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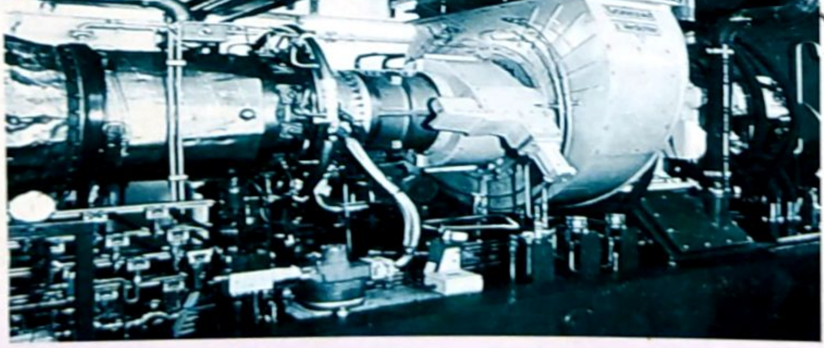

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AN EVALUATION OF MUNICIPAL WATER SUPPLY IN BOSSO, NIGER STATE USING GEOSPATIAL TECHNIQUES

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Abstract
The purpose of municipal water delivery systems is to transport potable water from a source to water treatment facility to residential consumers, for different uses. In most parts of Nigeria as in Niger state achieving this portable water delivery has been an issue of concern. This problem is in terms of quality and quantity of water which could be affected by the geological and geographical elements of an area. This research was set to evaluate municipal water supply in Bosso using geospatial techniques in order to identify the various sources of water for human consumption, evaluate the components of the existing system in use and to examine the problems associated with the available system. Questionnaires were administered, interviews, field observations, remotes sensing images as well as GIS analysis were carried out. The various sources of water were identified, to ascertain the extent of portable water supplied in Bosso,a part of Minna municipal area. The source point of the dissipated water were first identified then evaluated to ascertain its reliability by calculating the area covered. Similarly, the distribution was examined with respect to the terrain elevation. Various problems were identified and possible solutions were recommended. The analysis showed that a low percentage of the population receives portable water and the frequency of the supply is low. The existing system supplies water from Bosso dam which is undergoing sedimentation, thereby reducing the capacity. For a more efficient supply Tagwai dam also supplies Bosso. The digital elevation model shows that the terrain of the area is undulating and is partially responsible for the poor distribution of pipes. Routine monitoring of the dam as well as dredging was recommended, expansion of the existing system as well as designing of a better GIS system for the area among others was recommended.

Keywords: Municipal Water Supply, Water Quality, Water Quantity

1.0. Introduction

Human body needs three requisites for its smooth functioning oxygen, water and food. Water has been rank second only to oxygen as essential for life. Public water supply started in Nigeria early in the twentieth century in a few towns managed at the lowest administrative level. Amongst the early beneficiaries were Lagos, Calabar, Kano, Ibadan, Abeokuta, Ijebu Ode (Ogun State) and Enugu. The schemes were maintained with revenue from water sales with virtually no operational subvention from government. With the creation of regional governments in the early 1950s the financial and technical responsibilities for developing new water schemes were taken over by the regional governments who also assigned supervisory high level manpower to oversee operations and maintenance. The Federal Government got involved in the management of water resources in 1976 when the Federal Ministry of Water Resources and the 11 River Basin Development

Authorities (RBDAs) were created. The purpose of the RBDAs was to provide bulk water, primarily for irrigation. Water is considered to be a finite global resource.

As the cost of water treatment continues to escalate to meet drinking water demand and water quality regulations, focusing on improving the quality of raw water sources has become paramount. Based on available data, Nigeria has adequate surface and ground water resources to meet current demands for potable water, though the temporal and spatial distribution of water has led to scarcity in some locations in the middle belt of the country. This disparity has led to rapid depletion of groundwater, especially in the northern towns like Minna which have resorted to other sources in the presence of abundant surface water. As state capitals and larger towns become more and more dependent on surface sources and experience the difficulties associated with treating such water, water shortages are developing in areas of Minna especially Bosso and its environs. In Minna, Niger State, only 40% of the area within the capital has been reticulated. Furthermore, some areas have been found, most especially in Bosso community, not to have benefitted from government water supply.

Majority of water utilities use GIS technology to integrate all kinds of information and applications with a geographic component into one manageable system. Using GIS, one can organize and manage the flow of water to serve homes and businesses by tracking the location and condition of water major and minor pipes, valves, hydrants and storage facilities etc even to the point of recycling used water.According to Vijay *et al.* (2011) based on physicochemical and bacteriological analyses of groundwater, geospatial techniques were applied to identify and assess the groundwater potential zones for drinking water production. Due to uneven spatial and temporal distribution of rain-fall and lack of sufficient water management practices, developmental activities of the society are totally depend on groundwater resources (Yammani, 2007). Due to anthropogenic activities, lack of sanitation, improper waste disposal, faulty well construction and water source protection measures, groundwater is getting polluted (Shashikanth, 2008). Variation in groundwater chemistry with time provides information on the impact of land use land cover changes on the water quality (Bridget and Reedy, 2005). Domestic sewage, septic tanks and soak pits are also contributing to groundwater pollution significantly in most of the cities due to presence of nutrients, detergents, human and animal excreta (Eunice *et al.*, 2008). Among the groundwater pollutants, nitrates are perhaps the most ubiquitous of all groundwater contaminants. Heavy pumping and excessive use of near-coast groundwater has caused rapid depletion of water tables as well as deterioration of water quality in most of the coastal cities (Cruz and Silva, 2000).

Around 1.1 billion people globally do not have access to improved water supply sources whereas 2.4 billion people do not have access to any type of improved sanitation facility. About 2 million people die every year due to diarrheal diseases; most of them are children less than 5 years of age. The most affected are the populations in developing countries, living in extreme conditions of poverty, normally peri-urban dwellers or rural inhabitants. Among the main problems which are responsible for the effect of unhealthy water to the growing population of the world, Nigeria as well as Niger State are: lack of priority given to the sector, lack of financial resources, lack of sustainability of water supply and sanitation services, poor hygiene behaviors, and inadequate sanitation in public places including hospitals, health centres, schools and restaurants etc. Providing access to sufficient quantities of safe water, the provision of facilities for a sanitary disposal of excreta, and introducing sound hygiene behaviours are of capital importance to reduce the burden of disease caused by these risk factors. Water supply has been a matter of concern to Minna, Niger State and Nigeria at large, despite the effort of the government as well as the public, the major setback lies in the inability of the people as well as the government to critically identify all possible sources of water supply as well as adequate ways of channeling water to the point of consumption in Bosso and its environs. This has lead to the inadequacy of water supply in Bosso with a corresponding inability to meet the wide variety of water needs of the people as water is one of the most essential elements for survival and an important factor for industrial processes. This problem is in terms of water quality and quantity as the source of any water supply determines the quality and the geographical and geological elements of an area determines the quantity of water available in the area. Similarly, the water channeling and delivery system pose a great problem on portable water availability in the study area.

This paper aimed to evaluate municipal water supply in Bosso using geospatial techniques by identifying the various sources of water for human consumption, evaluating the components of the existing municipal water supply system in use and examining the problems associated with the available water supply system. The inadequacy of water supply can be attributed to the growing population as well as the socio economic consumption level of the people. This water supply problem has limited the productivity of the inhabitants of Bosso as well as exposed them to a higher standard of living due to the frequent purchase of clean water for consumption. On the other hand it has also endangered the life of the people due to the wide range of diseases which can be contacted by the consumption of unsafe water. One major challenge facing the residents of the area is that their water sources are limited despite the effort of the government to dig bore holes and manage the water board, the amenities are still inadequate and seems unavailable due to the unreliability and lack of constancy of the water supply and the seasonality and other factors that affect the water table thereby making the boreholes too unreliable.

2.0. Study Area

Niger state is a state in north central Nigeria; it is the largest in the country in terms of landmass. Minna was created as the capital of Niger State in 1976. As at the 2007 Minna had an estimated population of 304,113 and Bosso a population of 147,361. Minna is an area located on latitude 9° 33N and 9° 45N and longitude 6° 34E and 6° 42E (Figure 1). It is a local Gwari town. Cotton, guinea corn, yam and ginger are the main agricultural products of the city. It lied on the basement complex and sedimentary rocks. It experiences a distinct wet and dry season with annual rainfall varying from 1100mm to 1600mm. There are prominent ridges in the area and these ridges extend to a distance of about 7km, the major rivers that make up the drainage of the rivers are Ekpa, Suka and Gora most of these have extensive tributaries that cover most parts of the area and serve as a major source of water in Bosso and its environs. The topography of the study area is very sloppy. The highest altitude is estimated to be about 1200m above sea level and the lowest is 950m above sea level. The most common soil type is the ferruginous tropical soils which are basically derived from the basement complex rocks as well as from old sedimentary rocks.

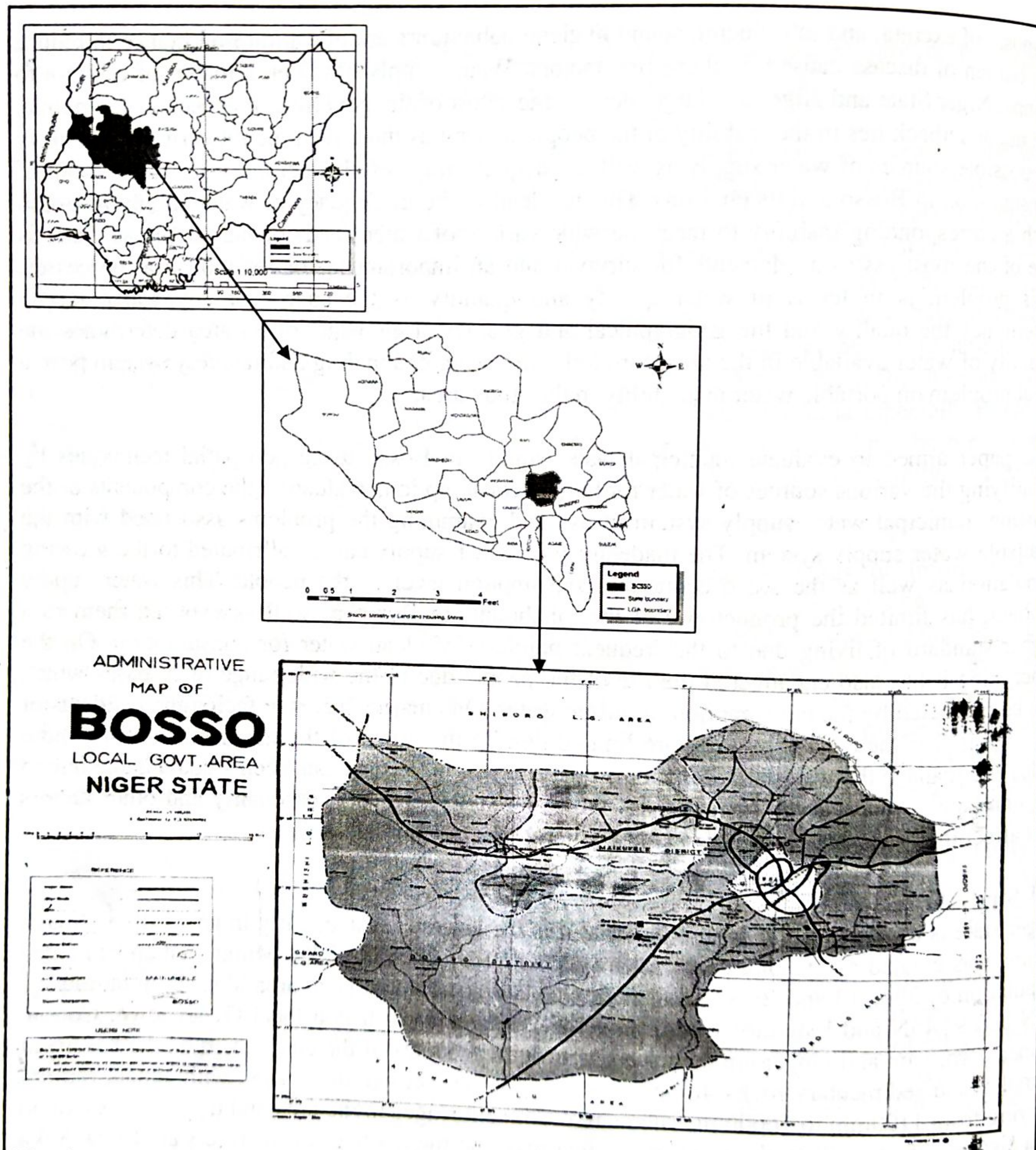

Fig. 1: The Study Area
Source: Ministry of Lands and Housing, Minna

3.0. Methodology

The researchers employed the use of two sources. These are: Primary and Secondary Data. For primary sources, the researchers used questionnaires, personal interview and physical observation directly from the field as part of ground truthing. This is meant to achieve a realistic outcome of the research. For the purpose of this research, the systematic random sampling was adopted in selecting the respondents. The researcher's sampling elements for this study are the residents and the service providers (Water Board, River Basin Authority etc). The geographical areas of targeted population were some selected neighborhoods in Bosso loçal government in Minna, Niger state which include: Angwa Biri, Bosso city (El-Waziri area), Hanya Gawri, Bosso low-cost and Bosso estate. Two hundred copies of a well structured questionnaire were administered using systematic random sampling and one hundred and seventy one were retrieved back from the respondents. In addition to the questionnaire, the researchers in the course of interactions with respondents asked relevant questions which were important to the success of the work but are not adequately catered for in the questionnaire. Through this medium, the respondents were free to respond to questions as realistic as possible. The category of data from secondary source includes those data obtained from written texts, journals, articles, dictionaries, internet, archived data from Niger State Water Board and reports relevant to the field of study.

Satellite Images: For this study, images were downloaded from the Global Land Cover Facility (GLCF) hosted by University of Maryland through the ESDI interface. Bands two three and four will be used. Other ancillary data used in the study included: the base map of laid down pipes, SRTM data of the study area.

Table 1: Satellite Data

Platform	Sensor Mode	Spatial Resolution	Source	Path/Row	Acquisition Date
Landsat	Multi spectral	30m	GLCF	189/53	Dec. 21st 1990
Landsat	Multi spectral	30m	GLCF	189/53	Dec. 27th 2001
Landsat	Multi spectral	30m	GLCF	189/53	Dec. 9th 2006

Source: Global Land Cover Facility (GLCF)

Results and Discussion

This deals with the analysis and discussion of the results based on the objectives of the study. The responses were analyzed in terms of percentages as shown by the bar charts below.

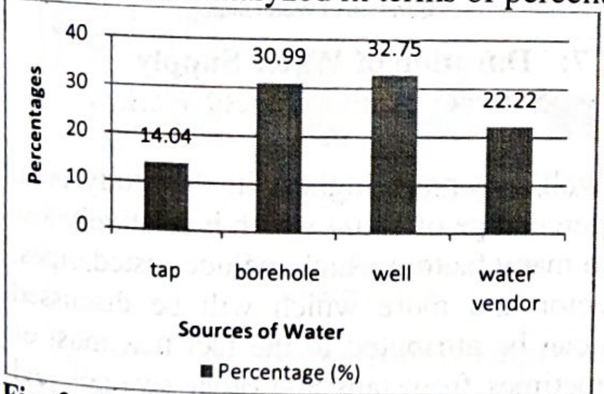

Fig. 2: Sources of Water
Source: Authors' Field Work

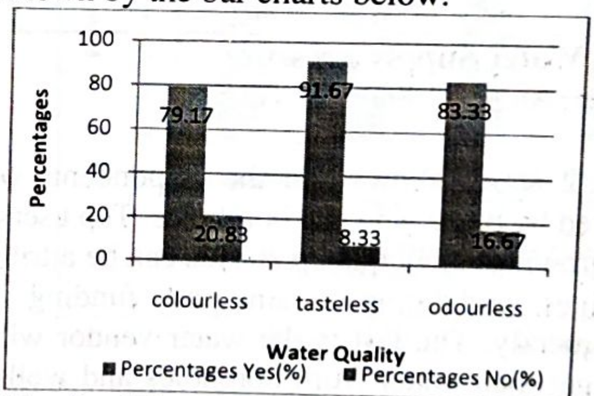

Fig. 3: Water Quality
Source: Authors' Field Work

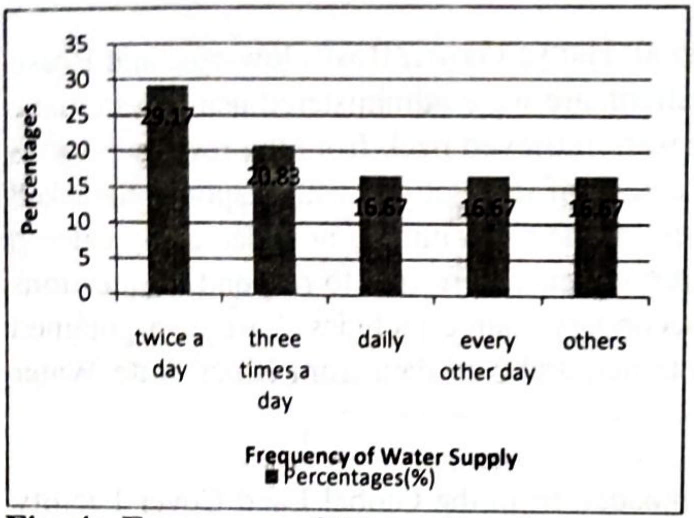

Fig. 4: Frequency of Water Supply
Source: Authors' Field Work

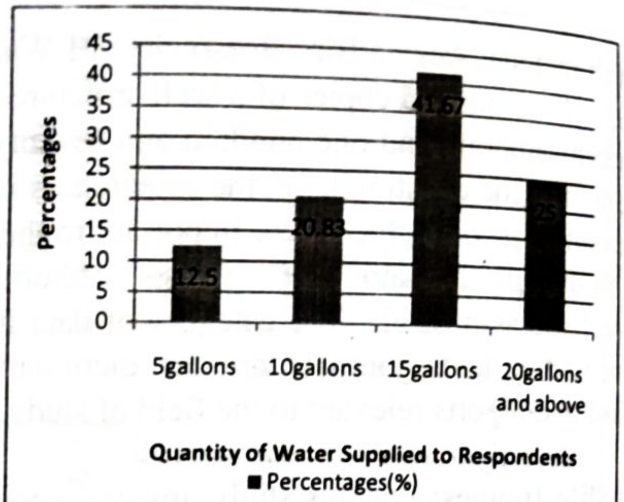

Fig. 5: Quantity of Water Supplied Respondents
Source: Authors' Field Work

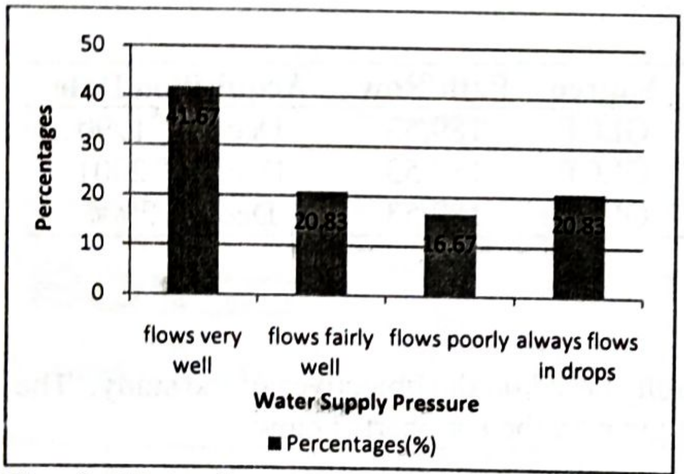

Fig. 6: Water Supply Pressure
Source: Authors' Field Work

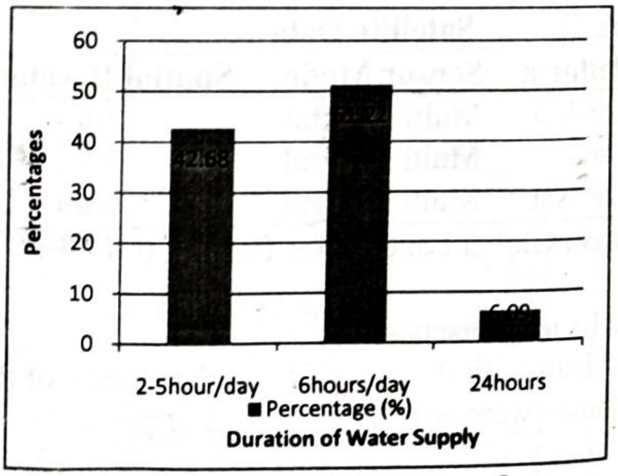

Fig. 7: Duration of Water Supply
Source: Authors' Field Work

Figure 2 above shows that the respondents who use well water are highest in the study area, followed by those who use boreholes. Tap users have a percentage of 14.04 which is relatively low for a growing municipal area. This can be attributed to so many factors which include rusted pipes, old pipes, undulating terrain, poor funding to the sector and more which will be discussed subsequently. The last is the water vendor with which can be attributed to the fact that most of them get their water from boreholes and wells and sometimes from taps and other swamps and small water bodies. This consequently increases the cost of living in the area as residents are forced to buy water even when the portability is not guaranteed.

Figure 3 above shows the quality of tap water using the colourless, tasteless and odourless parameters. The percentages of all the parameters used are high. This is an indication that even though the distribution of tap water is low the quality of the water is high. Figure 4 above reveals the frequency of water supplied. Only about 16.67 percent of the respondents receive tap water daily, then 29.17 percentage receive water twice a day,20.82 receive water three times a day while 16.67 receive water every other day, the percentage of the respondents that receive water once or twice in a period of weeks or months as the case may be is 16.67 percent. Figure 5 above points out the quantity of water supplied to the respondents in terms of gallons is highest for 15gallons and above, followed by 20gallons and above, then 10gallons and 5gallons respectively. Figure 6 shows that the pressure of water flow when supplied is high (41.67%), while for other respondents it flows fairly well. The flow is poor in some areas and flows in drops in other areas. Figure 7 indicates that about 51.22 percent of the respondents are usually supplied for at least 6hrs/day while 42.68percent are supplied for about 2-5hrs/day while only few respondents are supplied water for a whole day.

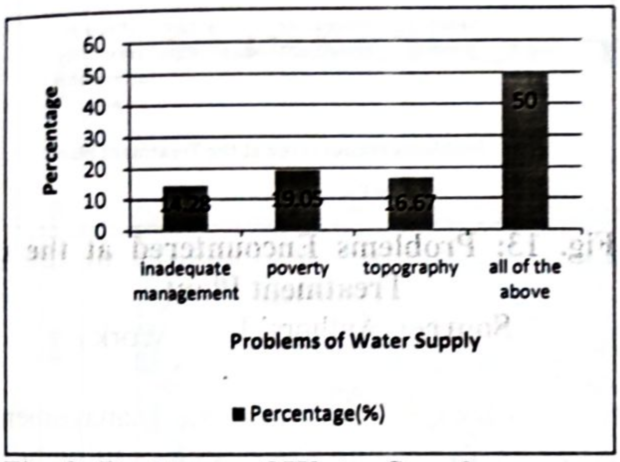

Fig. 8: Problems of Water Supply
Source: Authors' Field Work

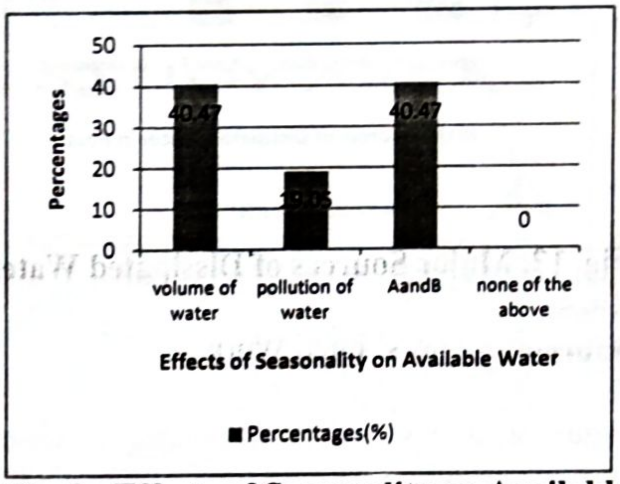

Fig. 9: Effects of Seasonality on Available Water
Source: Authors' Field Work

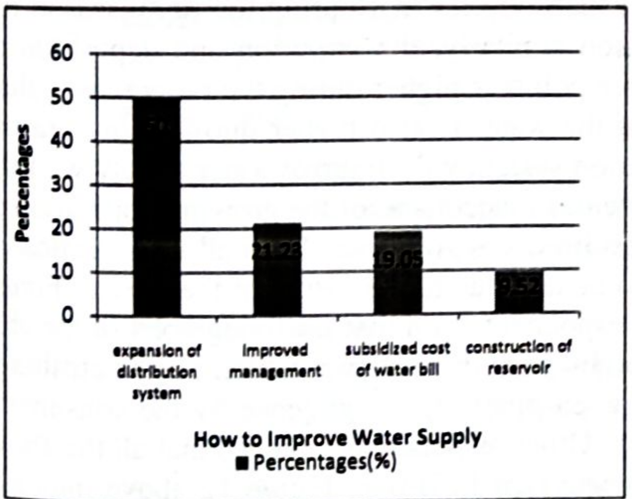

Fig. 10: Water Supply Improvement
Insufficient Taps in
Source: Authors' Field Work

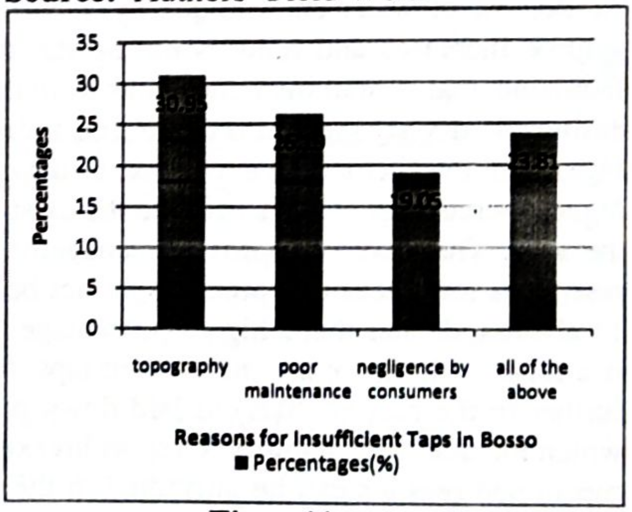

Fig. 11: Reasons for

Bosso
Source: Authors' Field Work

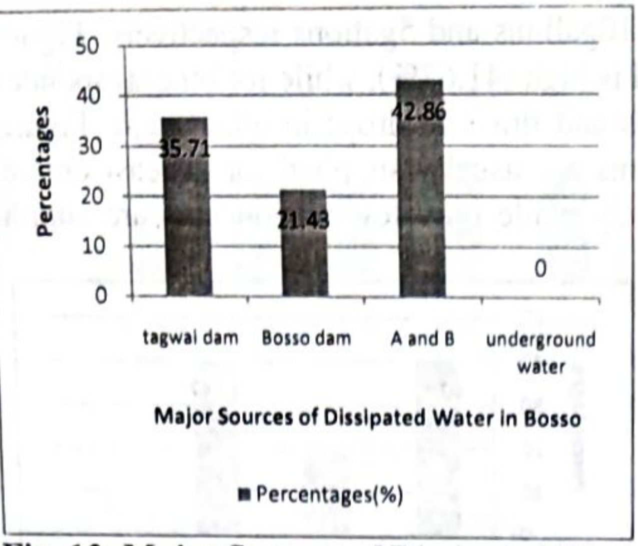

Fig. 12: Major Sources of Dissipated Water in Bosso.
Source: Authors' Field Work

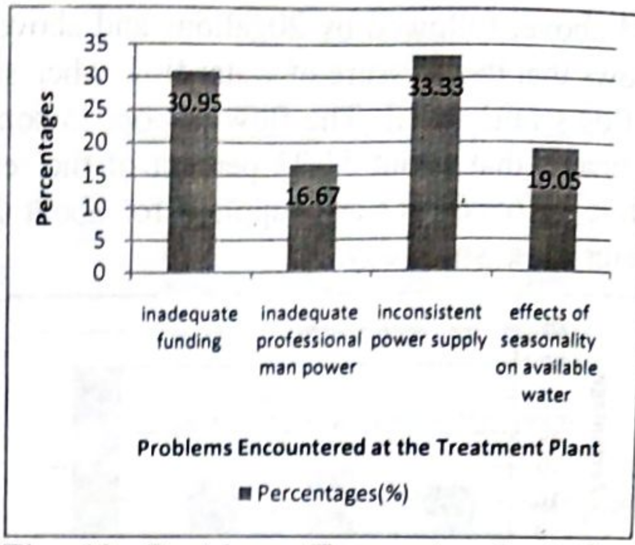

Fig. 13: Problems Encountered at the Treatment Plant
Source: Authors' Field Work

Figure 8 shows that the problems of water supply are associated to inadequate management, poverty which is attributed to the inability of consumers to pay up their water utility bills, topography which accounts partly for insufficient taps in Bosso and generally all the problems pose negative effects on the water supply. Figure 9 above points out that seasonality affects both the volume of water and the quality of the water which implies that during the rainy season the volume increases and reduces during the dry season similarly, the pollution and deposition of sediments that contaminate the water from the source points is higher during the rainy season than during the dry season. Turbulence and turbidity of the water is also higher during rainy season. Figure 10 reveals that the expansion of the distribution system will improve water supply with the highest percentage. This is because the existing system is inadequate for the growing population of the area. The next is improved management, subsidized cost of water bill and construction of reservoirs for places that pipes might not be able to be laid due to the nature of the terrain. Figure 11 above indicates that a higher percentage of the respondents said that the topography of the area is a reason why there are insufficient taps, followed by poor maintenance which can be attributed further to the reasons like old laid down pipes, broken pipes etc.; negligence by the consumers, which include their inability to report breakages etc. Other respondents believed that all the above mentioned reasons can be attributed to the insufficient taps in Bosso. Figure 12 above indicates that the source of dissipated water is both Tagwai dam and Bosso dam Tagwai dam. While others said it was Tagwai dam alone which might be attributed to the fact that it stores more water and is more functional and reliable, then Bosso dam. Figure 13 above signifies that inconsistent power supply is a major problem encountered at the treatment plant, followed by inadequate funding, seasonality and inadequate professional manpower.

Geospatial Analysis

LandsatTM and LandsatETM images were downloaded, which are displayed as false colour composite images using the bands 2,3 and 4. A subset of the two dams was made and displayed on arcGIS and digitized for the different periods (1990, 2001 and 2006). Shapefiles of the water bodies were created in form of polygons anad georeferenced to 32°N of the universal transverse mecartor. After this the area of the water bodies for the different years were calculated using raster calculator for the various years. This is done in order to acertain the changes that occur at the source of the water (the dams). This is because the source of the dissipated water is very important in every municipal supply system. Before the area of the water bodies were calculate a landsat image of path 189, row 53 was classified to identify the water bodies and based on this classification, the water bodies were identified on the subsequent images.

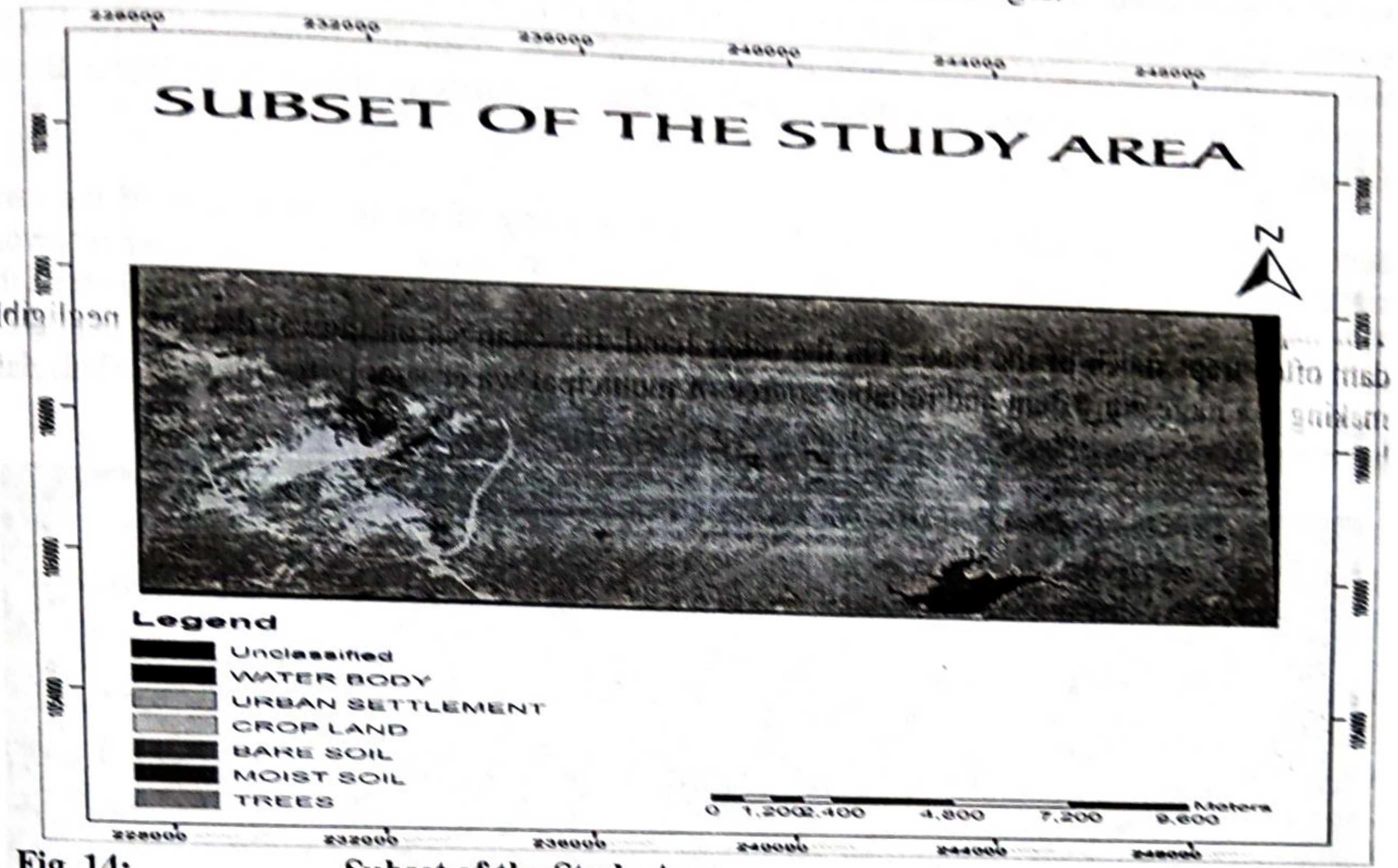

Fig. 14: **Subset of the Study Area**
Source: **Global Land Cover Facility**

Area of the Water Bodies

Table 2: **Calculated Area of Water Bodies**

Years	Area of Bosso Dam (km^2)	Area of Tagwai Dam (km^2)
1990	0.069813	4.763696
2001	0.65529	4.76397
2006	0.059702	4.751199

Source: GIS Work, 2012

Bosso dam has shown to have undergone changes much more than tagwai dam. This changes can be attributed to irrigational activities which affect both the quantity and quality of water(although negligible), the construction of the dam consequent on the location, the maintenance of the dam, seasonality etc. The dam is not located along any major river channels but depends on surface run off from rainfall through the collection drainage. There are about seven of these water channels that feed the dam. Some portion around the dam used for farming activities, both around and at upstream of the dam, erosion, animal grazing and sediment transported in form of sediment loads as the rivers flow. Due to the seasonal nature of the tributaries that feed the dam it was discovered that the volume of water in the dam fluctuates between seasons. The farms are mainly of subsistence as observed during the survey. When the farmers tilt the land, rear animals which graze on the land etc, they leave most of the land to be directly exposed to erosion as a result of being loosen up. As rain falls, this soil is easily washed away into river channels into the dam as is wrongly tilted along the path of the running water. Sedimentation has reduced the theoretical estimated life span of 60-70 years. It is observed that dam has lost over 70% of its storage capacity with only 30% to 45% left for use. The water volume of the reservoir has reduced while lead to the inability of the dam to meet up with the need of Bosso community (Niger State Water Board, Bosso).

Sedimentation can be said to be a process of washing away of the topmost layer of the earth surface by rain which is entrapped, transported, deposited and compaction in the water reservoir. This happens when a dam is built across a sediment laden river. The storage reservoir behind the dam often traps much of the load. On the other hand, the changes on tagwai dam are negligible making it a more consistent and reliable source of municipal water supply for the area. This dam has constantly augumented for the inadequacy of Bosso dam.

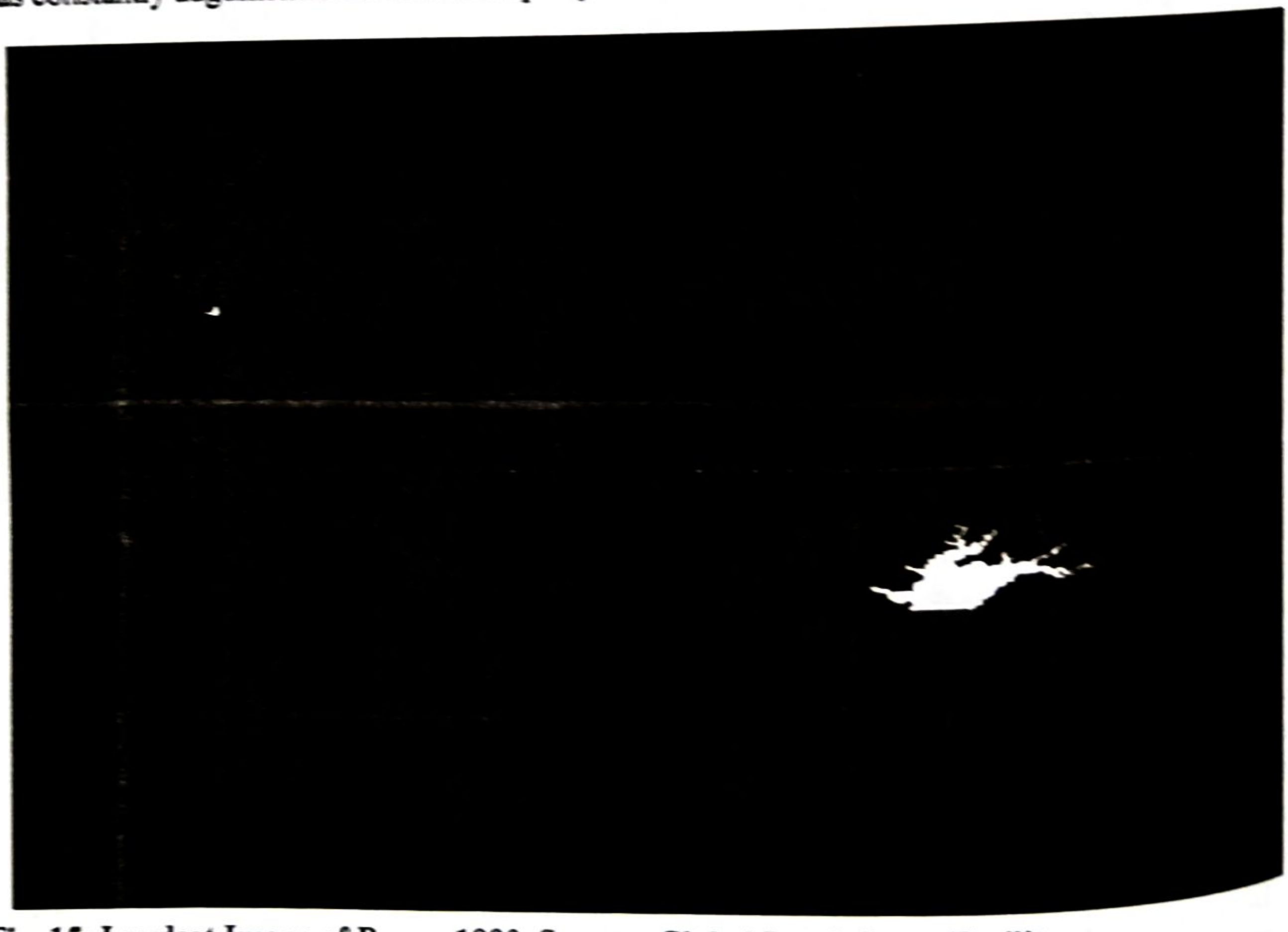

Fig. 15: Landsat Image of Bosso, 1990. Source: Global Land Cover Facility

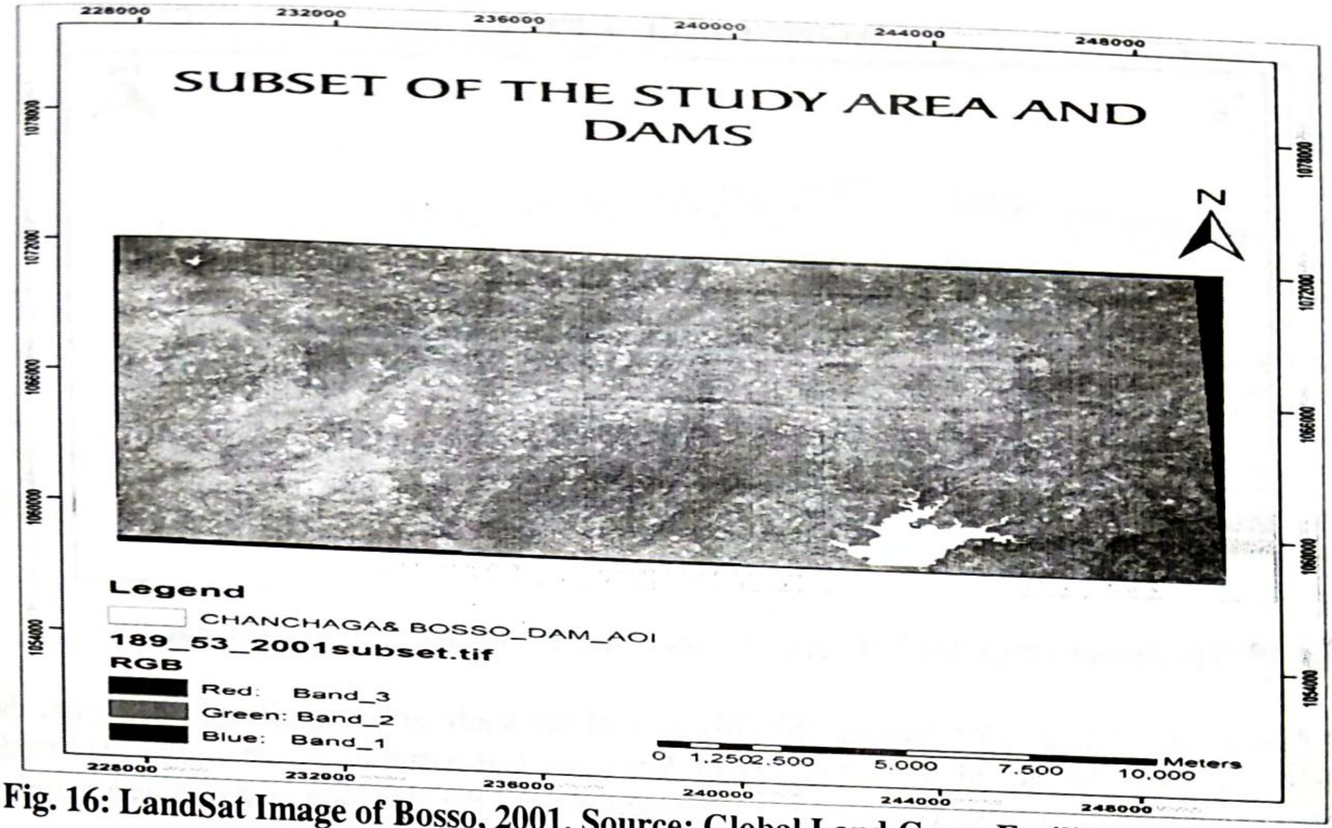

Fig. 16: LandSat Image of Bosso, 2001. Source: Global Land Cover Facility

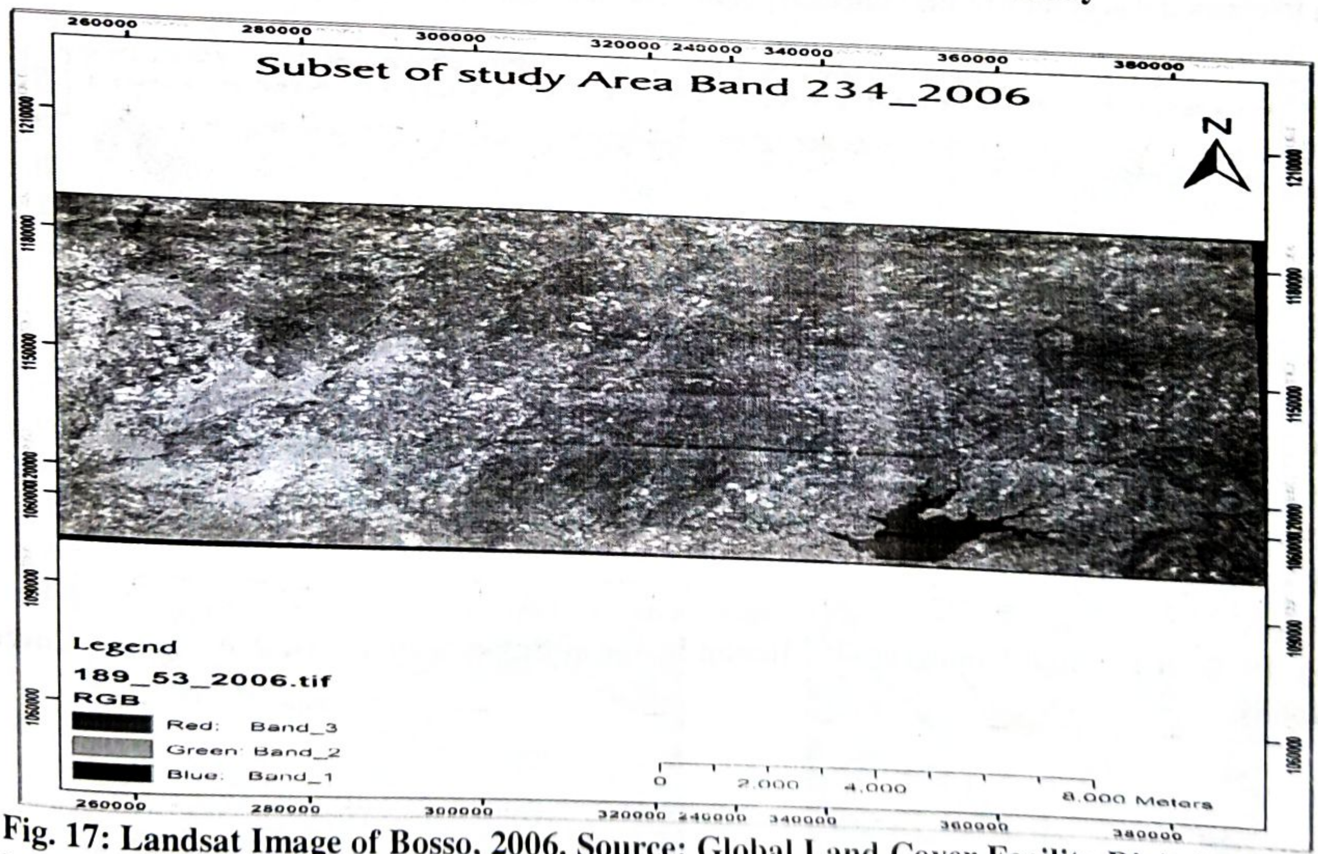

Fig. 17: Landsat Image of Bosso, 2006. Source: Global Land Cover Facility Digital Elevation Model

Coordinates across the study area were taken using a GPS device in terms of longitude, latitude and elevation. From the coordinates, a triangular irregular network was created which was used to generate the DEM.

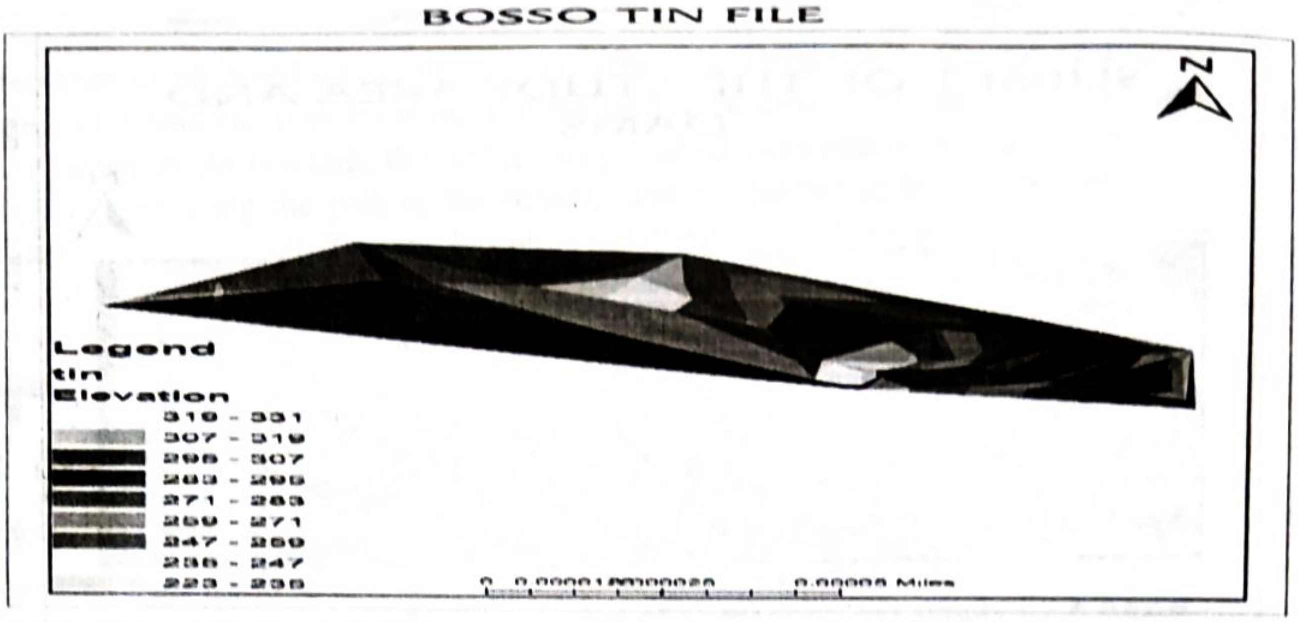

Fig. 18: Triangular Irregular Network of Bosso. Source: Global Land Cover Facility

A shuttle radar topographic mission (SRTM) data of the study area was downloaded from the global Landover facility of the University of Maryland and a subset of the image was made showing the area of interest. This image is a representation of the elevation of Bosso which serves as to check the accuracy of the collected coordinates through an overlay.

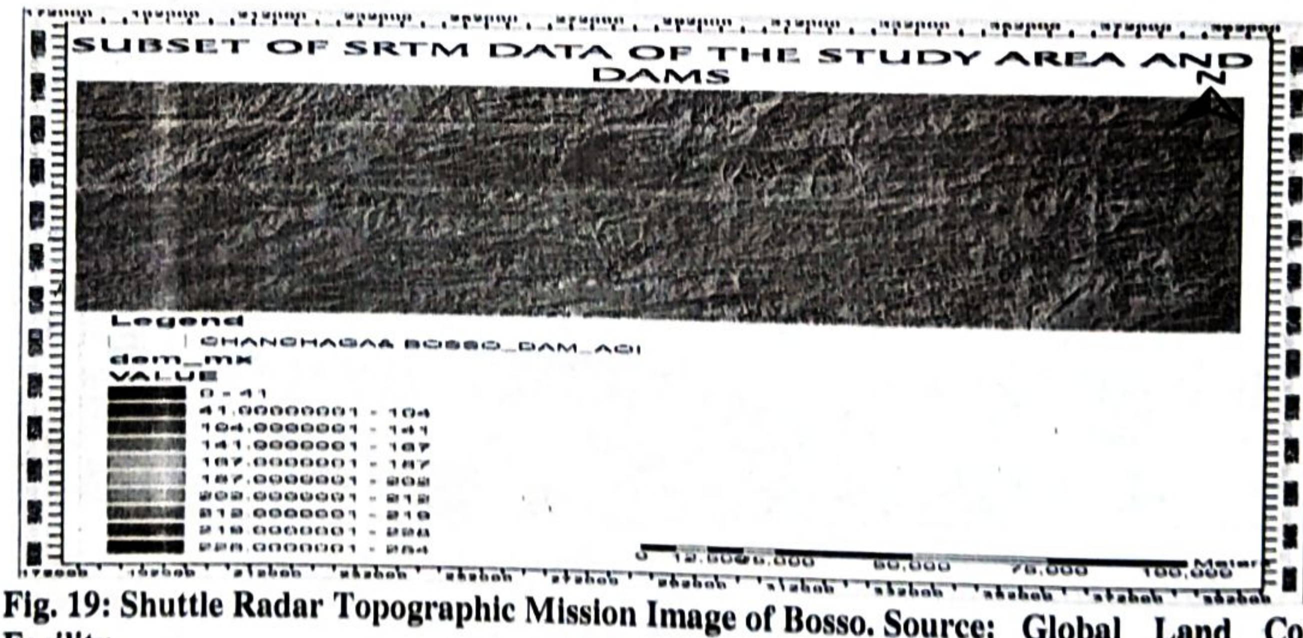

Fig. 19: Shuttle Radar Topographic Mission Image of Bosso. Source: Global Land Cover Facility

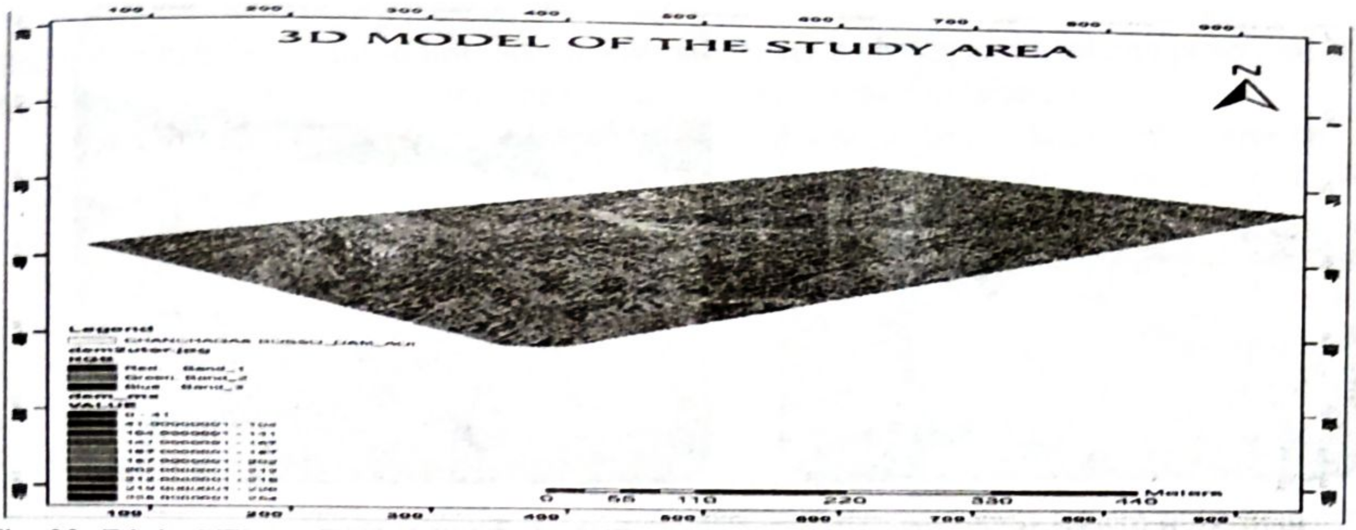

Fig. 20: Digital Elevation Model of Bosso. Source: Global Land Cover Facility

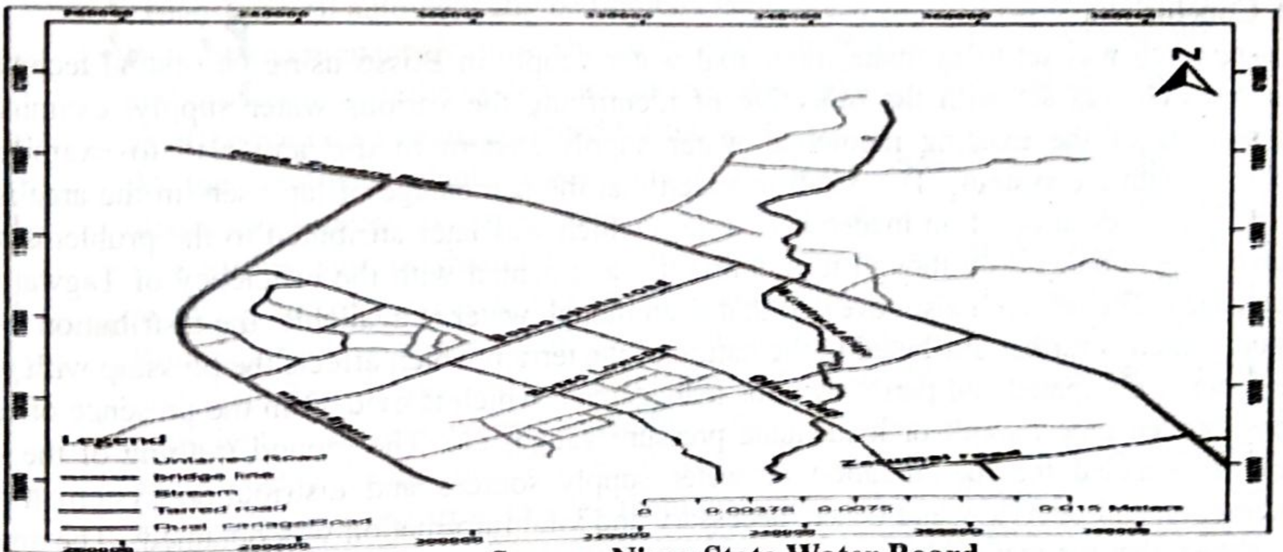

Fig. 21: Distribution Map of Bosso. Source: Niger State Water Board

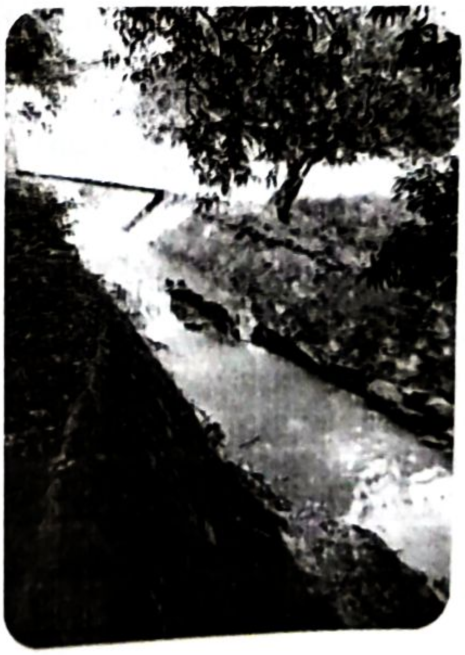

Plate 1: Surroundings of Bosso Dam

Plate 2: Bosso Dam.

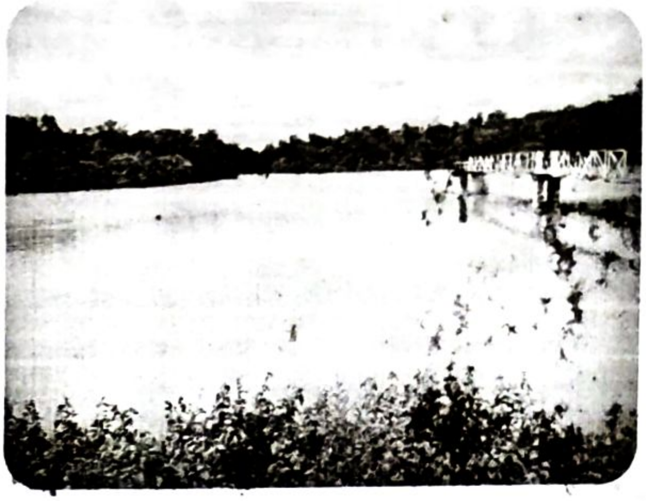

Plate 3: Tagwai Dam

4.0. Conclusions

This research was set to evaluate municipal water supply in Bosso using geospatial techniques. The research was set with the objective of identifying the various water supply, examine the components of the existing municipal water supply system in use and also to examine the problems with the system. The result revealed that the percentage of tap users in the area is low which is an indication of an inadequate system which was later attributed to the problems at the source (Bosso dam) even though it is constantly augmented with the efficiency of Tagwai dam, Chanchaga. The research also revealed that even though water is available, the distribution system is poor which is further attributed to the nature of the terrain which affects the pressure with which the water is dissipated and partly by poor management which is evident in the presence of rusted pipes, broken pipes, spoilt or inadequate pressure gauges etc. The ground truthing of the study area has enabled the identification of water supply sources and distribution system through observation and interview and hence, necessary and vital information was obtained. The analysis has shown that the major sources of water in Bosso are the well, borehole, water vendor and tap. The variation in the percentages of the respondents showed that tap users are few and even at that, the constancy of water supply is low. The analysis further showed that there are two sources of dissipated water to Bosso which are the Bosso dam and Tagwai dam. The capacity of Bosso dam is affected by sedimentation due to framing activities, rearing of animals and hence, erosion and deposition which has reduced its output although it may be consequent on seasons. On the other hand, Tagwai dam is in good shape and arguments for the insufficiency of Bosso dam is that the distribution network have been discovered to be inadequate due to the growth in population of the area The available pipes on the other hand have been placed wrongly following the undulating nature of the terrain. Also, some pipes are broken and not replaced as well as rusted or old and need replacement. This brings about breakages in supply even though water is dissipated and it can also contaminated treated dissipated water before it gets to the point of consumption. After evaluating the existing system, the research showed that the components are in place but inadequate, insufficient, malfunctioning or underused and this can be attributed to poor management. The laid down pipes are said to be done with respect to road networking of the area. On a general note, municipal water supply in Bosso is crippled and almost does not exist hence, there is a need for serious upgrade as well as routine maintenance.

Bosso dam had been built to last indefinitely and deliver high output, in order to protect the dam from such effects of sedimentation; the following measures need to be taken:

a. Agricultural activities outside the prescribed area can be checked to reduce erosion.
b. Erosion is a natural phenomenon which cannot be completely stopped but can be controlled; therefore it should not be overlooked.
c. Prepare and adhere to a schedule of regular maintenance for temporary erosion and runoff control.
d. The government should dredge the dam as well as expand the dam to enhance its storage capacity.
e. Monitoring activities of the dam should be more regular and thorough so that the exact value of the sediment effect can be obtained.
f. The water board should design a modern and effective supply system and ensure that it is put in place in the area. This will meet the needs of the whole population as expansion will automatically be implemented.
g. Routine maintenance culture should be taken more seriously so as to identify leakages and problems with the system and rectify appropriately. This can be achieved by using an effective GIS system designed for the area.
h. At the treatment plant, power supply problems should be fixed by looking for alternative sources so that water will never be dissipated without adequate treatment.
i. The billing system should be improved as meters should be fixed for the various residents and offices. So as to ensure a good turn over and hence a better system.
j. Routine check on the Pressure gauges should be carried out and spoilt ones should be replaced. This is due to the undulating nature of the terrain so as to ensure that sufficient pressure is exerted on the flow for it to be delivered.
k. More skilled labour should be employed and provisions made for the present staff to embark on training so as to keep them up to date on improved technological ways and methods in handling uprising situations for better service delivery.

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