN (hydrogen cyanide) all fall BPL, while SO_2 (Sulfur dioxide) and humidity fall WPL. For CO_2 (Carbon dioxide), 17 out of the 18 sampled points record readings way above the permissible limit of 250-350ppm, while NH_3 (Azanide) also records mean values APL. These permissible limits are set by Nigeria's FME, WHO (2006), Occupational Safety and Health Administration–Permissible Exposure Limit and other sources in the literatures. For temperature, permissible limit values were not provided. However, the recorded values at the study site generally appear to be high (mean = 35.9%) but within tolerable levels of human comfort. It is important to note that the relevance of temperature (and humidity) is in their combined effect on the buoyancy and eventual movement of particulate matter (and other air quality pollutants) as well as the concentration level at any particular area.

Table 14. Air quality results for Gurara and Azara/Jere Irrigation Projects

S/N	**Parameters**	**Point 1**	**Point 2**	**Point 3**	**Point 4**	**Point 5**	**Point 6**	**Poin t 7**	**Point 8**	**Point 9**	**Point 10**	**Point 11**	**Point 12**	**Point 13**	**Point 14**	**Point 15**	**Point 16**	**Point 17**	**Point 18**	**Min**	**Max**	**Mean**	**SD**	**Limit**
1	PM_{10} (mm/m^3)	49	44.5	116	68	62	46	46	35.6	37.6	31.2	29.2	47.6	36.3	57.6	19.6	28.6	27.9	33.4	20	116	46.22	21.9	150-230 $\mu g/m^3$
2	Noise (dB)	70	83.9	51.1	48	100	185	95	78.9	52.1	39	38.1	47.3	38.2	72	36	43.1	46.1	34	34	185	65.81	37.24	90 dB(A)
3	Humidity (%)	43	37.2	39.9	36		60.1	59	52		60.2	49.9	46.6	50.1	30.5	50.2	40.5	45.7	46.7	31	65.9	48.78	10.51	30-60%
4	T^0C	38	37.3	39.4	36	31	33.1	36	35.5	30.6	31.4	35.5	38.6	36	42.2	35.2	38.8	36.6	35.5	31	42.2	35.98	3.11	NP
5	CO (ppm)	0	0.02	3	3	6	4	5	4	16	4	6	20	4	17	3	7	4	4	0	20	6.12	5.82	9ppm
6	CO_2 (ppm)	287	579	487	609	739	698	661	486	698	585	687	644	408	696	602	775	667	654	287	775	604.41	125.6	250-350ppm
7	NO_2 (ppm)	0	0.04	0.04	0.1	0	0.04	0.1	0.05	0.03	0.04	0.04	0.04	0.04	0.02	0.04	0.04	0.03	0.04	0	0.05	0.039	0.007	0.06ppm
8	NH_3 (ppm)	0	0.03	0.03	0	0	0.03	0	0.04	0.02	0.03	0.03	0.03	0.03	0.01	0.03	0.03	0.02	0.03	0	0.04	0.027	0.007	0.21ppm
9	CH_3 (Flammable) (ppm)	0	0.04	0.02	0	0	0.02	0	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.04	0.02	0.02	0.03	0	0.04	0.025	0.007	500ppm
10	HCN (ppm)	-	0.01	0.02	0	0	-	0	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0	0.02	0.013	0.005	4.7ppm
11	SO_2	-	-	-	-	-	0.01	-	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0,01	0.02	0.012	0.003	0.01-0.1 ppm

Recorded noise levels ranged from a minimum of 34.0 dB(A) to a maximum of 185.4 dB(A), and a mean value of 65.4 dB(A) across all 18 sampled points. Although the noise levels recorded were generally low, the highest recordings are taken from points 6, 5 and 7 (that is, Power House, Reservoir Inlet, and Sprinkler Irrigation Plot, respectively) while the least noise level is recorded at Farm 3 of the Azara/Jere irrigation site. The recorded trend shows higher noise levels at the Gurara dam site with lower noise levels recorded at the Azara/Jere site. Generally, the recorded noise levels are all below the Federal Ministry of Environment's regulatory limit of 90 dB(A) for 8-hour exposure at all locations, except for points 5, 6 and 7.

Land Cover, DEM and NDVI (Gurara & Azara/Jere)

Figure 3a and 3b shows the river and road/rail, respectively networks within the Upper Niger River Basin, while the land cover map showing 6 main land cover types (Woodland, Grassland, Urban, Agricultural land, Bareland and Water) is presented as Figure 3c. Other maps include (d) NDVI with the Gurara and Azara/Jere project areas showing a vegetation index range of between 0.527 - 0.601; (e) a high DEM of 1,362m and low of 30m; and (f) population density as distributed across the basin. The classification, quantification and distribution of land cover within the UNRBDA was determined through the identification of 6 land cover classes as shown on Table 15 and Figure 3c. The land coverage (using a 2018 satellite imagery from the Landsat platform) shows that grassland, not unexpectedly, is currently the most expansive land cover type within the basin. The least land cover is bareland. Niger state is the largest state by land mass. In addition to rural parts of the FCT (around Yaba and other interior locations) and parts of Kaduna state, there is a vast area/expanse of un-inhabited land hence, it is not unexpected that the built-up area constitutes less than 1% of the land cover of the Upper Niger basin. The area coverage of water bodies is attributed to the several dams within the basin some of which include Gurara, Galma, Kainji, etc. Agricultural land is expectedly the 3rd largest land cover within the basin as farming is the major pre-occupation within the region, given the amount of rainfall incident within the region especially around parts of the FCT, most of Niger State, and southern parts of Kaduna around Kachia and Kagarko LGAs).

Table 15. Land cover status within the Upper Niger Basin

S/No.	Landcover type	Area		
		Km^2	%	Pixels
1.	Woodland	126.252	10.3	14,028
2.	Grassland	901.179	73.5	100,131
3.	Agricultural land	177.678	14.5	19,742
4.	Urban	7.236	0.6	804
5.	Water	9.972	0.8	1,108
6.	Bareland	4.068	0.3	452
Total		1,226.385	100	136,265

A Digital Elevation Model (DEM) is a spatially geo-referenced raster-based data set that is popularly used for environmental modeling purposes (Toz & Erdogan, 2008). DEMs are widely used tools to better assess, visualize and examine topographic features. Each cell of the DEM contains a representative value of the elevation related to the areal limit of the cell (Moglen & Maidment, 2005). In this work, the National Aeronautics and Space Administration (NASA) Shuttle Radar Topographic Mission (SRTM) digital elevation data was used to extract DEM. It is important to note that the NASA SRTM has provided DEMs for more than 80% of the globe. The National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) Normalized Difference Vegetation Index (NDVI) data sets used in this study were obtained from the NASA Global Inventory Modeling and Mapping Studies (GIMMS) group stretching from the period 1985 to 2015 (30 years). AVHRR GIMMS was selected because it is the only global updated records and also the most widely used AVHRR dataset (Yin *et al*, 2012). For accuracy reasons, the GIMMS NDVI is considered most suitable for the NDVI analysis of this study.

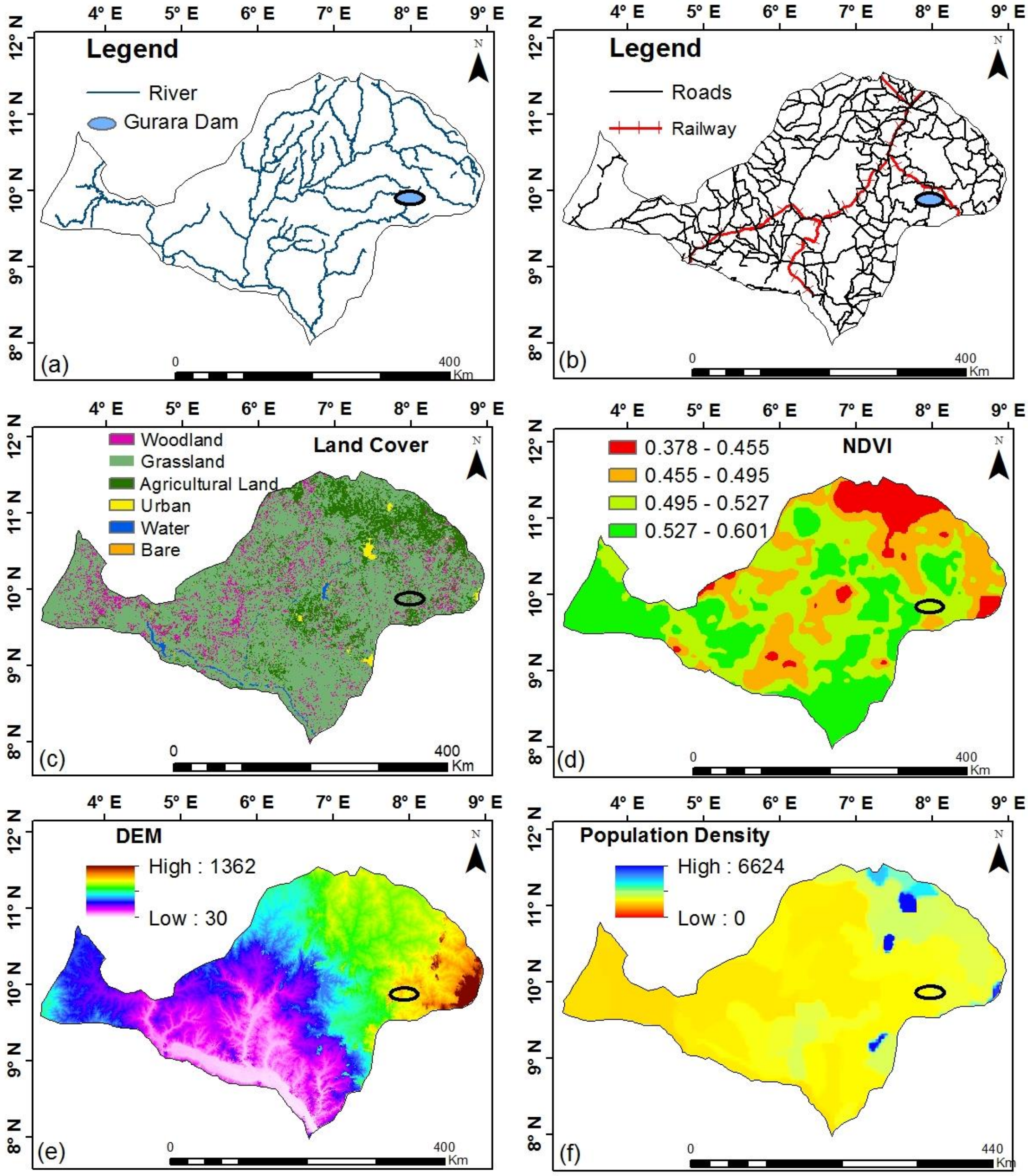

Figure 3. Upper Niger Basin-wide maps of (a) river network (b) road and rail network (c) Land cover classification (d) NDVI distribution (e) DEM (f) Population density.

Remote Sensing Based Soil Parameters & Climate Elements Analysis

Figure 4 shows analyzed maps of (g) mean precipitation from 1985-2015 which ranges from 1,115.6 mm to a low of 76 mm; (h) mean temperature with a high of 28.2 ^{0}C and a low of 23.3 ^{0}C from 1985-2015; (i) a high Cations Exchange Capacity of 51 cmol/ to a low of 0 cmolc/ kg; (j) soil pH from a high of 6.5 to a low of 0; (k) a high concentration of soil organic Carbon of 141g/kg and a low concentration of 0g/kg., and, (l) high bulk density of 1158g/cm^3 to a low of 1150g/cm^3. These statistics were generated from satellite remote sensing platforms as against the in-situ records and laboratory analysis results discussed in the preceding sections above. Climate factors, particularly temperature and rainfall, present favorable conditions and in some situation's unfavorable conditions for cultivation, development and production of crops (Samanta *et al*, 2011). This study used gridded rainfall and temperature data obtained from the

Climate Research Unit (CRU) of University of East Anglia (UEA) from 1985 to 2015 (30 years). The CRU data set is a gridded observation which has been widely applied in many studies over West Africa.

The Soil pH describes the level of acidity or alkalinity in the soil which ranges from 0-14 and pH lower (higher) than 7 indicate acidity (alkalinity). Neutral soils have pH of 7. Soil pH affects crop development, yields, suitability, nutrient availability, and soil micro-organism activity, thereby influencing crucial soil processes (USDA-NRCS, 1998). All plants are affected by excessive levels of pH but there is wide variation in their tolerance of acidity and alkalinity in the soil. A pH range between 4 and 8 is most favorable for rice cultivation (Widiatmaka *et al*, 2016). Given that the CEC is a property of a soil that shows its ability to supply nutrient cations to the soil solution for plant uptake (Sonon *et al*, 2014), it is appropriate for especially rice cultivation because the topography in the study area is vulnerable to constant digging and surface run-off during the wet season (Ujoh *et al*., 2019). However, it is important to note that many soil parameters (especially soil pH, texture, and organic matter content) affect the CEC to a certain extent (Tomasic *et al*, 2013). According to Foth (1990), Soil pH is positively correlated with CEC which implies that high pH may increase the number of exchangeable cations in the soil. Collectively, all of these combines to determine the suitability of rice (and similar crops) cultivation within the basin. Soil Organic Carbon (SOC) is the basic component of organic matter content, which is a vital source of carbon for soil processes, and a sink for carbon sequestration (Arunrat *et al*, 2017), and is found to be helpful in mitigating climate change and food security (Sun *et al*, 2013). Application of fertilizers to soil causes an initial increase in nutrient concentration in the soil which results in soil nutrients shifting toward clay particles (Sonon *et al*, 2014). For long term double rice (and similar crop) farming without application of fertilizers, there is a significant increase in SOC concentration which suggests that double (and similar crop) farming expedites the accumulation and storage of SOC (Sun *et al*, 2013). The bulk density of a soil sample is referred to as the ratio of the mass (or weight) of that sample to the bulk volume (Chaudhari *et al*, 2013). It is commonly used as a standard of measurement for assessing soil compaction resulting from land management activities (Starr & Geist, 1988). Bulk density is also considered as a dynamic property that changes with the structural condition of the soil which can be altered by farming, agricultural machinery and animal movement and weather (Arshad *et al*., 1996). According to Askin and Ozdemir (2003), bulk density shows a positive relationship with sand and very fine sand content, a negative relationship with silt, clay and organic matter content. In general, bulk density increases with soil profile depth, due to changes in organic matter content, porosity and compaction (Chaudhari *et al*, 2013). It is for the foregone reasons that bulk density is considered as a critical component in this study.

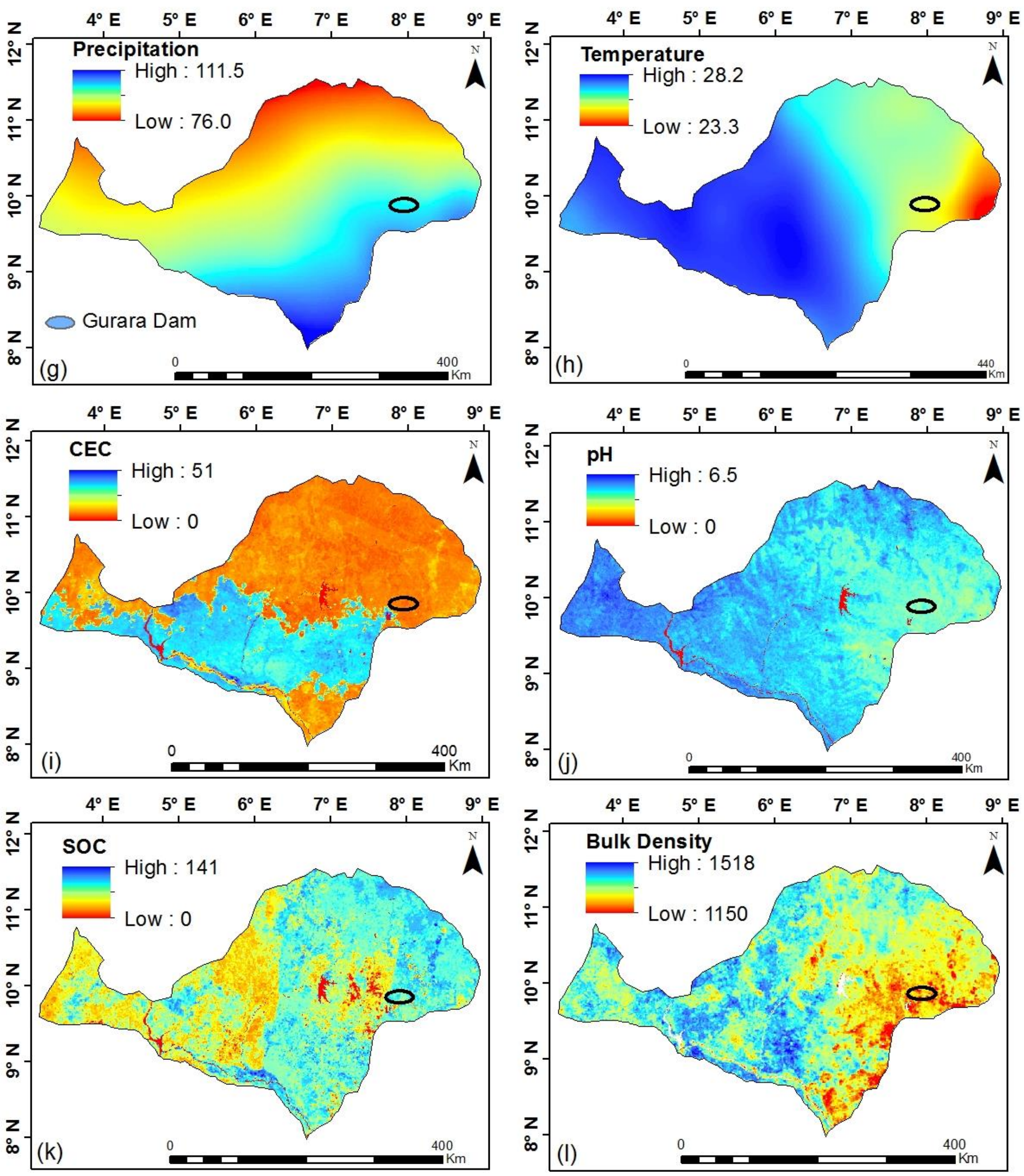

Figure 4. Upper Niger Basin-wide maps of (g) mean precipitation (mm) from 1985-2015, (h) mean temperature (^{o}C) from 1985-2015, (i) Cations Exchange Capacity (cmol/ kg), (j) soil pH, (k) soil organic Carbon (kg C/m2), (l) bulk density (g/cm3).

Social Components

Health Status Assessment

During interviews with a Chemist who operates a drug dispensing outlet at Kushinda village and a nurse at the Primary Health Centre at Anturu community (plates 2 a & b below), it was discovered that the common diseases found around the Gurara dam area include typhoid fever, malaria, peptic ulcer, arthritis and rheumatism, common cold, diarrhea and vomiting, pelvis inflammatory disease, hepatitis, helminthrasis, pruritus, hematuria, urinary tract infections, and gastro-intestinal disorder. However, we were informed that there were no documented records of patients treated at the PHC at Anturu. A third interview was conducted via telephone with the relatively largest healthcare facility at Katari, the closest to the dam site. Generally, the ailments listed by these 3 medical experts interviewed appear to be consistent with those listed by the members of the communities interviewed (plates 2 a, b, c & d).

Plate 2a & b. KIIs with healthcare officials (up) and the building housing the PHC at Anturu

Stakeholder Consultations & Engagement

Social Characteristics of Respondents:

A total of 33 interviews were conducted at 5 communities (2 Gurara and 3 at Azara/Jere irrigation sites). The checklist/questionnaire is presented as. The outcome of the interviews show that 32 males and 1 female were interviewed out of which 34% obtained primary school education and 9% without any formal education (see Figure 4a). The only female interviewed is a university graduate below 40 years of age at Dan-Baba community. Generally, the age distribution of respondents is shown in Figure 4b which shows that majority of the respondents (about 64%) were old enough to understand the activities that preceded the Gurara dam construction. In all, 32 out of the 33 respondents have lived/worked in and around the sampled communities over a period of between 10 and over 20 years. Based on the analysis of data generated, the average household size within the communities is 27 persons. In total, 30 out of the 33 respondents are Christians while 3 practice Islam. Predominantly (85%), farming and fishing are the major occupations with only a few people engaged in other activities (Figure 4c). However, all respondents agree that the main occupation of the communities are farming and fishing. About 57.6% of respondents believe the Gurara dam project have had positive impact on the communities while 42.4% think otherwise. The listed positive impacts include access roads, electricity and potable water, jobs/business opportunities, population increase, irrigation activities, and improved markets for agricultural produce. By and large, the complaints are from communities who do not have facilities provided for them especially Danbaba and Atara communities.

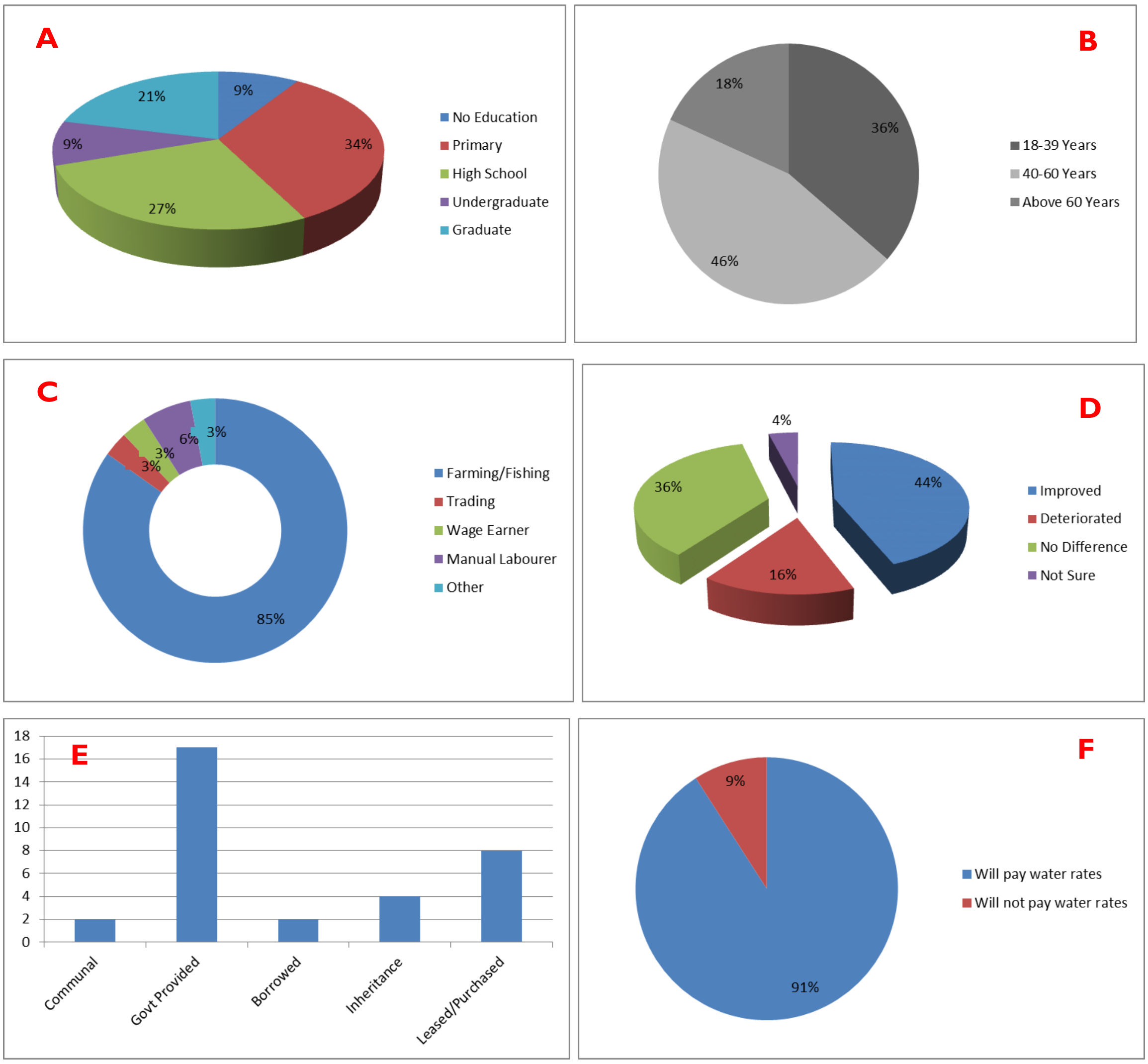

Figure 4. (a) Educational status; & (b) Age distribution of respondents at sampled communities; (c) Occupation of respondents at communities; (d) perception of status of security at sampled communities; (e) Method of land acquisition; & (f) Willingness-to-pay water rates for irrigation services by communities

Environmental and Socio-economic Issues:

About 15% of respondents agree that they experience floods and erosion (80% of these responses came from Atara community). About 57.6% of respondents stated that there were no amenities such as boreholes, schools, etc., in your communities before the Gurara dam project commenced, while only 11 out of 33 respondents agreed that new facilities were provided at their communities as a direct result of the Gurara dam project. Basically, all respondents unanimously agree that there are no waste products generated from the current operations of the dam. This is not unexpected as there is actually very limited utilization of the dam and related uses at the moment. Regarding access to potable water sources, 33.3% of responses indicate that their water sources were overtaken by the dam reservoir without a replacement. About 66.7% of responses think that the project has impacted vegetation cover within the area to some considerable extent. In the opinion of 9.1% of the respondents, the air quality within the project area has been compromised due to operation of harvesters, machinery and generators. A total of 57.6% of responses rate noise levels as normal while 9.1% think the noise lever are very high. About 76% of responses affirm that they have lost agricultural land due to the project. The loss ranged from as low as 1 acre to 200 acres with 72% of respondents stating that their farms were under cultivation at the time they were inundated by the dam or cleared by construction works. Regarding buildings, only 24% of responses affirmed to have lost some buildings (homes, school, and cemetery) to the dam construction.

Among the sites of cultural and religious significance lost to the dam project are shrines, traditional site for turbaning, churches, cemetery and ancestral graves. Most of those who provided these responses were above the ago 40 years. About 22 out of the 33 respondents affirm that compensation have been paid by FGN for the land and other lost items, although about 50% of respondents think the compensation was not fully done to cover all lost land and cultural structures. A majority of those who stated this position are above 40 years. About 70% of respondents agree that public forums were held to seek the opinion of communities before the compensation was carried out. However, about 82% of responses suggest that the compensation exercise was not fairly carried out. They would have preferred that more amenities and facilities such as schools, hospitals, potable water, electricity, etc., were provided as part of the compensation package. Regarding markets, it is not clear whether the markets are positively affected by the project even though a majority of the responses indicate an increase in population within their communities. The classes of additions are company workers, market people and service providers.

On the whole, security has improved within the communities since the inception of the Gurara dam project (see Figure 4d above). The survey results also show that community members believe that there has been increased traffic flow in communities since the project inception. Also, the table shows that majority of the respondents do not use irrigation facilities for farming while among the 4 who responded in the affirmative, the agricultural produce are soya-beans and maize. However, every respondent agrees that their communities have need for irrigation agriculture. It was learnt that cereals and grains are the most widely cultivated category of agricultural produce in all communities sampled. Others include ginger, and water melon. About 50% of the respondent’s state that the average farm size for a family is between 1-5 acres. Majority of respondents stated that government provided the land they currently own (Figure 4e). The average agricultural produce per family ranges from 1-5 bags to 1-2 tonnes. Presently, there is no agro-processing facility at any of the communities sampled. Interestingly, 91% of the respondents agree that they will pay to use water and other irrigation facilities if they are made available and accessible to them (Figure 4f). However, the specific amount willing to be paid was not discussed. About 70% of responses indicate that there are cases of specific ailments especially malaria, typhoid fever, and diarrhea. The UNRBDA Project Office complained of security challenges with regards to securing irrigation installations that are constant targets for vandalization mostly by herdsmen and their cattle living within the compensated land.

Land Acquisition and Compensation

According to the EIA study report and discussions from the Upper Niger River Basin Development Authority (UNRBDA) staff, all land required for the dam, irrigation and other related activities have been fully compensated for. However, discussions with the Leader and some members of the Atara community (Plate 3a) in Kachia LGA revealed that the community was improperly re-settled/relocated. The land ownership status of the reserved areas (where they currently inhabit) was not properly documented hence, none of the inhabitants hold proper title to the lands given to them as part of compensation after the displacement. The lack of adequate land for cultivation is seriously impacting the communities' livelihood. The affected/displaced communities at the Gurara dam site (Lot A) include Doka, Asawe I, Asawe II, Atara, Akami, Unguwar Kankan, Anturu, Igoh I, Igoh II, Akwana I, Akwana II, Tudun Wada, Apele and Kushinda.

Additionally, and indeed as a result of the improper land documentation process for the resettled communities, there is the problem of boundary clashes between the communities of Toka and Atara. The Toka community (which was not resettled) believes they own the land upon which the Atara community was resettled in 2006. So, they sell any piece of land around the Atara community which leads to crises. There is therefore, the need for the FGN and responsible MDAs to provide a definitive demarcation between the two communities to avoid further clashes. Atara community relocated to its present location in 2006 and now with a population of about 418 people and 57 households.

The main communities at the Lot B (Azara/Jere irrigation site) are Azara, Jere, Chinka and Danbaba. These communities are concerned about inclusion in the process of running the irrigation scheme by the government and the private investors.

Plates 3. Engagement with the Community Leaders of (a) Atara Community (arrowed) Chief David Akwada; (b) Kushinda Community, Chief Joseph Audu; (c) Jere Community, Alhaji Abdullahi Jere; & (d) Danbaba Community, Chief Okwu Danjuma (arrowed).

Table 16. Summary of existing and potential environmental impacts at the project sites

Environmental & Social Parameters	**Gurara (Lot A) & Azara/Jere (Lot B), Upper Niger RBDA**
Floods & Erosion	• Erosion is largely insignificant at Lots A & B; • Marginal, annual floods at Lots A & B could destroy farms/crops;
Siltation	• No reports of siltation received as there is no sedimentation study to confirm occurrence and rate at Gurara dam. • Observation indicates relatively low erosion given the stability of vegetal cover around the reservoir area
Soil Pollution	• EC, Organic carbon & Na all occur APL thus, creating sodicity conditions; • Cu, Fe, Mn & Zn are APL thus, hindering occurrence of other vital soil nutrients; • FeO_3, P_2O_5, SO_3, CaO and K_2O all occur APL thus, threat to soil structure, organic matter & carbon; • Less bacterial is most samples imply high acidic soil and higher fungi concentration.
Aquatic biodiversity	• Reports from community members indicate abundance of fish species and crocodiles
Terrestrial biodiversity/Wildlife	• Unregulated hunting, grazing and land clearing for cultivation, if unchecked, hold the potential to exert immense pressure on wildlife
Water Quality	• EC, Na & K all occur APL; • Ca, Fe, Mg, Mn & Zn all occur APL; • TCC & TTC are high in most samples while bacterial count is generally low in all samples. Faecal Streptococus and Clostridium Perfringens Spore absent in all samples.
Ambient air quality & noise levels	• CO_2 & NH_3 recorded APL at Lots A & B; • Noise levels fall BPL of 90dB; • This means: stress conditions (leaf injury, stomatal damage, premature senescence, decreased photosynthetic activity, disturbed membrane permeability & reduced growth & yield in plants.
Landcover/Vegetation	• Vegetation cover within the basin stable & relatively healthy; • Vegetation cover around dam area recovered/stabilised; • Irrigation land not fully cleared at Gurara dam site (Lot A) thus, full extent of impact yet known; • Lot B (Azara/Jere) vegetation is highly disturbed; • Basin-wide population density is low.

Table 17. Summary of existing and potential social impacts at the project sites

Environmental & Social Parameters	Gurara (Lot A) & Azara/Jere (Lot B), Upper Niger RBDA
Compensation	Full compensation paid for all project aspects.
Water-borne Diseases	Medical record from Anturu PHC, phone interview with Dr. Arome at Katari Clinic, & interview with a Patent Medicine store operator reveal the following: typhoid fever, malaria, peptic ulcer, common cold, diarrhea & vomiting, pelvis inflammatory disease, hepatitis, helminthrasis, pruritus, hematuria, urinary tract infections, and gastro-intestinal disorder.
Livelihood	Status not ascertained at this stage. Require a full social study & LRP against which evaluations can be made going forward. However, Ataka resettled community complained of lack of farm lands to support their livelihood.
Resettlement	Resettlement done for all communities to give way for the reservoir area of dams and irrigation land.
Encroachment	Encroachment is not reported at Gurara.

Conclusion

The outcome of this study serves to advance the importance of assessing environmental impacts from anthropogenic activities, as well as measurement and intervention to relevant criteria/conditions, particularly as the resolution of central global issues of sustainability actually reside at the local level, an agglomeration of local efforts (such as this study) would, in turn, produce regional, then global effect. Additionally, the study bears in mind the many cases recorded elsewhere in Nigeria where the local/host environments bore (and continue to bear) disproportionate environmental degradation, social and health risks as completed projects agglomerate population while environmental quality (and its capacity to support them) continually decline due to the absence of an initial and subsequent periodic risks assessment of this nature. These concerns are summarily highlighted and contained in 10 (out of the 17) SDGs: 1, 3, 6, 9, 11, 12, 13, 15, 16 & 17 which are targeted for attainment by year 2030, and to which Nigeria is a prominent signatory.

Specifically, this study identified the existing impacts and likely major impacts that may arise from the proposed projects at the RBDAs in Kaduna. While these sites are not Greenfields, the projects are largely non-operational. The impacts expected have been identified and discussed. Generally, it is expected that there would be no severe negative impacts from the proposed development during the project construction phase of the planned project if mitigative measures are strictly implemented. The environmental monitoring programme for this project will focus on air quality and noise level, water quality monitoring, health status, vegetation status studies and terrestrial/aquatic ecosystem monitoring as well as other social components (livelihood, compensation, resettlement, etc.) which would collectively mitigate the identified impacts during the projects operational phase.

In conclusion, the proposed rationalization of the RBDAs projects, at completion, would have mostly positive but also minimal negative environmental and social impacts as discussed in this study. The project requires relatively less intensive construction activities and the period of construction is also expected to have impacts that are mostly temporary in nature. Emphasis must be placed on the land acquisition and compensation processes of these projects in order to avoid asset vandalization, ensure communities' buy-in and a sustainably peaceful business environment. At this stage, it is clear that the implementation of the partial commercialization of RBDAs projects would greatly improve the mandate of the RBDAs (which brings along several socio-economic and environmental benefits) and is therefore, worthy of implementation.

Recommendations

Based on the findings of this study, the following recommendations are made:

i. Preparation of a detailed ESIA study for new projects, or a comprehensive EA for existing projects that would require expansion and additional investments;

ii. Preparation of a comprehensive LRP which will identify the key stakeholders, vulnerable population and PAPs, and also develop a mechanism to mitigate any livelihood losses arising from the rationalization of services and projects under the mandate of the RBDAs. The LRP is even most important for the Ataka Resettled community which is currently having conflicts over farm lands with Toka community at the Lot B (Azara/Jere Irrigation Project site, Upper Niger RBDA) in Kagarko LGA, Kaduna State;

iii. Provide guidance to the BPE, FMWR, and the RBDAs to ensure that the land acquisition procedure is in strict accordance with global best practices and acceptable to the communities and PAPs; and,

iv. Assist in setting up an Environmental Monitoring Unit within all RBDAs with appropriate schedule of duties as spelt out in the E-QMS prepared for the RBDAs.

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APPENDIX I

A1: Water Analysis Procedure

The analyses were done at the Kaduna Environmental Protection Authority (KEPA) Laboratory in Kaduna State, northern Nigeria. The laboratory analyses of the water samples applied the following steps:

- ***Digestion Procedure for Water Samples***

At the Laboratory, 50ml of thoroughly shaken water sample was measured accurately into a beaker and digested 5ml of concentrated HNO_3 for a few hours on a hot plate at 100^0C till the solution was reduced to less than 20ml by volume. The solution was allowed to cool again then filtered with 125mm filter paper into 100ml standard flask and made to the mark with de-ionized water. The 100ml digested sample solution was transferred to 100ml plastic container and taken for heavy metals determination on Atomic Absorption Spectrometer (AAS). A blank of the de-ionized water was also prepared using the same procedure and subjected to the same analytical procedure.

- ***Calibration standards***

Calibration standard containing only the elements analysed was prepared. 5 sets of standards were also prepared in order to obtain a good precision while working standard solutions were also prepared by diluting stock and intermediate standards. The working standards were determined as follows: 2, 4, 6, 8 and 10 ppm. Standard Pye Unicam hollow cathode lamps were used for each element.

- ***Spectrometer specification***

Thermo scientific iCE 3000 series AA spectrometers

6 lamps Automated carousal

Coded hollow cathode lamps

Wavelength range 180nm to 900nm

Absorbance range -0.150A to 3.000A

- ***Flame parameters***

Flame type: Air/acetylene

Nebulizer uptake: 4secs

Burner height: 7.00mm

Fuel flow: 1.2L/min

- ***Calibration parameters***

Calibration curve: normal

Excess curvature limits: -10% to +40%

Line fit: segmented curve

Rescale limit: 10.0%

Scaling factor: 1.000

A2: Soil Quality Analysis Procedure

- ***Digestion Procedure for Soil***

The procedure adopted at the laboratory was as follows: 1g of soil/sediment was weighed accurately into a conical flask.12ml of conc. HNO_3 was added to the sample in the conical flask and placed in a fume cupboard and allowed to be heated to boiling on a hot plate until fumes of acid evolved and continued heating to precipitate most of the silica. The mixture was allowed to cool and 20ml of de-ionized water was added and boiled again to bring the metals into solution.

The solution was allowed to cool again then filtered with 125mm filter paper into 100ml standard flask and made to the mark with de-ionized water. The 100ml digested sample solution was transferred to 100ml plastic container and taken for heavy metals determination on Atomic Absorption Spectrometer (AAS). A blank of the de-ionized water was then prepared using the same procedure and subjected to the same analytical procedure.

- ***Calibration Standards***

Calibration standard containing only the elements analysed was prepared. 5 sets of standards were prepared in order to obtain a good precision. Working standard solutions were prepared by diluting stock and intermediate standards. The working standards were categorized as follows: 2, 4, 6, 8 and 10 ppm. Standard Pye Unicam hollow cathode lamps were used for each element.

- ***Spectrometer Specification***

Thermo scientific iCE 3000 series AA spectrometers

6 lamps Automated carousal

Coded hollow cathode lamps

Wavelength range 180nm to 900nm

Absorbance range -0.150A to 3.000A

- ***Flame parameters***

Flame type: Air/acetylene

Nebulizer uptake: 4secs

Burner height: 7.00mm

Fuel flow: 1.2L/min

- ***Calibration Parameters***

Calibration curve:	normal
Excess curvature limits:	-10% to +40%
Line fit:	segmented curve
Rescale limit:	10.0%
Scaling factor:	1.000