F130: HYDROLOGICAL DISASTER MONITORING USING GIS IN PARTS OF THE NIGER FLOODPLAIN

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Abstract
The frequency of occurrences of flood hazards is likely to increase because of increasing uncertainties in the natural-physical systems resulting from climatic change and variability. This will likely increase human risk in the floodplain because the search for livelihood and the home perception of people may continue to outweigh their desire to move from an original place. This study creates and analyses a GIS database for the settlements and resources lying in parts of the Niger floodplain. Existing base maps and socio-economic data for settlements were integrated with other data layers within Arcview GIS. The results show that 17,276km^2 or 69% of the area under assessment is devoted to agriculture. 648 settlements, 50 of which can be classified as urban areas fall within the floodplain. The database also provides a useful baseline data for further large scale (small area) assessment of impacts and mitigative strategies for flood, and blueprint for indicative planning within this part of the Niger floodplain.

Keywords: GIS, Floodplain, Flood hazard, Niger River

1. INTRODUCTION

Flood is perhaps one of the commonest and most disastrous of all natural hazards afflicting man. A hazard denotes potential for negative outcome such as loss or damage. Pramojanee, et al (1997), describe hazard as a potential event that can cause loss of life, or damage to property or the environment. Natural hazards, according to White (1974) are results of an interaction of people and nature governed by the coexistence state of adjustment in the human use system and the state of nature in the natural events system. According to White, by definition, no natural hazard exists apart from human adjustment to it. Hazards always involve human initiative and choice.

Globally, and in Nigeria in particular, widespread flood progressively cause devastating ecological havocs by destroying lives, properties, agricultural lands and social infrastructures (Fubara, 1987). In densely populated coastal wetlands and floodplains such as the Ganges-Bramaphutra-Meghna valley of Bangladesh, the Niger-Benue floodplains and the Niger Delta coastal wetlands of Nigeria, lives and properties are still being lost to flood annually. The reasons for these annual losses have been adduced by Burton, et al (1978), as: the forces propelling the world towards more and greater disasters will continue to outweigh by a wide margin the forces promoting a wise choice of adjustments to hazard. Of course, this is understandable because the search for livelihood and the home perception of people may often outweigh their desire to move from an original place. For example, floodplains are fertile and productive agricultural lands and yet they are great flood disaster prone areas. In a situation where water impoundment (dams, reservoirs, etc) lies at the upper reach of the floodplain, the situation could be worse if carefully managed.

Arms (1994) observed that millions of Bangladeshis live on sandbars in the Bay of Bengal that are awashed away every year by high tides and floods. He also observed that 1200 people died and 25 million people left homeless in 1988 when monsoon rains flooded the Ganges River. In the Niger floodplain of Nigeria, thousands of people in floodplain towns and villages are rendered homeless at high flow of the Niger. Lives and properties are lost while farmlands are destroyed leaving the remnants of the population economically dislocated. The situation had reached such magnitude in September/October 2003 that His Excellency, President Olusegun Obasanjo had to survey the upper Niger floodplain especially around the study area from a helicopter to assess the true scenario. In Nigeria, there is no disaster prevention and mitigation plan, what obtains is emergency relief measures. Emergency relief materials are rushed to the people affected by flood disaster as soon as they occur. After that, nothing is heard or done again until flood disaster recurs in the same place, then another session of emergency relief materials donation to victims. In plain language, there is no articulate disaster mitigation programme in the country (Oladipupo, 1990). This lack of articulate disaster mitigation plans in the country basically results from lack of information about the people and places involved. There is no proper documentation of information on location and other attributes of high risk flood plain settlements to carry out early warning and emergency response planning systems.

The objectives of this paper are: to map the land, settlement and other resources of the study area; to assess the number and status of settlements/communities that lie in the Niger floodplain including the Kaduna River floodplain, and to generate a geographic information systems (GIS) database which are vital for early warning purposes and can be accessed for disaster prevention and mitigation strategies for high risk settlements within an area in parts of the Niger floodplain south of the major water impoundments and hydro projects.

2. STUDY AREA AND THE HYDROLOGY OF THE NIGER RIVER

This study is focussed primarily on areas with elevation ranges of 200m-300m on the Niger flood plain around and south of the two major hydro electric power projects - the Kainji reservoir and Jebba dam which falls within administrative jurisdiction of Niger State in the north-west of Nigeria (fig 1).

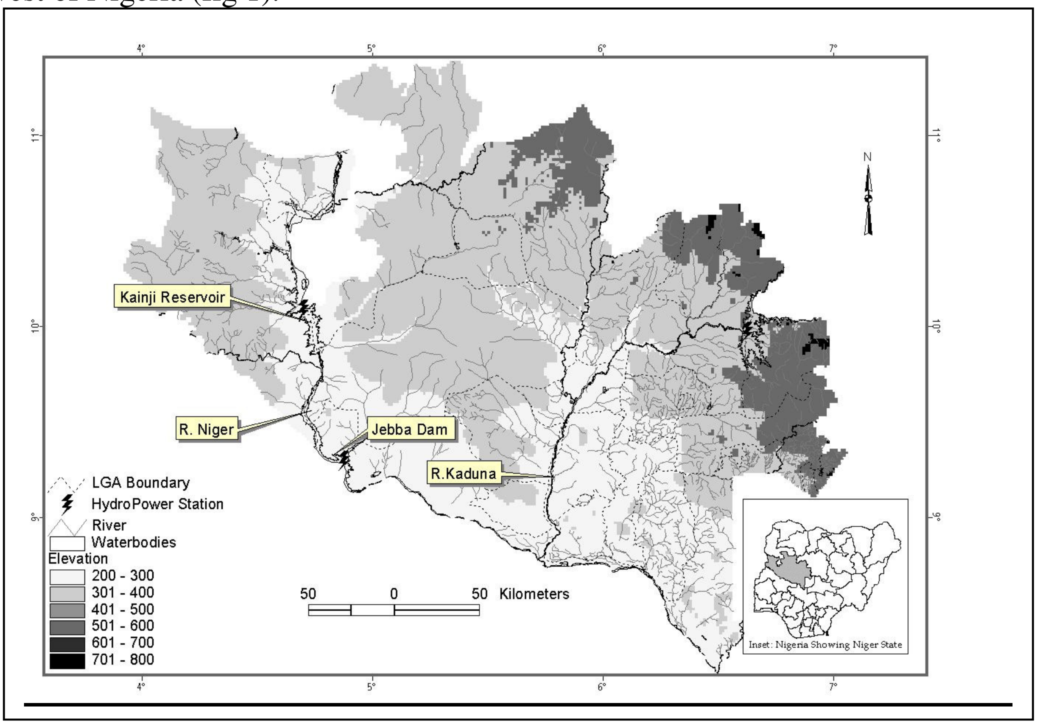

Fig 1: Niger State: Drainage and grid elevation surface of the general area

The Kainji reservoir and Jebba dam were designed around the concept of multipurpose water scheme for water use for HEP, agriculture, industrial and domestic uses. The Kainji reservoir was constructed in 1968 and further expanded in 1976, while Jebba dam was constructed in 1986. The area consists of the basement complex geological formations with metamorphic outcrops. The elevation ranges for the general area is between 200 meters and 800 meters above sea level with very steep slope and high gradient in some upper parts away from the area of interest. The area is well dissected with almost all the rivers running into the Niger River system. The Niger River is the most important in the West Africa flowing over 4,200km; 1,271km in Nigeria and 488km around the study area. The Niger takes its source from the Guinean highlands a few kilometres to the Atlantic and dramatically runs northwards into the Sahel before making a detour downward around Burkina Faso. The Niger basin covers nine countries including Guinea, Cote d'ivoire, Mali, Burkina Faso, Niger, Benin, Nigeria, Cameroon and Chad.

The Niger has a catchment area of 2,156,000km^2, sediment load of 40000x1000tyr^{-1} (tonnes per year) and sand load of about 2.5mm^3yr^{-1} (Folorunsho et al, 1998). Mean annual runoff is about 1,800mm and mean low water flow is about 0.37litres $s^{-1}km^2$. It receives input from several large tributaries. The major tributaries of the Niger in Nigeria are the Sokoto-Rima, the Kaduna and the Benue rivers; and the first two being of significance to the study area. Oyebande (1995) identified two distinct flood seasons for the Niger. The first is the black flood that originates from the high rainfall areas in the headwaters. It arrives at Kainji in November and lasts until March at Jebba with peak rate of about 2,000m^3s^{-1} in February. The second flooding season is the white flood which is laden with silt and suspended particles. The rainfall at headwaters in Guinean highlands is about 2,200mm. Runoff from local tributaries mainly Sokoto-Rima reaches Kainji in August attaining peak rates of 4,000m^3s^{-1} to 6,000m^3s^{-1} in September/October in Jebba. South of Jebba, the influence of Kaduna River becomes pronounced and most of the area is flooded. Around the study area which is north of Lokoja sediment input of the Niger is about 4.6$mtyr^{-1}$. This constitute the major fertile alluvial for the extensive Fadama agriculture around this area.

Table 1: Annual discharge (m^3/s) of river Niger

Month	$Q(m^3s^{1-})$	Deviation from mean
January	2200	-3725
February	2000	-3925
March	1800	-4125
April	1700	-4225
May	1500	-4425
June	2200	-3725
July	4300	-1625
August	8500	2575
September	17000	11075
October	19000	13075
November	8000	2075
December	2900	-3025
Mean	5925	0
Total annual	71100	

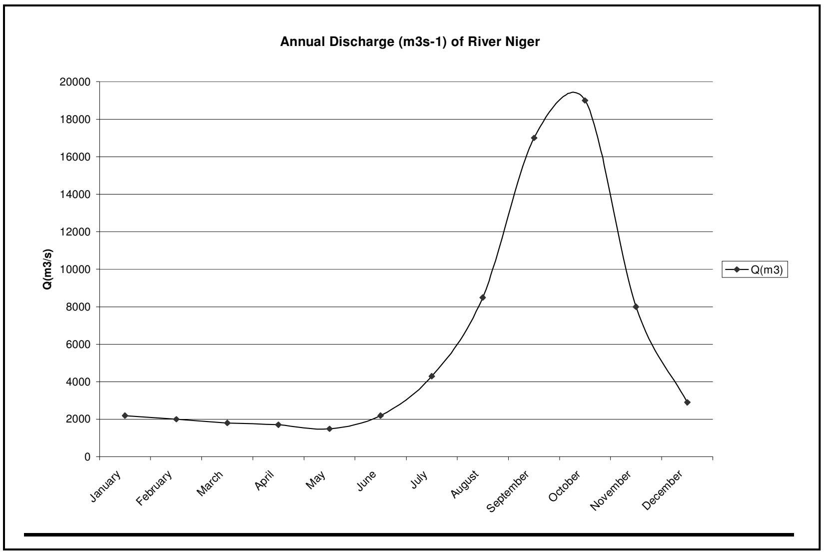

Fig 2: Annual discharge (m^3/s) of the Niger

The most important sediment discharge however occurs in September/October at the second peak of the rainy season in Nigeria. This equally corresponds to the time of peak flow and

release of excess water from the two upstream impoundments – the Kainji reservoir and Jebba dam.
Annual discharge in cubic meters per second of the Niger as reported by Folorunsho et al (1998) is shown on table 1 and fig 2. With a mean annual discharge of $5{,}925 m^3 s^{-1}$, the highest discharge figure of $19{,}000 m^3 s^{-1}$ is recorded in October and the lowest of $1{,}500 m^3 s^{-1}$ in May.

3. RESEARCH METHODOLOGY

3.1 Base data

The data for this study was generated from existing base maps including topographical, administrative and land use maps from various sources as shown on table 2.

Table 2: Data and data sources

S/n	Data	Identification	Scale	Year	Source
1	Topographical maps	Kubil, Auna, Kanji, Jebba, Mokwa, Lafiagi Pategi, Baro	1:100,000	1960 to 1965	Federal Surveys
2	Administrative maps for LGAs in Niger state	For the 25 LGAs in Niger State	1:100,000-1:250,000	1995-2000	Survey Directorate Niger State
3	Land use maps		1:250,000	1996	Federal Ministry of Agriculture

The sets of 1:100,000 base maps and the administrative base maps collated were scanned, imported into Arcview GIS and georeferenced with Image Analyst extension using existing control points on the maps. Using the head-up (on screen) digitizing method, data layers such as river/drainage networks and location and place names of settlements were extracted from the topographical base maps. Administrative {Local Government Area (LGA), District and Ward} boundary layers and administrative headquarters were extracted from the administrative maps. The characterization of present land use for the area was generated from a digital land use and vegetation data obtained from the Federal Ministry of agriculture. The data was generated at a scale of 1:250,000 from Landsat TM satellite data acquired in 1994 and interpreted by Beak/Geomatics/UNILAG Consult between 1995 and 1996. Due to dearth of elevation data the alternative source for generating DEM for the area is to digitize contours from existing topographical maps; this is ongoing for future work. For the purpose of this study however, a coarse resolution 6 arc second DEM for the Niger State obtained from the GIS Laboratory of the Department of Geography was used. This DEM was converted into vector contours for the area of interest.
Existing reports and field work data on demographic and socio-economic profile of various settlements in the study were also accessed from the Niger State Ministry of Health. These reports contain information field on local government, district, ward, major community (major ethnic groups), village name, village type, location, schools, health, water sources, and social infrastructures.

3.2 Data Integration and Building GIS Database

The process of building GIS database for hydrological disaster monitoring in the study area was executed within the Arcview GIS environment. Digitised settlements and drainage networks from the 1:100,000, topographic base maps; administrative (LGA, District, and Wards) layers, and land use and vegetation data were integrated within the GIS environment. The socio-economic database on settlements generated from the surveys by the Ministry of Health provided lots of attribute database for the settlements. These attributes were digitally attached to each settlement within the study area. Demographic and social profiles generated on settlements and attached to settlements are as shown on table 3.

Table 3: Locational attributes of Settlements

S/n	Attributes	Description
1	Local Government Area (LGA)	LGA Name
	District	District Name
	Community	Major Community (ethnic group)
	Ward	Ward name
	Village name	Name of settlement
	Village type	Settlement type – 1. <20 Buildings 2. >20 and <100 Buildings 3. >100 and <500 Buildings 4. >500 and <1000 Buildings 5. >1000 Buildings
	Location	Long/lat of settlement
	Education	Education facilities available: 1. primary 2. secondary 3. tertiary 4. Nomadic
	Health	Medical facilities: 1. primary 2. secondary 3. private pharmaceutical services 4. private curative services
	Water	Water sources: 1. pipe borne 2. borehole 3. pond 4. streams and rivers 5. motorised schemes
	Socials	Social facilities:

4. ANALYSIS AND DISCUSSIONS

The study area falls into the upper reach of the Niger River in Nigeria. The average elevation ranges from 200m to 800m. For this study the elevation range 200m-300m was chosen as approximating the flood plain extent and thus constituting the highest flood risk area. This was confirmed to some extent by the landuse data and even by a recent Nigersat-1 satellite imagery of the area. The area under this assessment for flood risk disaster monitoring is about 25,088km^2. The Niger river also runs for a distance of about 488km from the town of Binua at the upper boundary of Niger State with Kebbi State to Dere, south of Baro, some 40km to the confluence of the Niger with the Benue River.

4.1 Land Resources

An analysis of land use and vegetation data generated from the digital land use data for the study area showed the importance of agriculture in the local economy of the people. The dwellers rely so much on the floodplain of the Niger for sustenance. Table 4 and fig 3 indicate that about 17, 276km^2 of land representing about 69% of the area under assessment is devoted to agriculture. Both small and large scale mechanised agriculture are practised in this part of the Niger valley. These agricultural lands rely seriously on the natural free flooding of the Niger and the release of impounded water from the Kainji reservoir and Jebba dams. During low flows of the Niger, the local dwellers shift from crop farming to fishing.

Table 4: Landuse and Landcover of the study area

S/N	Land Use Class	Area (acres)	Area (km^2)	Percentage
1	Agriculture	4,269,007.46	17,276.44	68.86
2	Bare Surfaces	88,724.85	359.06	1.43
3	Forest	216,771.39	877.26	3.50
4	Urban	23,289.67	94.25	0.38
5	Water	232,838.63	942.29	3.76
6	Wetlands	72,458.47	293.24	1.17
7	Woodland/Shrub/Grassland	1,296,299.38	5,246.05	20.91
		6,199,389.84	25,088.59	100.00

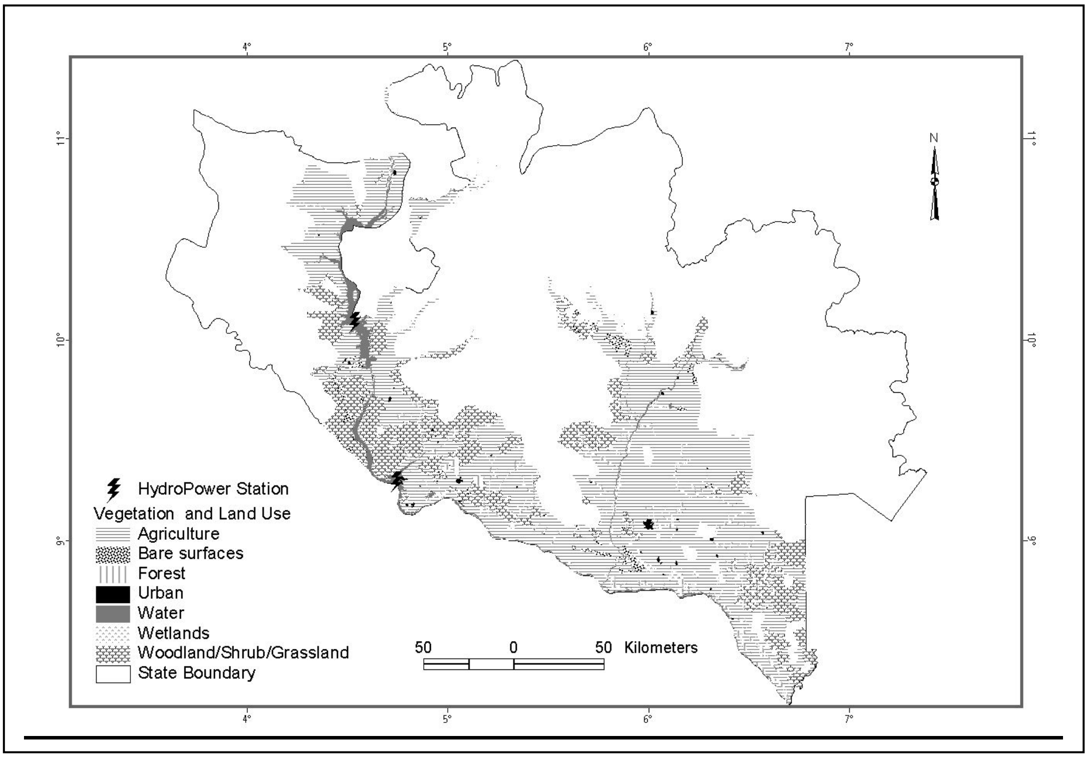

Fig 3: Landuse and Landcover of the Study Area

Most of the large scale farms such as Sunflag Agro millets farms, Nigeria Sugar Company (NISUCO) sugarcane farms, Guinness sorghum and millets farms, and the Nigerian Paper Mill farms all downstream the major HEP Dams and reservoirs are equipped and are therefore irrigated at low flows.

Other land use types around the study area include woodland/shrub/grassland, galleria forest, wetland, bare surface and built up area accounting for 5,246km^2 (21%), 877km^2, (3.5%), 293km^2 (1.2%), 359km^2 (1.4%) and 94km^2 (0.4%) respectively.

4.2 Settlements

Disaster as has been noted is a function of people in places. Were people not occupying the Niger floodplain neither the high flow of the Niger at certain seasons of the year nor the release of excess water from the HEP dams would constitute a hazard. Hence, the first step in risk assessment is hazard determination.

Table 5: Spatial characteristics of settlements of the study area

Code	Settlement type	No of settlements
1	< 20 Buildings	146
2	>20 and < 100 Buildings	202
3	>100 and < 500 Buildings	171
4	>500 and <1000 Buildings	79
5	>1000Buildings	50
		648

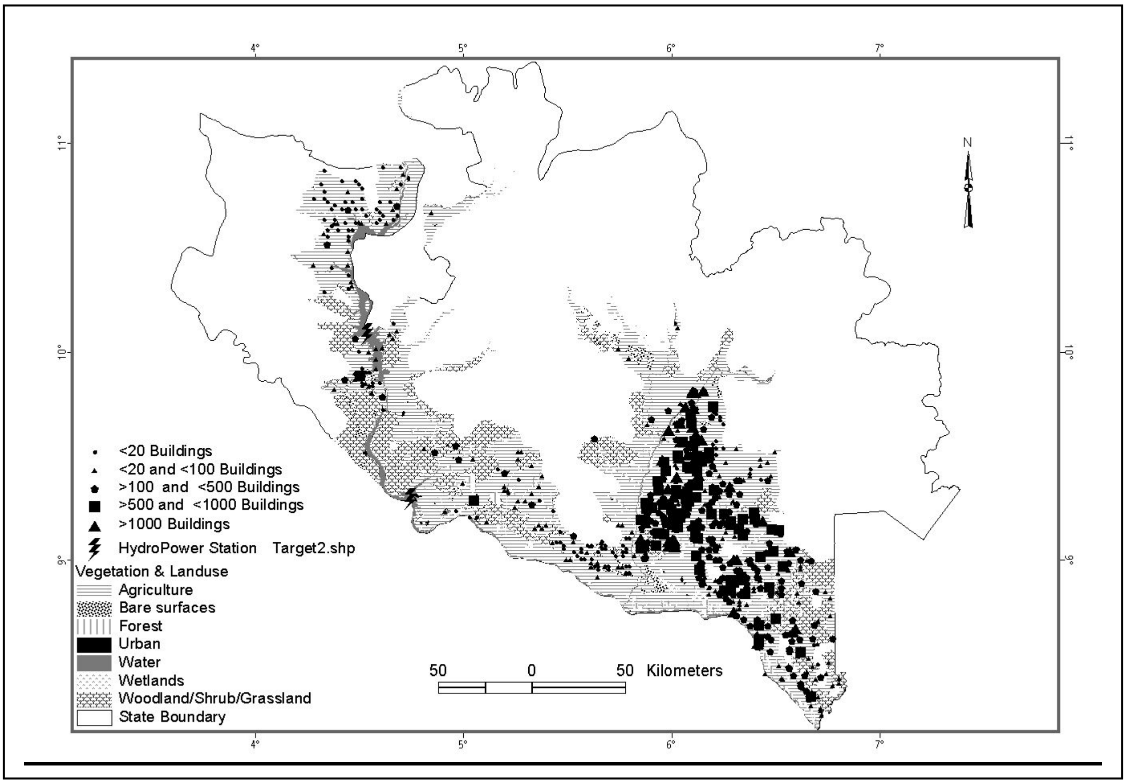

Fig 4: Settlement characteristics of the study area

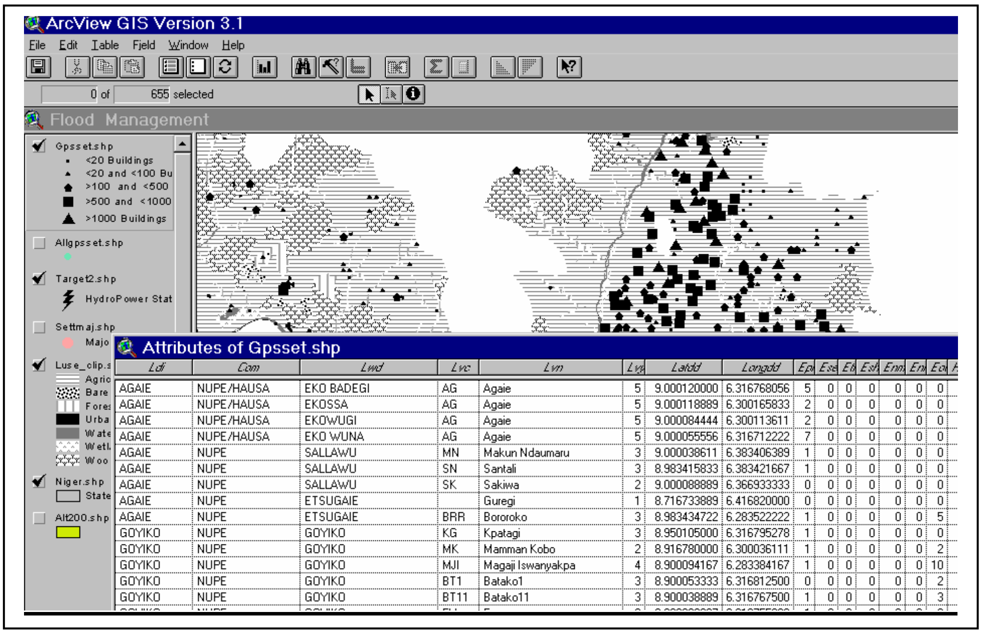

Fig 5: GIS database for flood risk settlements

The process of hazard determination begins through information about what are at risk given certain occurrences especially where no systematic and easily retrievable information for disaster mitigation planning is available. It was therefore part of the objectives of this study to integrate spatial and other information on the people and resources of the focus area within a GIS system that can trickle down into decision making for preventive and remediation policy planning as regards flood disasters.

From the analysis, there are 648 communities and settlements within the area of interest. 146 of the settlements are isolated farm stead of less than 20 buildings and 202 settlements are villages with between 20 and 100 buildings. 171 and 79 settlements respectively are major settlement categories with between 100 and 500 and 500 and 1000 buildings, while the rest 50 settlements are built up areas having over 1000 buildings (table 5 and fig 4).
An attribute database was created for each settlement with the field names including location of settlement, settlement name, local government, district and ward, major community of people, type of village, types of facilities available including education, health, water and social facilities (police, fire, town hall, etc), major occupation and livelihood sources, etc. as shown on table 3 and fig 5. This database therefore provides a baseline data for further large scale (small area) assessment of impacts, control and mitigative strategies for flood within the floodplain. It is also a useful baseline data for indicative planning in the Niger floodplain.

5. CONCLUSION

The frequency of occurrences of natural hazards is likely to increase because of increasing uncertainties in natural-physical systems resulting from climatic change and variability. Hence, the number of settlements likely to be exposed to the risk of inundation in the Niger floodplain is likely to increase in future. Yet, there is lack of integrated information on the spatial, economic and social characteristics and attributes of these floodplain resources and settlements, which makes floodplain planning and flood disaster management difficult. Preventive management of flooding and flood disaster especially below large HEP projects requires creation of large GIS database on the downstream settlements and resources that are at risk. This therefore makes it easy to manage flood risk, disaster, and safeguard lives and properties and to adequately respond to flood emergencies.

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