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Changes in flood risk in Lower Niger–Benue catchments

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Abstract. Floods are devastating natural disasters with a significant impact on human life and the surrounding environment. This paper analyses historical and recent flood (2012 extreme) peak flow at strategic locations, land use activities and Floodplain Vulnerability Index analyses of the Niger–Benue River Floodplain. The 2012 peak flow at Jederbode on the Niger River was about 50 % above the long term average. At Jebba (Niger), the 2012 peak flow of 1567 $m^3 s^{-1}$ was also far higher than the long term mean annual peak flow of 1159 $m^3 s^{-1}$. The 2012 peak flow at Lokoja was also about 50 % above the historical average. The Benue River at Makurdi had peak flow of 16 387 $m^3 s^{-1}$ which was also unusually higher than the historical average while Wuroboki (Benue) had peak flow of 3362 $m^3 s^{-1}$ which was also much higher that the historical average (694 $m^3 s^{-1}$). The mixed land use which supported diverse ecosystem services has the largest cover of 5654 km^2 (36.85 %) of the Niger–Benue floodplain. The flood vulnerability of the various land uses within the floodplain include; medium, high and very high levels. A four levels hierarchical implementation adaptation strategy for sustainable agricultural practices along the rivers flood plain was proposed. The implementation hierarchy includes: Community Concern, Local Authority Concern, State Concern and National Concern.

1 Introduction

Floods are natural disasters with a significant impact on human life and the surrounding environment. It occurrence worldwide has claimed many lives, displaced millions and cause the destruction of properties and degradation of contiguous farmlands, wetlands, forest and other natural resources of the environment. It is the most frequent disaster in the world and widely distributed, leading to significant economic and social damages than any other natural disaster (DMSG, 2001). Flood may be defined in a number of ways, according to type, origin and magnitude. Generally, it is an unusual high stage of water usually above the bank of its flow path (artificial or manmade). When it causes damage to goods and properties or impairs human activities, it becomes a hazard (Odunuga et al., 2012). However, recent events in terms of frequency, magnitude, extent and extreme of flooding events have shown that flood risk (probability that exposure to flood hazard will lead to a negative consequence) along the lower Niger–Benue floodplain is on the increase. Between July and October 2012, flooding in Nigeria caused rivers especially the Niger and Benue Rivers to overflow their banks and submerged hundreds of thousands of acres of farmland. By mid-October, floods had forced 1.3 million people from their homes and claimed 431 lives, according to Nigeria's National Emergency Management Agency. This paper analyzes historical and recent flood (2012 extreme) peak flow at strategic locations, the land use and Floodplain Vulnerability Index analyses of the Niger–Benue River Floodplain. It develops a hierarchical adaptation strategy for sustainable use of the Niger–Benue River floodplain.

2 Study area

The Niger River Basin covers 2.27 million km^2, with the active drainage area comprising less than 50 % of the total (Oyebande and Odunuga, 2010). At 4200 km in length, the Niger is the third longest river in Africa and the world's ninth largest river system. The basin is shared among 10 countries: Nigeria (27 %), Mali (26 %), Niger (24 %), Algeria (8 %), Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire and

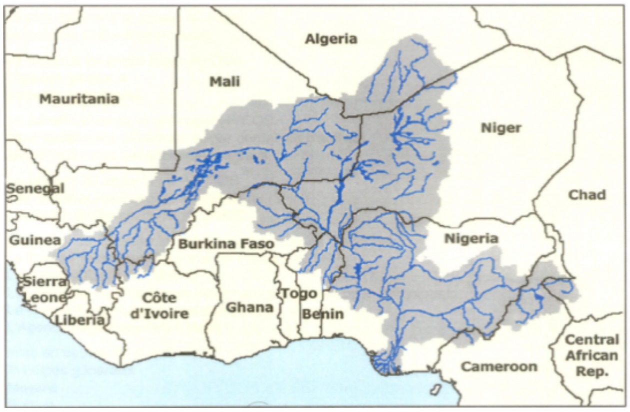


Figure 1. Niger and Benue in West Africa.

Guinea (each $< 5\,\%$). The study area falls within the Nigeria section and include the Benue (the Niger major tributary) that join it at Lokoja. Figure 1 shows Niger basin and its tributary Benue River in West African respectively. Annual rainfall ranges from about 1100 mm in the upstream basement complex area, to about 1400 mm south of Lokoja.

3 Methodology

Historical flow data (1960 to 2012) from Lokoja (Niger–Benue Confluence), Jederbode (Niger), Jebba (Niger), Worobokri (Benue) and Makurdi (Benue), obtained from Nigeria Hydrological Services Agency (NIHSA) were analyzed. The coefficient of variability (CV) of the peak flow and the long term mean annual peak flow from the stations was calculated and the percentage deviation of 2012 peak flow from the long term historical mean at the stations was established. Image from NigeriaSat X with 32 m spatial resolution in four multispectral channels (Red, Green, Blue and Near Infrared) was used to map the land use and land cover along 2 km buffer of the Niger–Benue Rivers floodplain. The mapping covers from Jederbode through Jebba to Lokoja on the Niger and from Worobokri through Makurdi to Lokoja on the Benue River (Fig. 2). A pragmatic land use classification scheme (Adeniyi and Omojola, 1999; Odunuga, 2008) that emphasized the hydrological/flood significance of the land cover was developed. In all eight classes of Land cover were identified. The mapping was carried out using on-screen digitizing while the topographic maps, the Nigeria vegetation maps and other ancillary maps/data provided the basic guide for interpretations. The knowledge of the researcher as well as random ground thruthing contributed to the completion of the mapping exercise.

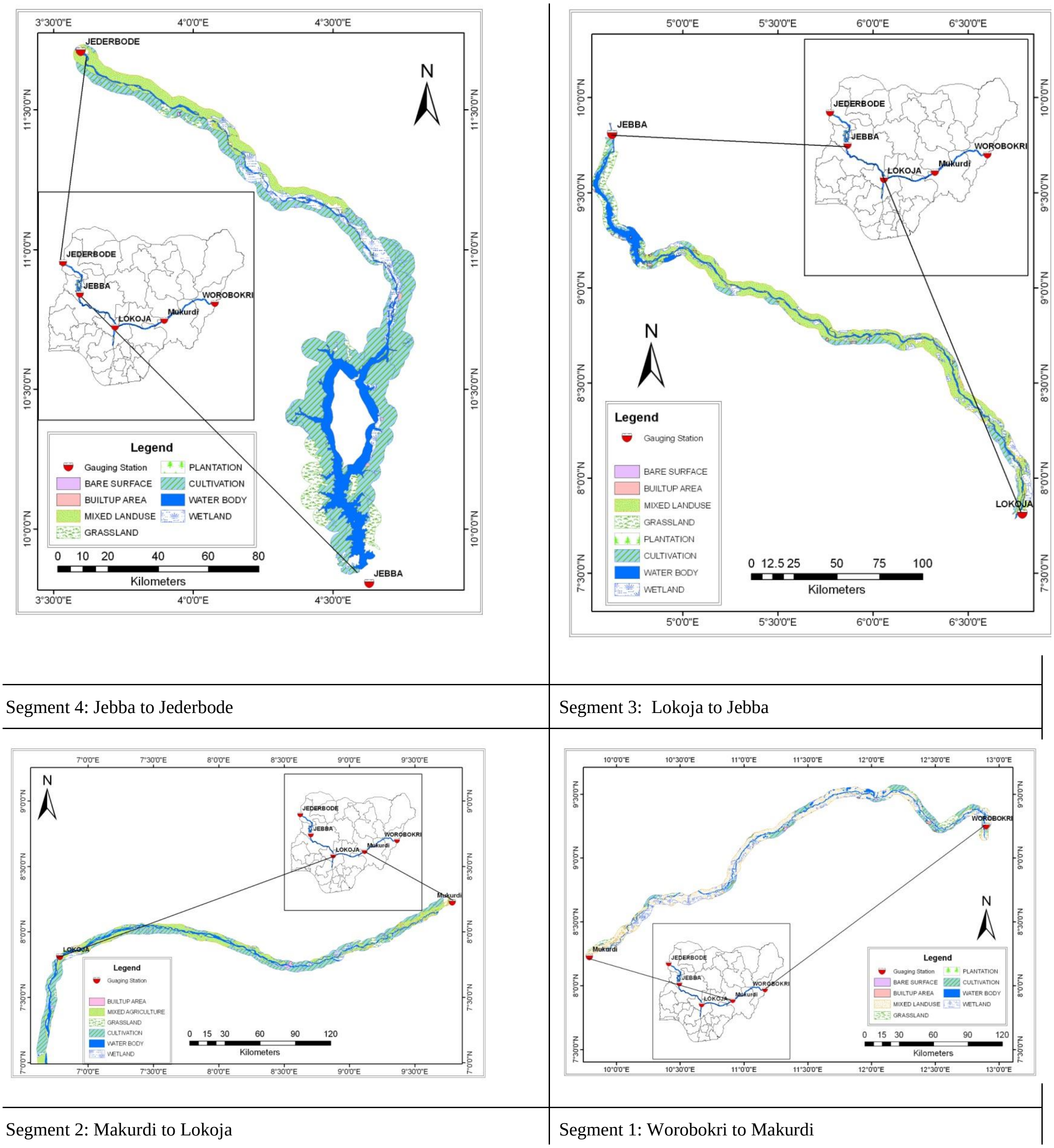
A Flood Plain Vulnerability Index (FPVI) based on two dynamics characteristics (Peak flow (mean and CV), and Land use) was developed for the Niger–Benue Rivers. The study area stretch was divided into four (4) segments (Fig. 2); Worobokri–Makurdi (segment 1), Makurdi–Lokoja (segment 2), Lokoja–Jebba (segment 3) and Jebba–Jederbode (segment 4). A vulnerability scoring for ranges of long term mean annual peak flow was developed (Table 1) to assess the weighted impacts of flow in the channel on the annual flooding of the floodplain. The scores for segments 1and 4 were based on long term mean annual peak flow from Makurdi and Jebba respectively while that of segment 3 and 4 were based on long term mean annual peak flow from Lokoja. Similarly, each of the land uses was assigned a flood vulnerability score that range between 1 and 4 (Table 1) where 4 is the most flood susceptible land use based on past experiences and local knowledge. The permanently water body was not included because it constitutes the perennial water body. The floodplain vulnerability index range was also developed for the vulnerability classes (Low, Medium, High and Very High) and the FPVI class for a particular location is the FPVI range obtained from adding the score that the location obtained from land use, long term mean annual peak flow and coefficient of variability of the peak flow as shown in Eq. (1).

$$\mathrm{FPVI} = X + Y + C \ldots \tag{1}$$

Where X is score of location on land use, Y is the score obtained from long term mean peak flow and C is the score obtained on coefficient of variability (CV) of the peak flow.

4 Peak flow analysis

The CV of the peak flow, the long term mean annual peak flow, the extreme peak flow of 2012 and the percentage deviation of 2012 annual flow from the long term mean are shown in Table 2. In 2012, the peak flow at Jederbode (9 September 2012) on the Niger was 3362 $m^3\,s^{-1}$. This is about 50 % above the long term average of 2300 $m^3\,s^{-1}$. Also, the daily flow in 2011 exceeded 2000 $m^3\,s^{-1}$ in 43 days while in 2012 it was exceeded in 80 days. The magnitude and duration of high flow in 2012 was about twice the corresponding value for 2011 (AFO, 2013). At Jebba (Niger), the 2012 peak flow of 1567.6 $m^3\,s^{-1}$ (14 September 2012) is also far higher than the long term mean annual peak flow of 1159 $m^3\,s^{-1}$, though, the flow at Jebba is regulated by Kainji dam. Lokoja (confluence of Niger and Benue) had 2012 peak flow of 31 692 $m^3\,s^{-1}$ (29 September 2012) which is also about 50 % above the historical average of 16 500 $m^3\,s^{-1}$ and the daily flow exceeded the 2011 peak value between September and October. However, the flow in River Niger at Lokoja between January and May 2012 was lower than the flow in 2011 (AFO, 2013). The rate of flow in 2012 at Lokoja increased considerably in June 2012 due to the flood flow in River Benue and River Niger. The Benue at Wuroboki had peak flow of 3362 $m^3\,s^{-1}$ (29 August 2012) which was also much higher than the historical average (694 $m^3\,s^{-1}$). The Benue River at Makurdi had peak flow of 16 387 $m^3\,s^{-1}$ (29 September 2012) which was also unusually higher than



Segment 4: Jebba to Jederbode

Segment 3: Lokoja to Jebba

Segment 2: Makurdi to Lokoja

Segment 1: Worobokri to Makurdi

Figure 2. Land use distribution along the Niger–Benue floodplain.

Table 1. FPVI Scores for Land use, Peak Flow and FPVI index Range for vulnerability classes.

Land use classes				Long Term Mean Peak Flow		CV (%)		FPVI	
Land use	Score	Land use	Score	Range	Score	Range	Score	Vulnerability Class	Range
Bare Surfaces	1	Plantation	1	< 2 000	1	< 25 %	1	Low	1–3
Built-up Area	4	Cultivation	2	2001–5000	2	25–50 %	2	Medium	4–6
Mixed land use	3	Water Body	–	5001–10 000	3	51–75 %	3	High	7–9
Grass Land	2	Wetland	4	> 10 000	4	76–100 %	4	Very High	10–12

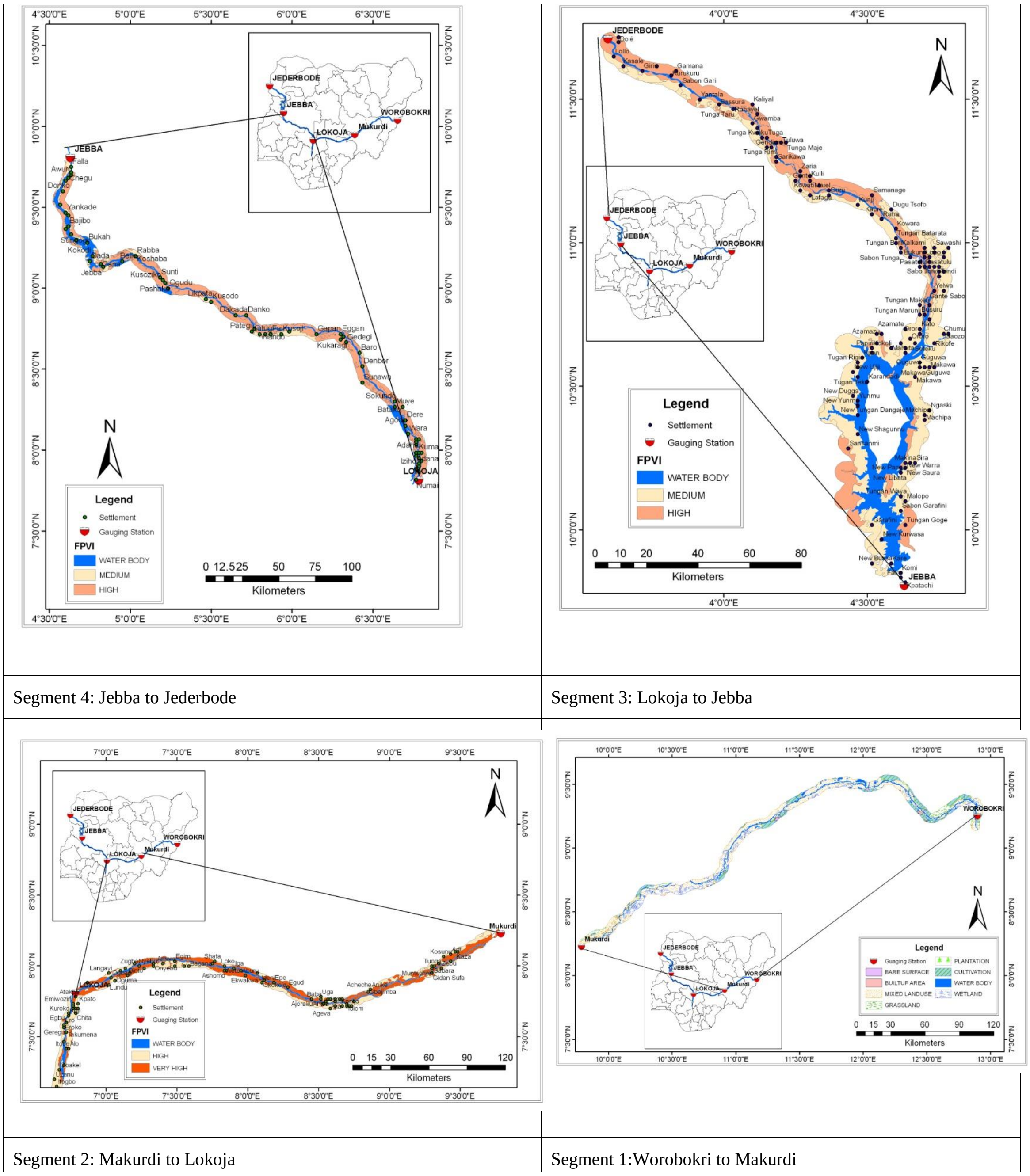


Figure 3. FPVI for Niger and Benue.

Table 2. Peak flow analysis.

Gauging Station	River	CV (%)	Long Term Mean Peak Flow $m^3\,s^{-1}$ (1968–2012)	Annual Peak Flow ($m^3\,s^{-1}$) 2012	Date Of Occurrence Of 2012 Peak Flow	Percentage Deviation Of 2012 Peak Flow From Long Term Mean Peak Flow
Jederbode	Niger	15	2300	3362	9 September 2012	46.21
Jebba	Niger	18	1159	1567	14 September 2012	35.25
Lokoja	Niger	35	16 500	31 692	29 September 2012	92.07
Worobokri	Benue	16	694	3362	29 August 2012	384.44
Makurdi	Benue	17	3042	16 387	29 September 2012	438.63

Table 3. Land use along the Niger–Benue Floodplain.

S/N	Land Use/ Land Cover	Area (km^2)	Percentage of LULC
1	Bare Surface	48.04	0.31
2	Built-up Area	103.91	0.68
3	Mixed Land Use	5654.46	36.85
4	Grassland	946.92	6.17
5	Plantation	6.03	0.04
6	Cultivation	4821.07	31.42
7	Water Body	2276.07	14.83
8	Wetland	1488.88	9.70
	Total	15 345.36	100

the historical average of 3042 $m^3 s^{-1}$. Apart from Jebba which is highly regulated by Kainji dam, the percentage deviation from the long term mean annual peak flow is about 46 % at Jederbode and 92 % at Lokoja while that of the Benue is over 300 % at Worobokri and over 400 % at Makurdi. The flow in the Benue which increased considerably from June 2012 was due to the flood flow from Lagdo dam in Cameroun. The release of water from the dam, however, was due to unusual rainfall in the Central Africa Region. These extreme deviations are a pointer to the changing flood risk of the Niger–Benue as manifested in the 2012 National Flood Disaster.

5 Land use analysis

Table 3 shows land use distribution along the Niger–Benue floodplain. The mixed land use that supports diverse ecosystem services has the largest cover of 5654.46 km^2 constituting 36.85 % of the total land area of the floodplain. The bare surfaces which in most cases are morphological rock outcrop by the bank of the rivers have the least area coverage of 48.08 km^2 (0.31 %). In all, the land uses of the Niger–Benue floodplain shows that the floodplain supports diverse anthropogenic activities including; human habitation, cultivation, animal rearing, fishing, hunting and transportation. This shows the complex ways by which land use and land cover are linked to hydroclimatic fluxes (Odunuga and Oyebande, 2007). Figure 2 shows the land use distribution along the Niger–Benue floodplain.

6 Flood Plain Vulnerability Index (FPVI)

Table 4 and Fig. 3 show the floodplain vulnerability levels of the Niger–Benue floodplain. The Flood vulnerability index of Benue River include; medium, high and very high vulnerability levels. About 83.52 % (1370.08 km^2) of the Benue floodplain between Worobokri and Makurdi falls within high vulnerable levels while remaining 16.48 % (270.36 km^2) falls within medium level. High vulnerability level constituted 82.32 % of the floodplain between Makurdi and Lokoja on

Table 4. Vulnerability Index of the Lower Niger–Benue Floodplain.

Location	River	Floodplain Vulnerability Levels (km^2)			
		Low	Medium	High	Very High
Worobokri–Makurdi	Benue		270.36	1370.08	
Makurdi–Lokoja	Benue			5417.06	1163.07
Lokoja–Jebba	Niger		698.07	1916.62	
Jebba–Jederbode	Niger		2779.52	1554.17	

the Benue River while the remaining (17.68 %) has very high vulnerability flood level. The high flood susceptibility of the floodplain between Makurdi and Lokoja as revealed by its high and very high vulnerability levels might have contributed to severe impacts that the 2012 National Flood Disaster had on the inhabitants of this area. However, if reservoir operations in the upstream Lagdo dam are rational, the Benue valley agricultural activities may be boosted as opposed to the 2012 destruction of farmlands by flood.

The Niger River floodplain on the other hand exhibits medium and high vulnerability levels from Jederbode to Lokoja (Table 4). It can therefore be explained that, any year that hydrological processes especially the peak flow event is above the long term historical average on the Niger, settlements between Jederbode and Lokoja in Nigeria will experience flood and the reservoir (Kainji dam) on the Niger within this segment will receive enough to operate at full capacity. However, if best practices in dam operation and reservoir optimization are not used, the downstream population will be highly impacted. The severity of impact may be much higher if corresponding high flow comes from the Benue River as it occurred in year 2012. Also, the floodplain vulnerability of Niger around the confluence and downstream of Lokoja to the acute delta will probably be very high class. This agreed with the results of (Nkeki et al., 2013) which identified high population at risk.

7 Governance/adaptation strategy

Based on the administrative/governance structure and functionality in Nigeria (Federal, State and Local Governments) as well as the results of the Niger–Benue floodplain land use activities and flood vulnerability analysis, adaptation strategy for sustainable agricultural practices along the floodplain is proposed. The strategy is hierarchical and the implementation hierarchy includes: community concern, local authority concern, state concern and national concern.

The national concerns includes; multilateral cooperation on the international rivers (Niger and Benue), the development and maintenance of critical infrastructures such as reservoirs, river monitoring, development of infrastructures for early warning systems and provision of enabling environment to enhance flood plain agriculture and subsidize farmers affected by flood related hazards. The state concerns includes: the development and implementation of dynamic flood plain land use strategies based on floodplain vulnerability index scenario analysis, identification of the Niger–Benue Rivers flood plain users and organizing them into groups under state institution, provision of technical support including extension services, legislature and funding of new incentive-based programmes to promote the widespread and mainstream new adaptation policy. The local authority concerns includes: public awareness on a range of issues including annual flood outlook, land use policy, climate change, efficient water use, other government policies, adoption of new innovative technology including capacity building of flood plain users etc. The community concerns will include: complying with state and local authority directives and adoption of new technology and innovation in the utilization of Niger–Benue River floodplain.

8 Conclusions

Based on the analyses of historical and recent flood (peak flow) of the Niger and Benue Rivers at strategic locations, the land use analysis and Floodplain Vulnerability Index analysis, the paper develops a hierarchical adaptation strategy for sustainable use of the Niger–Benue River floodplain. It is recommended that the strategy proposed be adopted by all concerned authorities so as to ensure sustainable development of rich agricultural land of the Niger Benue floodplain.

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