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MAPPING FLOOD VULNERABLE AREAS IN A DEVELOPING URBAN CENTRE OF NIGERIA

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ABSTRACT

This study exploits the integrated approach of Remote Sensing and GIS techniques in flood management with the goal of mapping areas vulnerable to flood hazard in Gwagwalada urban area. Topographic Map and Landsat TM image of 1991 and 2001 respectively were processed, scanned, digitized, interpolated, classified and overlaid using ILWIS GIS software modules to generate classified Land use/land cover map, Digital Terrain Map and Flood vulnerability map of the study area. The results obtained shows that, areas lying along the banks of River Usuma are most vulnerable to flood hazards with the vulnerability decreasing towards the northern part of the town, much of the area is built up and this gives rise to high vulnerability to flash flood hazards. The old town is the most vulnerable to flood threat. Phase 1, 2 and 3 are free from flood threat except for the extreme Northwestern part of Phase 3. The incessant violation of landuse plan, unchecked population growth, old nature of the structures and poor materials used in the construction of the houses exacerbate Old Town vulnerability to flood hazard. In reducing the vulnerability of the town from flood there is need for improved land use planning, removal of structures from River Usuma flood plains around the town, intensify environmental education residents and enhance the active participation of government agencies in the continual generation of Flood vulnerability maps of urban centres.

Keywords: Flood, Vulnerability, DEM, GIS, Remote Sensing, Gwagwalada Town.

INTRODUCTION

Flood is among the most devastating natural hazards in the world claiming lives and properties more than any other natural phenomena (Ologunorisa, 2001; Alcira and Martha, 1991). In the past decade in Nigeria, thousands of lives and properties worth millions on Naira have been lost directly or indirectly from flooding every year. In most urban centers of the country most especially in fast growing towns like Gwagwalada town of the Federal Capital Territory (FCT), human population increase, landscaping in paved areas, streams and channel obstruction due to bad waste disposal habit and other human activities at flood plains were considered to be the major causes of floods Olusegun, 2004a; Olusegun 2004b). Barroca (2006) and Blong (2003) felt that flood vulnerability mapping can offer a hundred percent security against floods.

Flood disaster management just as other disasters management can be grouped into (i) the preparedness phase where activities such as prediction and risk zone identification or vulnerable mapping are taken up long before the event occurs; (ii) the prevention phase where activities such as forecasting, early warning, monitoring and preparation of contingency plans are taken up just before or during the event and (iii) the response and mitigation phase where activities are undertaken just after the disaster and its includes damage assessment and relief management (Van Western et al., 1993).

Mitigation of flood disaster can be successful only when detailed knowledge is obtained about the expected frequency, character, and magnitude of hazardous events in an area as well as the vulnerability of the people, buildings, infrastructures and economic activities in a potential dangerous area (Van Western and Hosfstee, 2000). Unfortunately, Ifatimehin et al (2009), Ishaya et al(2008a), Ishaya et al (2008b) and Ifatimehin and Ufuah (2006) reported that this detailed knowledge is always lacking in most urban centres of the developing world especially Nigeria. One way to mitigate the effects of flooding is to ensure that all areas that are vulnerable are identified and adequate precautionary measures taken to ensure either or all of adequate preparedness, effective response, quick recovery and effective prevention. Before these could be done, information is required on important indices of flood risk identification which are elevation, slope orientation, proximity of built-up areas to drainages, network of drains, presence of buffers, extent of inundation, cultural practices as well as attitudes and perceptions.

To get information on most of these, and identify areas that are vulnerable to flooding, reliable techniques of collecting and analyzing geospatial information are required. In this regard, an integrated approach of Remote Sensing (RS) and Geographic Information System (GIS) has proved to be the most effective (Jayasselan, 2006), and perhaps the only option to flood hazard preparedness and to reduce potential risk. This will be part of a larger, long term effort to gain a better understanding of community vulnerability on the floodplains and low elevated areas to flood hazard.

In general flood hazard mapping is a vital component for appropriate land use planning in flood-prone areas. It creates easily-read, rapidly-accessible charts and maps that can facilitate administrators and planners to identify areas at risk and prioritize their mitigation/ response efforts (Venkata and Sinha, 2004).

MATERIALS AND METHODS

Study Area: Gwagwalada town is located about 40 Kilometers away from the Federal Capital City of Abuja and it is centrally located within the Federal Capital City (FCT). The town falls between latitude $8^0$55’ N and $9^0$00’N and longitude $7^0$00’ and $7^0$05’ (Figure 1). The study area has a total landmass of about $65km^2$ and with the rapid rate of urbanization, developmental processes are now taking places even outside where was earlier considered as the Gwagwalada boundary (Balogun, 2001).

The climate of the study area just like most climate in the tropics have a numbers of climatic elements in common, most especially the wet and dry season’s characteristics. Mean temperature in the area ranges from 30^0C – 37.0^0C yearly with the highest temperature in the month of March and mean total annual rainfall of approximately 1,650mm per annum (Balogun, 2001). Rainfall play a vital role with respect to flood threat within the study area and with most threatening events between July to September this is because 60% of the annual rains fall during the months. The study area is drained by River Usuma which is an important tributary of River Gurara and is the largest and major river within the study area (Balogun, 2001). The town has a population of 23,114 in the year 2000 people and is one of the largest satellite town and the third largest urban centre in the FCT (Balogun, 2001).

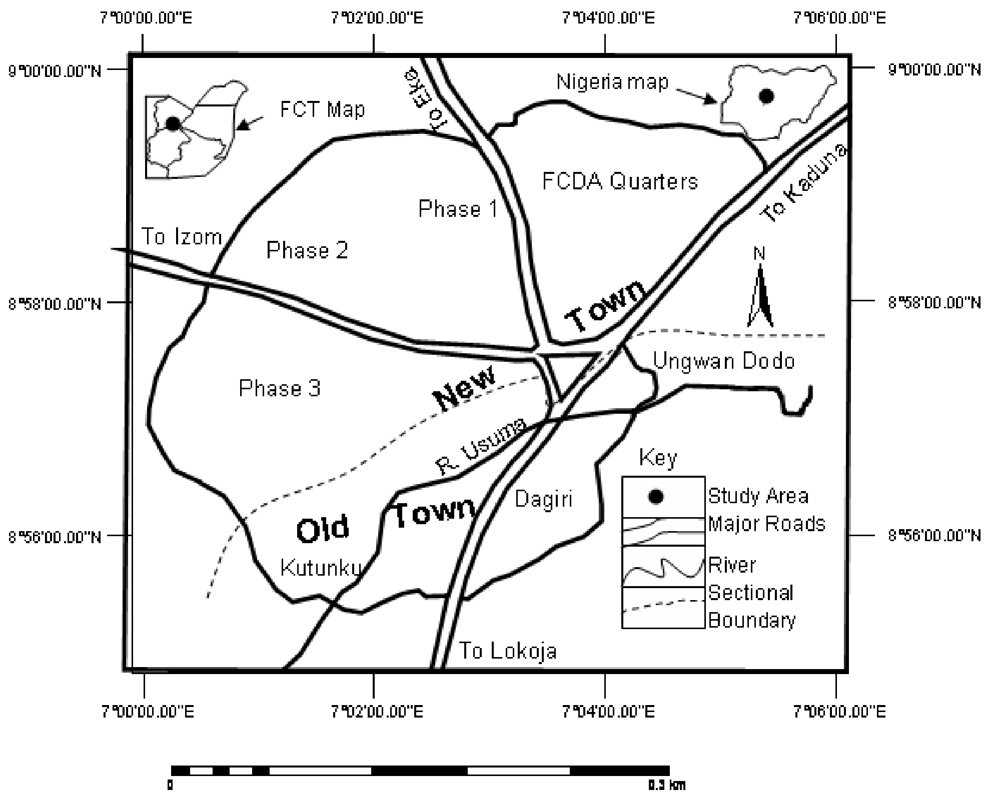
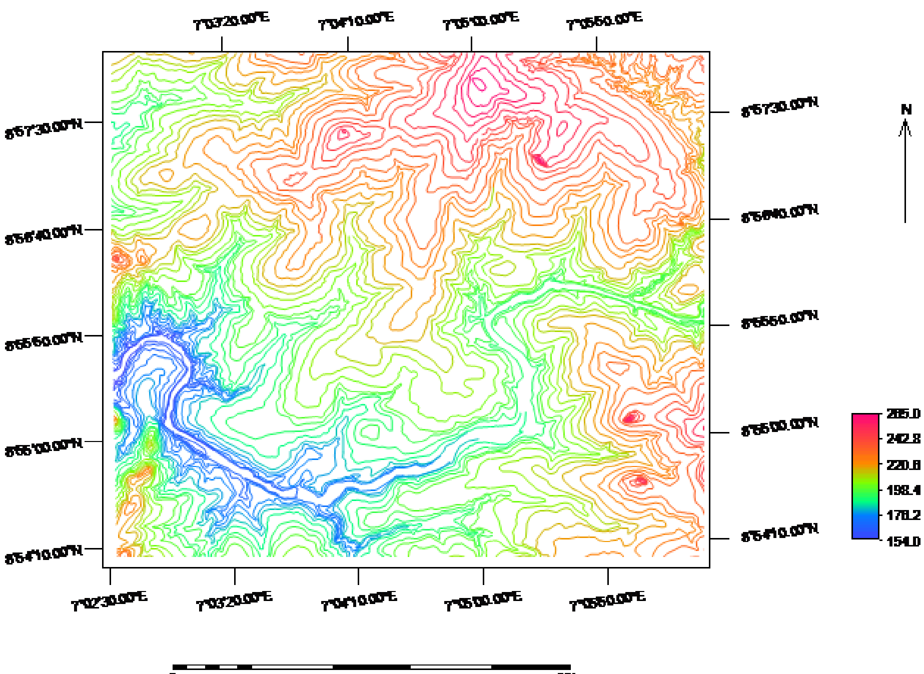


Fig. 1 Gwagwalada Town

The materials used in this study are Topographic map with scale 1:10,000 of Kuje (Sheet 207 NW) and Landsat TM image of 2001 with spatial resolution of 30m and spectral bands of 1 (Red), 2 (Green), 3 (Infrared) were used for the study. The GPS was used to acquire data on the point of distinguishing land use and points of elevation. A composite image was generated from the Landsat TM image and then classified to extract the different land uses of the study area using the Box classifiers and the supervised classification algorithm provided by the ILWIS 3.2 Academia software. The Topographic was scanned and imported into the GIS environment provided by the ILWIS 3.2 Academic software and was converted into segment map where the contours were digitized and interpolated to generate a Digital Elevation Model (DTM).

Results and Discussion

The digitized topographic map (Figure 2) was interpolated to generate DTM of the town (Figure 3) The DTM clearly shows that the lowest elevation is found around River Usuma with an elevation of 161.03m above sea levels in the South-western part of study area. The elevation of the town increases gradually up towards the Northern part of the town with the highest elevation at 218.46m above sea level.



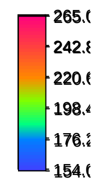


Figure 2: Digitised Topographic Map of The Study Area (1: 10,000) Showing Contour Lines (meters)

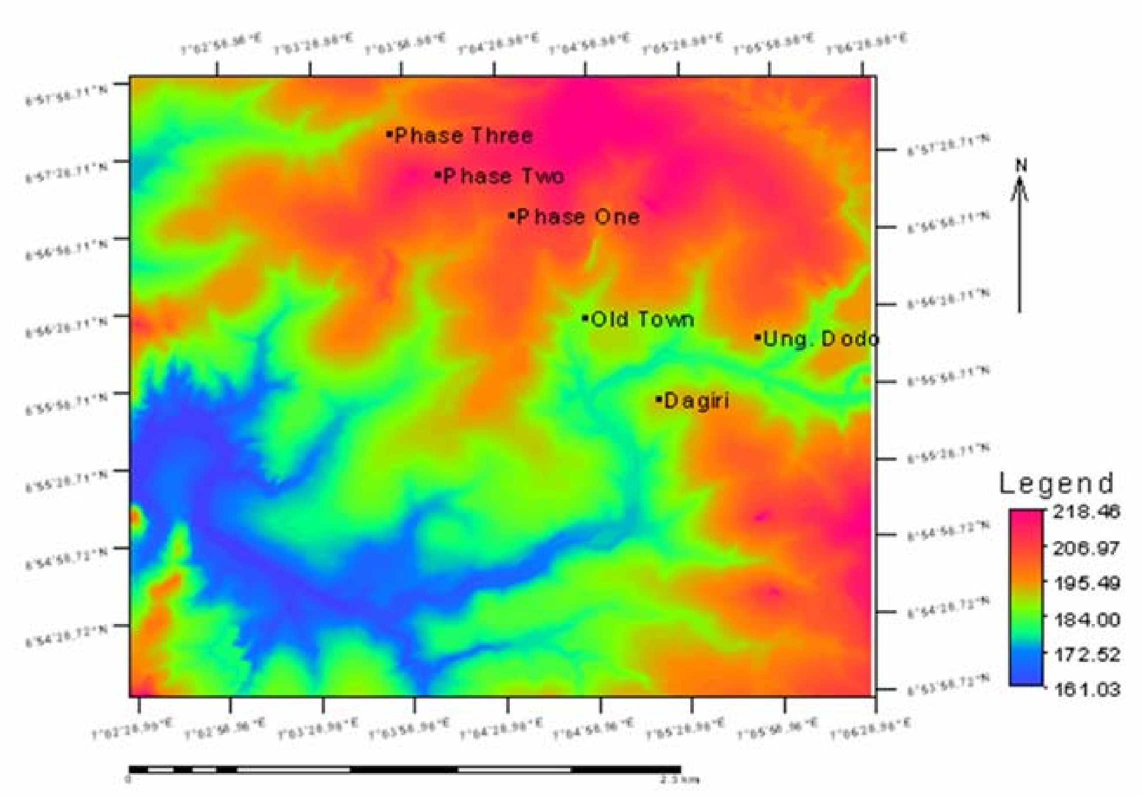


Figure 3: DTM of Gwagwalada Town Generated Through Contour Interpolationa

For the purpose of critical urban studies where many variables of the environment are considered with the aim of mapping from images, composites images are usually developed. A True Colour Composite (TCC) image of the study area was classified to generate the Land use/Land Cover map of the study area (Figure 4).

Table 1: Showing Data of the Land use/Land cover of the Study Area

Land Cover	Number of pixels	% of pixels	Area (m^2)
Roads and Pavement	928	1.39 %	753768.0
Urban Area	29413	44.04 %	23890709.3
Vegetation & Farmlands	27614	41.35%	22429471.5
Water	3761	5.63 %	3054872.3
Flood plain Vegetation	5064	7.58%	4113234.0
Total	66780	100 %	54242055.1

Source: Classified Landsat Image, October, 2007.

The data of the classified image (Table 1) shows that roads and pavement occupy 928 pixels, Urban area occupies 29413 number of pixels, Vegetation and farmlands occupy 27614 numbers of pixels, water occupy 3761 numbers of pixels and floodplain vegetation occupy 5064 numbers of pixels.

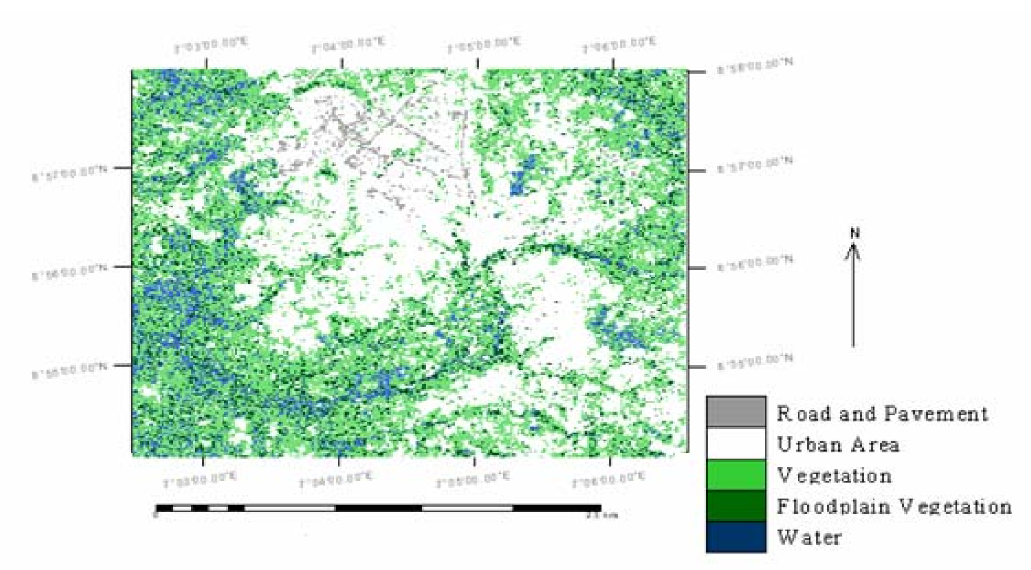


Figure 4: Classified Landsat TM Image of 2001 of the Study Area

A close look at the 5 reveals that urban buildings cover 44.04% (23890709.3m^2) of the total area, roads and pavements cover 1.39% (753768.0m^2) of the total area, farmlands and vegetation cover 41.35% (22429471.5m^2) of the total area, water cover 5.63% (3054872.3m^2) of the total area while floodplain vegetation cover 7.58% (4113234m^2) of the total area.

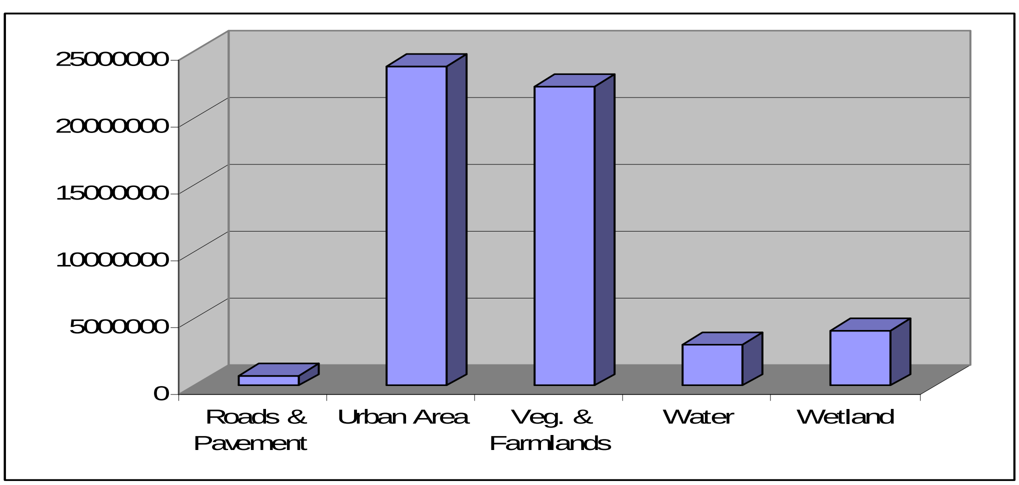


Figure 5: Total Area (m^2) Occupied by the Various Land Cover Types in the Landsat TM Image of Gwagwalada

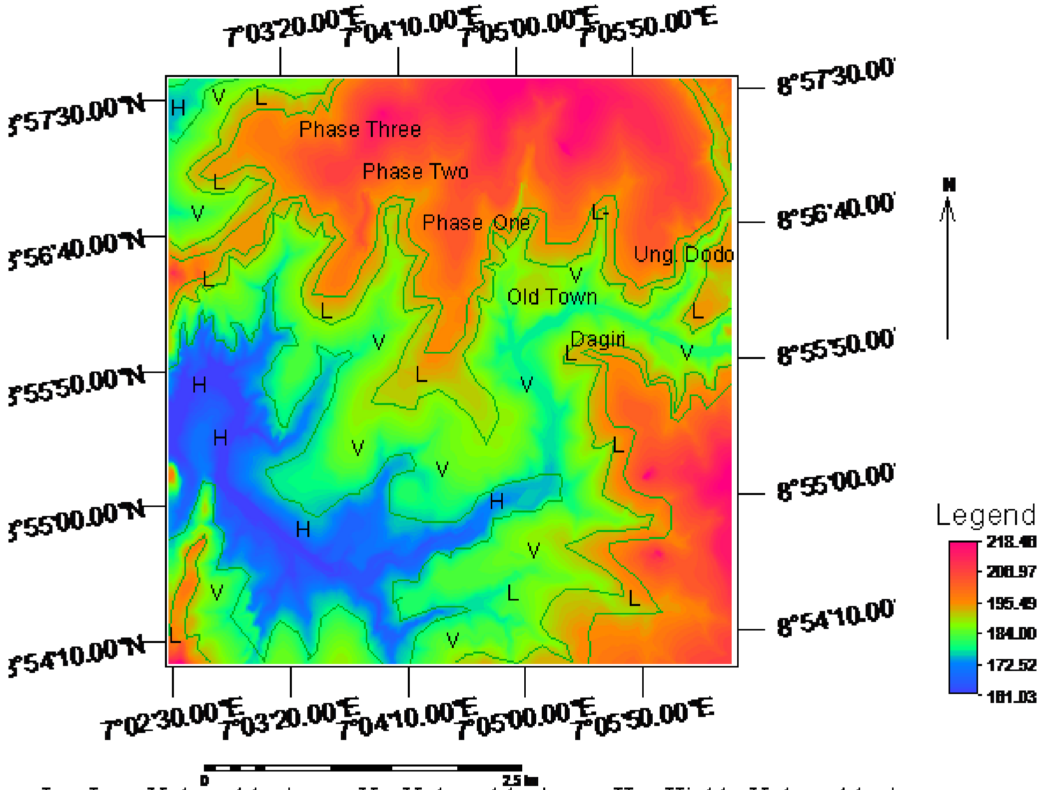
Table 2 gives the elevation and location characteristics data of the five different locations studied. Findings of the areas affected by the flood events are built-up areas while their elevations vary between about 175 to 185m. All the areas not affected by flooding are generally above 190m in elevation. These indicate that the areas that are largely at risk to flood are actually those lying at lower elevation locations.

From the data on elevations of locations flooded from the various areas within the town in July 2006 with the highest elevation of the points flooded at 186.00m above sea level approximately, the segment map produced from the DTM shows areas of different vulnerability to flood hazard. The maps shows areas that falls between 161.03m to 172.52m above sea level as areas highly vulnerable to flood, areas between 172.52m to 186.00m above sea level as areas vulnerable to flood, while areas falling between 186.00m to 195.49m as areas less vulnerable to flood (6, 7 and 8).

The spatial data stored in the digital data base of the GIS, such as DTM can be used to predict the future flood events (Sarma et al., 2005). The GIS data base may also contain agriculture, socio-economic, communication, population and infrastructural data. This can be used to adopt an evacuation strategy, rehabilitation planning and damage assessment in case of a critical flood situation. Definition of flood prone areas due to extreme events in natural rivers constitutes a problem of great interest. It is generally obtained by simulating flood wave propagation by means of 1D mathematical model and identifying the flood prone areas as the areas where the ground elevation is lower. To map these areas a DTM is required. However in many cases the cross sections used to define the river channel, commonly obtained by means of land surveys, do not agree with the DTM and consequently significant discrepancies may occur in the mapping of the flood prone areas (Natale et al 2007 and Sarma, 2005).

Table 2: Points and Elevations Bounding Area in the various Neighborhoods in the Study Area

Abattoir			
Selected points	Easting	Northing	Elevations above mean sea level (m)
1	7^0 04.892'E	8^0 56.085'N	179.520m
2	7^0 04.883'E	8^0 56.061'N	183.794m
3	7^0 04.885'E	8^0 56.034'N	180.746m
4	7^0 04.887'E	8^0 56.035'N	184.099m
5	7^0 04.885'E	8^0 55.973'N	183.794m
6	7^0 04.882'E	8^0 55.953'N	185.041m
7	7^0 04.891'E	8^0 55.940'N	178.613m
Ungwan Aguma			
1	7^0 04.944'E	8^0 55.944'N	181.66m
2	7^0 04.948'E	8^0 56.015'N	181.97m
3	7^0 04.951'E	8^0 56.949'N	178.92m
4	7^0 04.958'E	8^0 56.077'N	185.32m
5	7^0 04.934'E	8^0 56.097'N	185.62m
6	7^0 04.919'E	8^0 56.096'N	177.39m
Dagiri			
1	7^0 05.479'E	8^0 56.153'N	182.50m
2	7^0 05.305'E	8^0 56.055'N	181.97m
3	7^0 05.260'E	8^0 56.050'N	185.23m
4	7^0 05.127'E	8^0 55.972'N	184.40m
5	7^0 05.042'E	8^0 55.974'N	185.01m
6	7^0 05.002'E	8^0 55.949'N	182.88m
7	7^0 04.987'E	8^0 55.936'N	185.93m
8	7^0 05.008'E	8^0 55.922'N	185.93m
9	7^0 05.028'E	8^0 55.924'N	185.32m
10	7^0 05.002'E	8^0 55.865'N	185.93m
11	7^0 05.015'E	8^0 55.834'N	185.62m
12	7^0 05.064'E	8^0 55.804'N	181.36m
13	7^0 05.086'E	8^0 55.766'N	185.93m
14	7^0 05.117'E	8^0 55.737'N	185.01m
15	7^0 05.110'E	8^0 55.762'N	185.93m
Ungwan Shanu			
1	7^0 04.943'E	8^0 56.451'N	185.320m
2	7^0 04.942'E	8^0 56.427'N	183.794m
3	7^0 04.942'E	8^0 56.404'N	186.195m
4	7^0 04.896'E	8^0 56.394'N	184.440m
5	7^0 04.886'E	8^0 56.337'N	185.020m
Ungwan Bassa			
1	7^0 05.107'E	8^0 56.141'N	185.23m
2	7^0 05.129'E	8^0 56.139'N	184.71m
3	7^0 05.133'E	8^0 56.107'N	175.26m
4	7^0 04.852'E	8^0 56.325'N	185.62m
5	7^0 04.844'E	8^0 56.291'N	182.88m
6	7^0 04.858'E	8^0 56.244'N	177.09m
7	7^0 04.904'E	8^0 56.265'N	183.49m
8	7^0 04.967'E	8^0 56.117'N	179.53m
9	7^0 04.974'E	8^0 56.111'N	181.66m
10	7^0 04.987'E	8^0 56.112'N	185.62m
11	7^0 04.879'E	8^0 56.096'N	181.36m
12	7^0 04.858'E	8^0 56.112'N	174.65m
13	7^0 04.840'E	8^0 56.124'N	179.53m
14	7^0 04.826'E	8^0 56.128'N	180.75m



L = Less Vulnerable Areas, V =Vulnerable Areas, H = Highly Vulnerable Areas

Figure 6: DEM Overlaid with Segment Map of Gwagwalada Town showing Areas Prone to Flood Hazard.

The mapped DTM (Figure 6) show highly flood hazard vulnerable area falling between 161.3m to 172.52m above sea level. Areas vulnerable to flood hazard falls between elevations ranging from 172.52m to 186.00m above sea level and with areas falling between 186.00m to 195.49m above sea level as less prone to flood hazard. The areas that fall on elevation ranging from 195.49m to 218.46m above sea level are highly free from flood threat (Figure 5, 6 and 7).

Areas mapped H (Highly Vulnerable to Flood Hazard) on the classified and unclassified image of the town also are the areas that fall between 161.3m to 172.52m on the DTM and this area constitutes 18.18% of the study area. On the other hand an area that falls between 172.52m to 186.00m on the DTM are the areas term V (Vulnerable to Flood Hazard) on the classified and unclassified image of the town and this area constitutes 34.23% of the study area. Areas that fall within 186.00m to 195.49m on the DTM are areas considered L (Less Vulnerable to Flood Hazard) on the classified and unclassified image of the town and this area constitutes 12.67% of the study area. The remaining 34.93% of the area that falls outside the less vulnerable area is consider to be free from flood threat (Figure 6, 7, 8, and Table 3).

Table 3: Showing Data of the Areas cover by Various Levels of Vulnerability

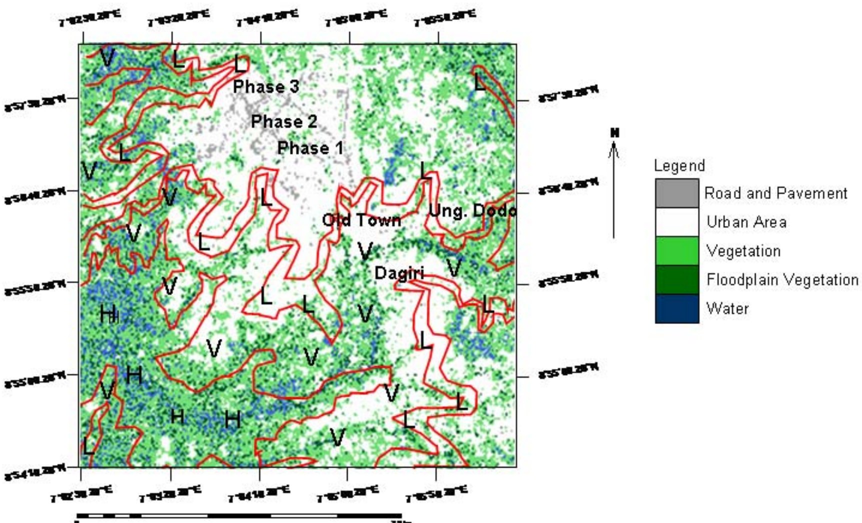
Vulnerability Class	Areal Extent (m^2)	Percentage of area
Highly Vulnerable to Flood Hazard	9861205.617	18.18%
Vulnerable to Flood Hazard	18567055.46	34.23%
Less Vulnerable to Flood	6872488.381	12.67%
Free From Flood Hazard	18946749.85	34.93%
Total	54247499.3	100%

Source: Digitised DTM.

From the classified LandSat TM image it can be clearly seen that areas Highly Vulnerable (H) to flood hazard are found closely around River Usuma in the Southwestern part of the study area. Areas map as Vulnerable to Flood Hazard (V) are to a large extent dominated by Urban Structures, Vegetation and Farmlands.

Considerable area of the Old town (Dagiri, Ungwan Dodo, Ungwan Shanu, Ungwan Bassa, Ungwan Gwari, Ungwan Aguma and Abattoir) and the so-called Stadium Layout with elevation less than 186.00m above sea level are mapped vulnerable to flood hazard. The vulnerability of these areas to flood hazard is very disastrous this is because of the high degree of the planning violation in the areas, high population concentration, poor nature of materials used in building of the houses, old nature of the houses, solid waste disposal in streams and River Usuma, high level of concentration of houses around the streams and River Usuma draining the town causes serious constriction of the streams exacerbating an unease flow of surface water after a heavy down pour, which usually instigate flash flood. One important finding during the verification study is that clogging of drains which are usually caused by dumping of solid waste in the drainage system is a usual thing in these areas which is actually a double-dealing factor to flood vulnerability of an area.

In phase 3 locations such as longitude $8^0$57’43.15’’N; latitude $7^0$03’23.57’’E and $8^0$57’43.15’’N; latitude $7^0$03’23.57’’E and $8^0$57’39.71’’N; latitude $7^0$03’40.07’’E at the extreme end of Phase 3 are considered vulnerable to flood hazard this is around the stream that separate Phase 3 and Passo a satellite settlement away from the Gwagwalada town. Points with elevations 186.00m to 195.49m are considered less vulnerable to flood hazard; such points with urban structures are $8^0$57’35.33’’N; latitude $7^0$03’23.57’’E, $8^0$57’40.07’’N; latitude $7^0$03’41.11’’E and $8^0$57’37.39’’N; latitude $7^0$03’27.20’’E



L= Less Vulnerable Areas, V= Vulnerable Areas,
H=Highly Vulnerable Areas

Figure 8: Areas Vulnerable to Flood Hazard on Classified LandSat Image of the Town.

Based on these research findings Phase 1 with average elevation of 210m above sea level and Phase 2 having average elevations of 200m above sea level are highly free from flood threat and this can be clearly seen from the DTM, classified LandSat image of the town (Figure 7, 8).

CONCLUSION

This study was hence initiated with the central aim of making use of RS and GIS techniques in mapping out areas that are vulnerable to flooding within Gwagwalada Urban area. To address this, a methodology was developed involving, pre-processing and classification of Landsat TM (2001) of the study area to show landuse/land cover information, digitising of topographic maps of the area, generation of digital terrain model (DTM) of the area from the produced contour data, integration of the imagery data with the contour data and DTM to generate maps showing areas of different vulnerability to flood hazards within the town. Areas lying along the banks of River Usuma are at locations that are most vulnerable to flood hazards with vulnerability of the town to flood decreasing towards the northern part**.** Much of the area is built up and this gives rise to high vulnerability to flash flood hazards. Dagiri, Ungwan Shanu, Ungwan Gwari, Ungwan Bassa, Ungwan Aguma, Abattoir, Ungwan Dodo and the so-called Stadium Layout are the main areas of the town that are vulnerable to flood hazard. The entire area of Phase 1 and Phase 2 are free from flood threat. Phase 3 is also free from flood threat except for the extreme Northwestern part of the area. Lack of landuse planning, population growth, old nature of the structures and poor materials used in the construction of the houses exacerbate Old Town vulnerability to flood hazard. The following can be recommended for a flood free town:

- There is the need for improved land Use Planning;
- Removal of structures within the reach of river Usuma flood plains around the town;
- Raise awareness of residents of the town;
- Improving the functionality of Nigeria National Emergency Management Agency (NEMA);
- Develop GIS Data Base for the Town and the Country At Large;
- Utilizing Remote Sensing Data from Nigeria National Space Research; Development Agency (NASRDA) for flood disaster related researches;
- Develop Reliable Forecasting and Warning System; and
- Continual Vulnerability Mapping.

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