Flood hazard assessment of River Dep floodplains in North-Central Nigeria

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Flood is a recurring event that leads to hazards. The probability of a flood occurring is normally investigated followed by flood hazard mapping which defines the areas that are at risk of flood inundation. This study carries out flood hazard assessment for the flood prone areas within the low-lying flat river valley of the River Dep watershed using Remote Sensing (RS) and geographic information system (GIS) for 2-year to 1000-year return periods, with regards to inhabited areas and other land uses that will be affected. Result shows that the most affected land use within the floodplain is agriculture with inundated area ranging from 68.82 to 146.10 km². Low to medium flood hazards predominantly dominate the floodplain with area extent increasing from 112.2 to 140.75 km² for low hazard and 35.65 to 163.65 km² for medium hazard. High hazard is mainly within the deep part of the floodplain with minimal area extent of 4.11 km².

The study recommends low hazard areas to be used for irrigation farming and early rainy season farming, medium and high hazard areas for irrigation farming only while low, medium and high hazard areas for the 100-year flood should be avoided with respect to construction of residential or commercial structures. Generally areas close to rivers should be avoided for rainy season farming and residential or commercial development.

Key words: Flood hazard, remote sensing, geographic information system (GIS), land use, land cover.

INTRODUCTION

Hazard is defined as a ‘potentially damaging physical phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation’ (Damayanti, 2011). Alkema and Westen (2005) defined flood hazard as ‘the chance that a flood event of a certain magnitude will occur in a given area within a given period of time’. Each hazard is characterised by its location, intensity, frequency and probability. Flood hazard can be described by different parameters including flood extent, water depth, flow velocity, duration and the rate at which the water rises, where flood depth, velocity and duration are important factors in flood damage (de Moel et al, 2009). While flood hazard is the impact of flooding on development and people, the velocity and depth of floodwaters greatly affect personal safety and damage to infrastructure and agricultural lands (Floodplain Development Manual). The manual suggests that at velocities of over excess of 2 m/s grass and earth surfaces begin to scour affecting stability of foundations,
and depths of over 2 m with less velocity can cause damage to light-framed buildings. Catchment flood hazard assessment focuses on the catchment as a whole and looks at how the different characteristics of the catchment integrate to contribute to flooding within the floodplains. There is a yearly occurrence of floods of different severity within the River Dep floodplains resulting in loss of human lives, destruction of flood infrastructure, livestock and crops. Flood depth and velocity affect agricultural activities within the Dep floodplain including harvest and transportation of crops within the area. During the rainy season, the farms become submerged in floodwater which can be over 1 m in depth, sometimes taking several days to recede and resulting in destruction of submerged crops.

The inhabitation and use of the floodplains results in encroachment into a land that should be left to the natural elements, posing a great danger to the inhabitants and users, and high risk of destruction and loss of investments and lives. People living within the River Dep floodplains can still enjoy the agricultural benefits that it provides and yet avoid the hazards that come with floods. This can be achieved by ensuring that man's activities do not conflict with the natural occurrence of flooding by adequately planning the use and management of the floodplain. Though conventional traditional methods can be used for flood hazard assessment, the use of remote sensing and geographic information system techniques have been suggested to provide quick, efficient and effective results as investigated and documented by Balanova and Vassilev (2010), Damayanti (2011), Kafle et al. (2006), Salimi et al. (2008), Ahmed et al. (2010) and others. This study is aimed at carrying out flood hazard assessment for the flood prone areas within the low-lying or flat river valley of the watershed with regards to land uses that will be affected. Flood hazard maps for some extreme flood events will be analysed and the affected land uses estimated.

Study area

The Dep River Basin lies between latitudes 8°00′00″N to 9°20′00″N and longitudes 8°20′00″E to 9°35′00″E as shown in Figure 1. It falls within the Lower Benue River Basin Development Authority in North Central Nigeria. The flood plain is within the relatively flat river valley with elevations between 78 to 200 masl. The land within the area is predominantly used for agriculture.

MATERIALS AND METHODS

Softwares

1. ERDAS Imagine 9.2 for remote sensing analysis.
2. ArcGIS 9.3 for GIS analysis. It has the capability of accepting compatible add-on extensions such as the HEC-GeoRAS.

Satellite data

30 m x 30 m resolution Landsat ETM image of Dep River watershed was downloaded from Global Land Cover Facility. It is the only one available for the complete study area. Date of acquisition is 02/11/2001.

Flood hazard assessment

Flood hazard assessment was carried out by assessing the impact of flood depth and flood velocity where deep inundating water and high velocity were classified as the destructive force, deep inundating flood with low velocity as less destructive and shallow inundating water with high velocity as more destructive (Damayanti, 2011). The classification of flood hazard according to depth by Cooper and Opadeyi (2006) and the relationship between flood depth and flood velocity established in the Floodplain Development Manual were taken into consideration.

The following criteria were used by multiplying the depths and the velocities to assess flood hazard:

- Level 1: Shallow water and low velocity
- Level 2: Shallow water and medium velocity or deeper water and low velocity
- Level 3: Shallow to medium or deep water with high velocity or deep water with medium velocity.

The different categories of velocities and depths are tabulated below for the 100-year flood:

- Table 1 implies that the threshold for high hazard was set at 1.4m of flood inundation depth and 2m/s of flood velocity.
- Flood hazard analyses were carried out for 2, 5, 10, 20, 50, 100, 200, 500 and 1000-year floods, with more emphasis on the 100-year flood, using flood inundation maps previously obtained by Daffi (2013). The map was overlain on the settlement map of the study area to view those that will be affected by flood of these return periods. It was also overlaid on the Landsat land use classified map to view and analyse the land uses that would be inundated by the floods.

RESULTS AND DISCUSSION

Assessment of flood inundation on settlements

Figure 2 shows the flood inundation extent on a 3-D map of the study area. It shows the floodplain is within the low lying river valleys of the Dep River.

Overlaying the 100-year flood inundation map on the settlement map showed that about four settlements are likely to be affected by the 100-year flood as seen in Figure 3.

Ground validation however, showed that of the four settlements seen to be within the flood area, only one settlement called ‘Wuse’ is under risk of inundation from the flood because of its proximity to the adjacent river.

Assessment of flood inundation on land uses

Overlaying the flood inundation extent map on the land use land cover classification map gave an indication of the area and percentage area inundated by the 100-year flood.
flood shown in Table 2.

Of the total land area of the floodplain, generally shrubs/scattered trees make up the highest land cover class inundated by floodwaters with percentage area of between 46.4 to 46.5% for the 2-year and 1000-year floods respectively. This is because the areas closest to the river, most especially around the confluence of River Dep and River Benue, are made up of dense shrubs and trees and some of the areas are even impenetrable. There was a general increase of 77.28 km$^2$ or 52.9% for the agricultural land affected by flood from the 2-year to the 1000-year floods.

Also, for all floods agricultural cultivated land is the land use that is significantly affected with an area of 119.86 km$^2$ for the 100-year flood. A lot of dry season (irrigation) farming takes place within the floodplain which is commonly referred to as ‘fadama’. This is the most important land use within the floodplain.

Bare surface/degraded land is the land cover that is least affected by the flood with area of 1.57 km$^2$ or 0.6% for the 100-year flood. This is because there are hardly any bare surfaces available within the floodplain; the land is mostly cultivated or covered with shrubs or trees because of the swampy nature of the area.

The remaining 6.4% or 16.62 km$^2$ is made up of water bodies and rock outcrops where the rock outcrops are mainly within the upper parts of the Dep River catchment which mainly make up the source of the river.
Generally, the land use that is more prone to flood hazard is agriculture and the worst affected land cover is shrubs and scattered trees.

**Flood hazard with respect to flood velocities and depths**

Figure 4 shows the flood hazard areas within the Dep River catchment with sections of flood areas for different return periods. These are within the low lying and flat parts of the catchment. The flood hazard classification for the different return periods is shown in Table 3.

The floodplain is majorly inundated by low to medium hazard flood with an area of 105.4 and 150.1 km$^2$ respectively for the 100-year return period while high hazard flood covers 5.82 km$^2$. This agrees with the result of a similar study by Damayanti (2011) which showed the area studied to be mostly of high to medium hazard. A marked increase of 145.7 km$^2$ was observed for medium hazard (71.28%) and high hazard increased by 12.87 km$^2$ (93.94%). This means that as the return periods increased, the hazard level of the floods was also increasing significantly.

Considering the problems of lack of institutional and infrastructural measures to solve the problem of flooding within the Dep River floodplains, the flood hazard analysis carried out from this study will greatly enhance the suggestion of solutions to the incessant flooding and its effects within the basin. This is because the extent of the area that flooding will affect has been determined by this process thereby locating the critical areas which should be avoided and left for flood waters or used with proper management with regards to how and when to use them.

**CONCLUSION AND RECOMMENDATIONS**

The most affected activity within the floodplain is agriculture with area inundated ranging from 68.82 to 146.10 km$^2$ for 2-year to 1000-year return periods. Low to medium flood hazards predominate the floodplain with maximum area of 105.7 km$^2$ for low hazard and 204.4 km$^2$ for medium flood. High hazard is mainly within the deepest parts of the floodplain.

It is recommended that:

1. The low hazard areas can be used for irrigation farming and early rainy season farming starting between
March and first week of April or as indicated by the time of rainfall for any particular year.
2. The medium and high hazard areas can be used for irrigation farming only.
3. All the hazard areas for the 100-year flood should be avoided with respect to construction of residential or commercial structures.
4. Generally, areas close to rivers should be avoided for rainy season farming or any other activities during the rainy season.
Figure 4. Flood hazard classification for different floods.

Table 3. Flood hazard classification for different return periods.

<table>
<thead>
<tr>
<th>Hazard</th>
<th>TR-2</th>
<th>TR-5</th>
<th>TR-10</th>
<th>TR-20</th>
<th>TR-50</th>
<th>TR-100</th>
<th>TR-200</th>
<th>TR-500</th>
<th>TR-1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low hazard (km²)</td>
<td>88.7</td>
<td>99.2</td>
<td>103.5</td>
<td>105.5</td>
<td>105.7</td>
<td>104.5</td>
<td>104.1</td>
<td>100.7</td>
<td>97.2</td>
</tr>
<tr>
<td>Medium hazard (km²)</td>
<td>58.7</td>
<td>79.8</td>
<td>95.9</td>
<td>112.6</td>
<td>133.9</td>
<td>150.1</td>
<td>166.4</td>
<td>188.2</td>
<td>204.4</td>
</tr>
<tr>
<td>High hazard (km²)</td>
<td>0.83</td>
<td>1.22</td>
<td>1.49</td>
<td>2.09</td>
<td>3.98</td>
<td>5.82</td>
<td>7.79</td>
<td>10.88</td>
<td>13.70</td>
</tr>
</tbody>
</table>

5. More detailed flood hazard mapping can be carried out with high resolution satellite data like QuickBird or IKONOS.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES


