JOURNAL OF FLOOD ENGINEERING
Vol. 9 No. 1 (January-June, 2018)

FLOOD VULNERABILITY ASSESSMENT FOR ENHANCED UTILIZATION OF WETLAND ECOSYSTEM DOWNSTREAM OF JEBBA HYDROELECTRIC DAM

Abdul Kadir A.
Department of Geography, Federal University of Technology,
PMB 65, Minna, Bosso Campus 920003, Nigeria.

ABSTRACT: Constant and widespread flooding in recent years is a threat to rural livelihood. Agricultural production has been devastated by repeated flood that characterized the hydrological growing season downstream of Jebba dam. These events coupled with under utilization of land and water resources in the riverine ecosystems have intensified poverty level, food insecurity in the rural areas and the country in general. Flood intensity, its consequences and misguided relocations that have yielded no results have dominated the literature over the years. The present study identifies measures of adaptation to natural changes for enhanced utilization of wetland ecosystem as a tool for poverty eradication. Data sets for the study are the dam Inflow and discharge, Landsat ETM and TM images acquired in November 2000 and 1986, and 1978 topographical map. Flooding summary, frequency, trend analysis and spatio-temporal changes were used to identify flood vulnerability. The results reveal changes in reservoir size and depth, ecosystem and vegetation degradation, increased dam in inflow and discharge escalating the spread and intensity flood as indications of higher flood risk in the area especially, in September which marks the peak of flooding. Thiam’s Transformed Vegetation index analysis and Standardize image class are vital for wet land ecosystem assessment and change detection. The study suggests cropping calendar; identify crop suitability and construction of small scale dams downstream of Jebba reservoir such that flooding may become a resource rather than disaster.

Keywords: Discharge; Wetland; Flooding; Degradation; Enhanced landuse.

1. INTRODUCTION

The current rate of population growth in the last four decades has been a major problem in Nigeria, particularly in the rural areas. The population figure of Nigeria was 55.67 million in 1963, 88.575 million in 1991, and rose to 140 million in 2006 with not less than 2/3 of this population living in the rural areas. The ever increasing numbers of people to be fed coupled with continuous pressure on the natural resources in the past four decades has led to increased degradation of the natural resources. Thus, flooding and soil erosion have been on the increase and the consequences of these include malnourishment, crop failure, famine, and poverty in the country.

Agricultural sector has been the focus for poverty alleviation and rural livelihood initiatives of World Bank, (DFID) and other national and international organizations (FAO, 1989; Conway, 1997; and Ambastha *et al.* 2005). Since independence, successive governments have embarked on several measures aimed at improving rural livelihood and increasing agricultural productivity, food security, and eradication of poverty among others. However, these have not yielded the required results. In Nigeria, the socio-economic livelihood of the rural population is highly dependent on natural resources. The main activities are farming, fishing, animal herding and other resources based occupation. This is a typical issue for investigation in most developing countries; (Junk, 2002; Kvist and Nebel, 2001; Nebel *et al.*, 2001; and Stoneham *et al.*, 2002). Despite all these, many people in the rural areas are mal-nourished or even starving for a variety of reasons which include degradation and deterioration of natural resource coupled with the effect of climate change, which has led to increased natural hazards like flood and drought. In Nigeria, it is observed that the real issue is yet to be addressed.

Wetland eco-system is dominant along the entire river courses all over the country; these are generally zones of recent deposit, fertile alluvial soils and humid land for cultivation of rice and other crops. These resources served as pull factor that attract most flood plain settlements along the river courses in Nigeria. However, the construction of dams in 1960s and 1970s has altered the terrestrial environment and the hydrological regime, since it is a natural system which man has manipulated. Olofin (1990) pointed out that dam construction upset the equilibrium relationships which pre-existed between the variables of land and those of water in the affected basin.

The inhabitants of the flood plain settlements are accustomed to natural flooding and replenishment of the soil after flood subsides. Consequently, the inhabitants perceive flooding as a resource and are adapted to the natural ecosystem; therefore construction of the reservoir has constituted not only social economic problem but degradation of ecosystem as well. Yaw and Edmund (2007) documented the dams designed to impound water have the potentials to cause the major environmental changes in the hydrology of the river basin. Furthermore, remote sensing images have been vital tools for assessing spatio-temporal environmental dynamics across the globe. The studies have confirmed that natural resource degradation is escalated by human activities (Roger, *et al.* 1985; and Sivakumar, 2007). These together with lack of soil and moisture management in the rural areas contributed to extreme poverty, due to decline in productivity.

On the other hand, people have attributed the main reason for recent flooding to the release of excess water from the reservoir, which usually sweep away farm land and settlements. In disaster management, relocation /resettlement is more often seen as the worst option as it gives the impression that nothing else can be done about the hazard (Ngai, 1995). In Nigeria, reactive approaches other than proactive usually characterized the decision. Despite the constant flooding the inhabitants settle back on the same piece of land because of the resource of the flood plain, since the perception level of hazard by them can not be compared to vital floodplain resources. Hence, there is a need to use geographic information in assessing vulnerability of the inhabitants for enhanced utilization of wetland ecosystem and rural livelihood.

2. STUDY AREA AND DATA

Jebba hydrological dam is located downstream of Kanji reservoir between latitude 9^0 8′ and

9^0 9′ and longitudes 4^0 47′ and 4^0 48′ North of the Equator. Kanji dam is constructed on river Niger; it is the longest river in West Africa and drains the largest area; Niger River takes it source from Guinea highlands, flows through Mali, Niger Republic and finally empties its water into the sea in Nigeria. Naturally, river Niger is characterized by two major flood episodes in Nigeria; the black flood between November and February which has its origin from high precipitation recorded in the source region, and white flood occurs between July and October due to flash floods from the catchments in the region which is always loaded with sediments. Jebba dam was constructed in 1979 to utilize discharge from Kanji dam up stream. Other rivers like river Kontagora and Moshi drain into the dam. The maximum capacity of the dam is about 3880 MCM (Abubakar and Yisa, 2004).

The construction of these two dams in the late sixties and seventies represent a fundamental problem in the downstream region, affecting relevant socio-economic sector particularly agriculture. This study covers the downstream areas of Niger and Kwara states, however the floodplain settlement selected for ground truth were randomly selected to identify sustainable measures for entire the downstream region across the country. The area is characterized by tropical hinterland climate with two alternate distinct, wet (May–October) and dry seasons (November–April), the length of the rainy season is over 150 days.The soil is mainly lateritic type with predominantly shallow soil and low level of organic matter, hydromorphic soils are dominant in the lowest part of the valley thereby attracting flood plain settlement across the country. The vegetation is Guinea savannah type which has been highly modified by human interference. This flood plain settlement is mainly utilized for subsistence rain fed agriculture, small plot of shaduff farming and animal rearing during the dry season because of availability of pasture and water for livestock. Food crops such as maize, millet, guinea corn, groundnut and rice are cultivated.

The data assembled for this study included Jebba mean monthly dam inflow, gauge height and discharge 1984 to 2000, Landsat Images; Enhanced Thematic Mapper, (ETM) and Thematic Mapper (TM) acquired in November 2000 and 1986, respectively. In addition to these, the topographic map of Jebba produced in 1978 by federal survey was the primary data for the study. These were complimented by ground truth.

3. METHODOLOGY

Descriptive statistics (totals and mean) were used to summarize the inflow, gauge height and discharge data. This information was plotted graphically. Paired sample test and curve estimation of fit were used to determine relationship and trend, these in addition to flood frequency analysis were used to assess flood vulnerability. Furthermore, for accurate assessment, satellite images of the same period were used; ETM $^+$ and TM images were processed using Idrisi for Windows 32.0 image processing software. There are growing bodies of potential tools that can be utilized to study and monitor these large complex ecosystems (Haase and Haase, 1995; Steven *et al.*, 2005; Kloub *et al.*, 2010; and Rao and Rogers, 2006). The images were imported into Idrisi as single band images using Idrisi file format GEOTIFF. Bands 4 and 3 of the two images were reformatted and geo-referenced. These were transformed using Thiam‘s

Transformed Vegetation index (TTVI) model, which are simple linear combination of the visible red and near infrared bands with positive figure as output and low values representing low vegetation and verse versa. This was used for quantitative assessment of vegetation and moisture degradation; the two TTVI images were subjected to visual comparison, software analysis using classified standardized image difference (Z-scores). The resultant image was used to identify changes over time and space, adapting commonly used threshold of ± 1 standard deviation for no change and beyond ± 1 is an indication for change. Topographical map of the study area was digitized manually. The *X*, *Y*, *Z*, Co-ordinate of all parts was determined. These co- coordinates were input into the Idrisi softwares which display the surface in digital form and interpolate the digital surface into surface image. This DEM was used to identify the areas liable to flood.

4. DATA ANALYSIS

The hydrological data analysis reveals high variability; three levels of inflow, discharge and gauge heights were identified; these as low, moderate and high respectively (1, 2 & 3). The low discharge occurs from March to July, the moderated discharge occurs from November to February and high discharge is dominant from August to October. In addition, the gauge height and discharge from the dam is highly determined by inflow into the dam. Paired samples *T* test confirms a strong correlation between the two variables (0.8). The major concern is the high discharge due to its effect on relevant socio-economic sector, high discharge from the reservoir implies higher runoff, which may constitute flooding downstream. Generally, the flow of river Niger and its tributaries are the driving power for inflow, gauge height and discharge from the dam; these are mainly functions of the hydrological and meteorological processes in the region.

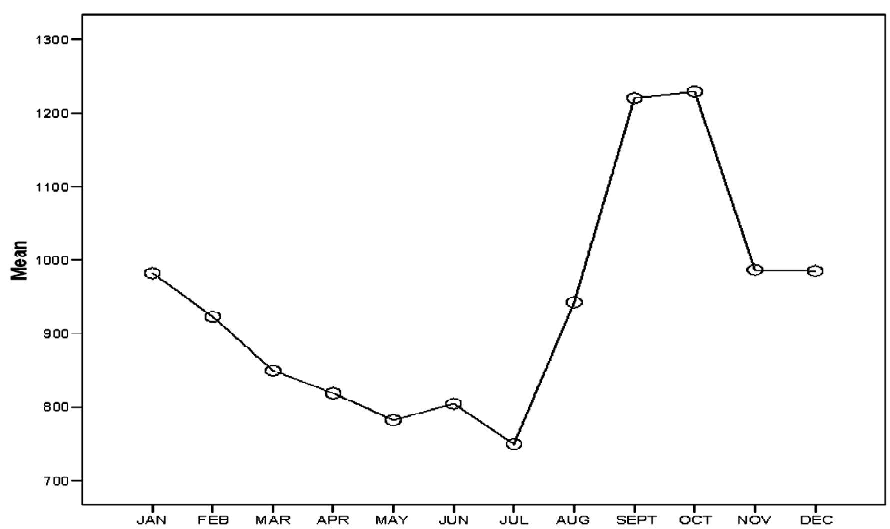

Figure 1: Jebba Mean Monthly Inflow (1984-2000)

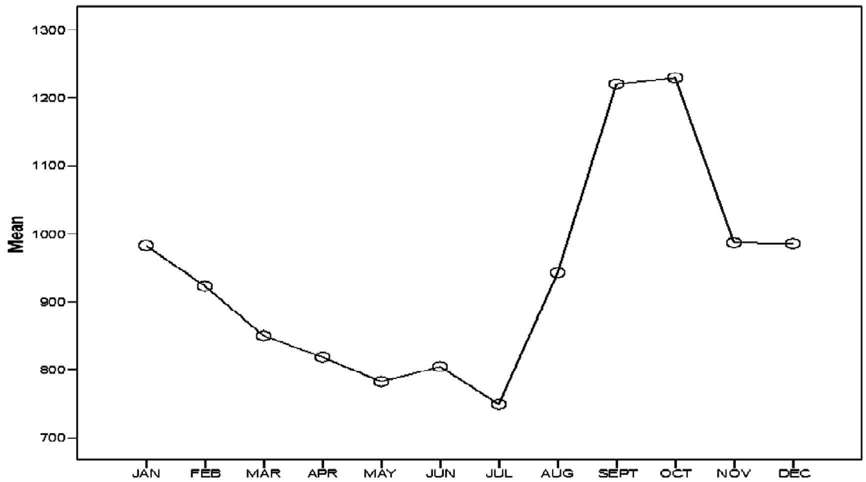

Figure 2: Jebba Mean Monthly Discharge (1984-2000)

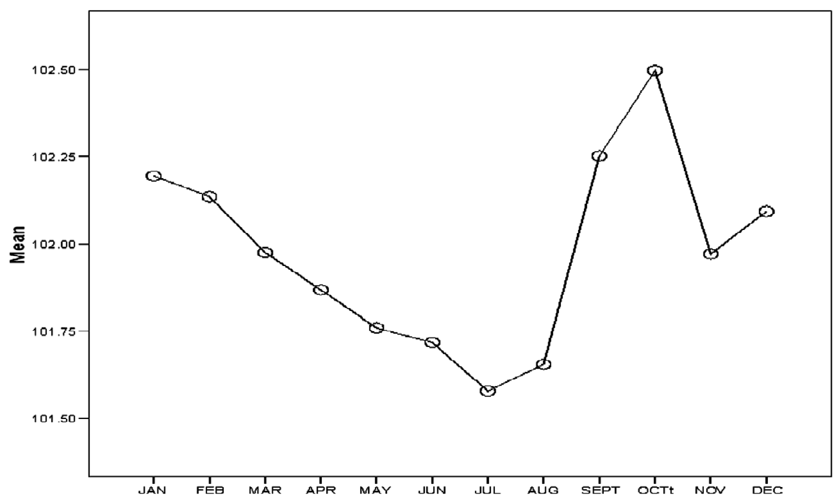

Figure 3: Jebba Mean Monthly Gauge Height (1984-2000)

High discharge value above 1300 m^3/sec per month during the hydrological growing season may be an indication of downstream flooding as the runoff may be too much that the river may overflow its banks. Subsequently the water table of the surrounding wetland may be too high for crop survival. The value is used to determine flood occurrence for the study period; the results identified 1985, 1989, 1991, 1994, 1998, and 1999, as years of severe flood (Fig .4). This agrees with other findings such as (Abubakar and Yisa, 2004). Specifically, the flood is always at its peak in September, in response to the high inflow that usually elevates the gauge

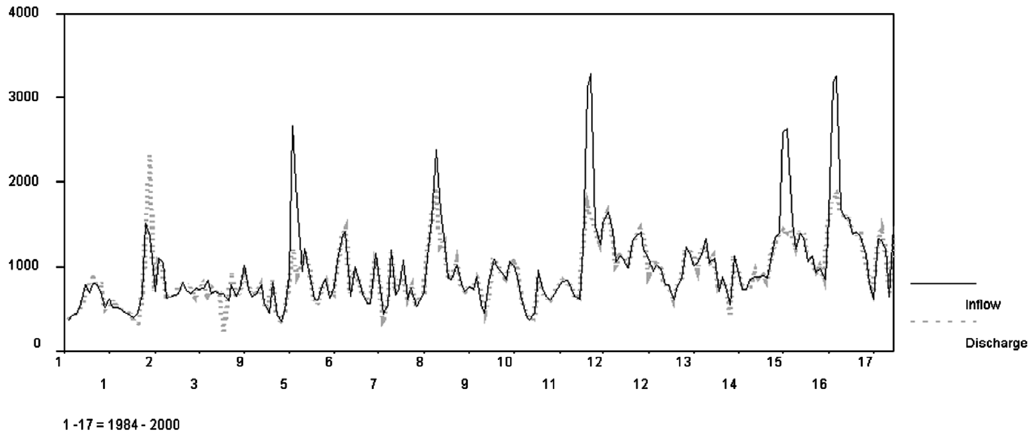

Figure 4: Jebba Maximum Inflow and Discharge (1984-2000)

height to its peak in September/October. Accordingly, the discharge from the dam during this same period is high and constitute severe flood downstream particularly within September when rainfall is at its climax across the region. However, despite the high discharge in October, flooding during the period is not severe mainly as a result of reduced rainfall translating to decline in the level of soil moisture.

Generally inflow and discharge tend towards high intensity in recent years. Maximum inflow for 1984 is about 800 m^3/sec while above 3,000 m^3/sec was recorded 1998 and 1999. Consequently, discharge maximum for 1984 is 886 m^3/sec and above 1800 m^3/sec in 1999. Curve estimation of fit confirms this trend. Also there is an increase in the months of high discharge as indicated in Table 1. Therefore flood has been on the increase in terms spread and intensity.

Table 1
Spread of High Discharge in Years of Severe Flood

YEARS	*MONTHS OF DISCHARGE (above 1500 m^3/sec or +1300 m^3/sec for more than one month)*	*VALUES (m^3/sec)*
1985	September& October	1396 & 2323
1989	September& October	1357 & 1466
1991	July, August & October	1556,1927 & 1304
1994	September, October & November	1746, 1579 & 1464
1998	August, September, October, & November	1387,1451,1387 & 1422
1999	August, September, October, November & December	1549,1767,1855,1655 & 1606

Visual comparison of Landsat ETM and TM Thiam's Transformed Vegetation Index classification for the two years reveals that there are changes in natural vegetation cover, the reservoir, and floodplain coverage. Most natural vegetation on the lower and moderate terrain has been tempered with due to human intervention, hence degradation of the wetland ecosystem. Reservoir coverage increased in size and reduced in depth by 2000 compared to 1986. Classified standardized image difference and ground truth confirm this (Plate 1). As earlier noted, wetlands

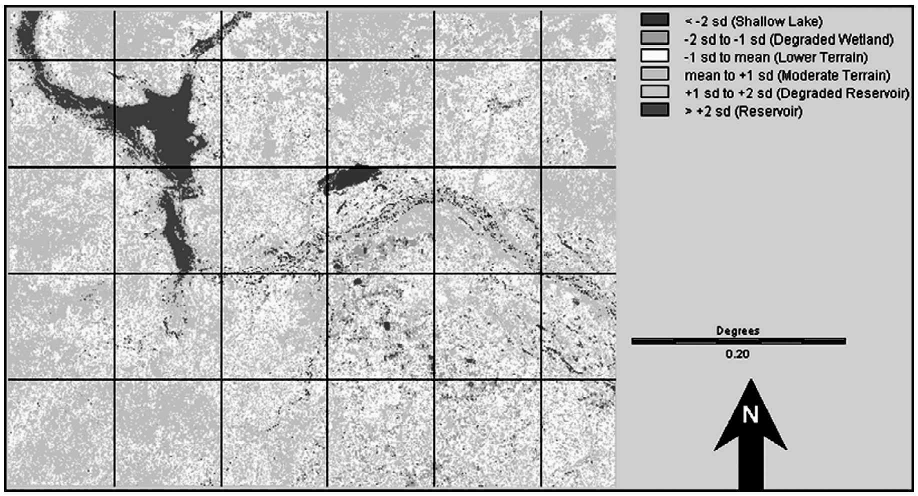

PLATE 1: TTVI STANDARDIZED CLASS IMAGE

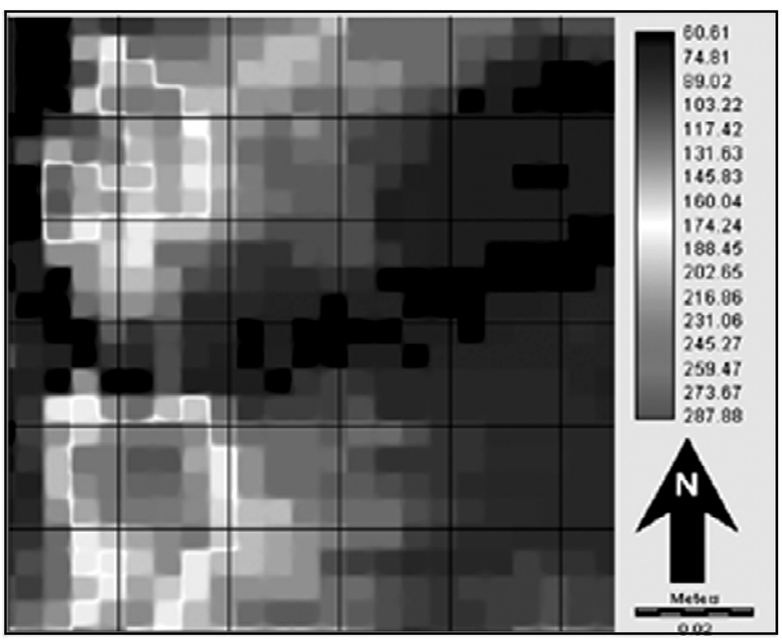

PLATE 2: DIGITAL ELEVATION MODEL

are rapidly disappearing from the earth's surface (Ambastha *et al.*, 2005). The value of TTVI standardized class image for the reservoir is < –2, an indication that the reservoir size and depth declined as part of the reservoir edge is now shallow lake while the others are degraded, using the relation later-earlier for difference. Wetland and its vegetative cover are also confirmed to have changed from 1986 to 2000, as their standardized class value are beyond ± 1 and natural lake standardized class is >2 indicating that the lake is wider. Areas with little or no change are vegetation on higher terrain and the cultivated land with less vegetation covers. Their standardized image class values equal ± 1 (Plate 1).

Digital elevation model image gives the indications that all areas below 100 m above sea level are generally liable to flood. Above this value to less than 180 m are moderate terrain that can support cultivation during abundant moisture while, values above 200 m are rock outcrop part of which provided the favourable environment for construction of the dam (Plate 2).

5. RESULTS AND DISCUSSIONS

It has been documented, Peng *et al.* (2006) that reservoir system/construction are one of the most efficient measures of integrated resource development and management. The variability in the dam inflow, gauge height and discharge, translate into variability in amount of runoff and flooding (Figures 1, 2 & 3). The three classes of runoff can be used to determine the agricultural activities downstream of Jebba dam. The mean onset date of effective rainfall downstream of Jebba is not later than 20th may (deduced using Intra-Seasonal Rainfall Monitoring Index, Abdulkadir, 2000). Planting of crops with short time growing period of 80 to 90 days may commence on the lower terrain and by August these are harvested. The moderate terrain above (100 m) may be used for cultivation of crops with longer growing season.

The strong correction between inflow, gauge height and discharge reveals that, the higher the intensity of inflow the higher the gauge height and discharge. Consequently discharge has been on increase. The implication of this is that flood has been on the increase and the ecosystem has become more vulnerable. Despite the high risk or vulnerability of inhabitants and poverty level, the perceived resources of flood plain may continue to make them stay in the same environment. The flood event downstream of Jebba Hydroelectric dam is only a function of high discharge from the dam as evident in 1985, 1989, 1991 1994 1998 and 1998 flood events (Table 1).

These high discharges are disastrous to agricultural and socio-economic sustainability. As a result, the major problem is high discharge above monthly mean of 1300 m^3/sec during the hydrological growing season (April to October). The analysis reveals that 2/3 of the years are characterized with high discharge and these results in severe flood events. The flood events are hazardous to plants and animals downstream of Jebba. Thus, constraints to the agricultural sector is affecting the socio-economic sustainability of the inhabitants. Generally, the food insecurity and poverty level of the inhabitants signal the need for mitigation measures, such as adaptation to the natural eco-system that may enhance the socio-economic and ecological well being of the inhabitants. High risk zones (70 m to 100 m above sea level) may be cultivated with crops having short growing periods or with moisture loving crops like banana, sugar cane and palm trees. High discharges recorded in recent years are mainly a function of increased runoff due to the changed pattern of precipitation and land use. This was recorded for four to five months in 1998 and 1999; thus, the years were identified as years of very severe flood downstream of Jebba. The severity of floods depends on the amount, spread and intensity of discharge; hence the need to identify measures for accumulating these excess discharge from the dam for sustainable utilization of wetland ecosystem if the feature must be sustained.

September may be used for natural replenishment of the lower terrain and cultivation may be avoided on this terrain (below 100 m) during this month. The crops that are drought resistant like melon or vegetables may be cultivated on the lower terrain immediately where the flood subsides; the moderate runoff of November to February will support these crops until they are due for harvest. Freebairn and King (2003), state that indicators need to be integrated with the development of improved management systems. Shaduf farming may also be practiced downstream to support cultivation using small scale irrigation during this period and low runoff periods of the dam. The wetlands that are not cultivated may be used for animal grazing during the dry season and, small ponds or lakes may be developed for fish production.

Field observation at Kpasuwa, Belle, Likpta, Yelwa and Bacita sugar plantation confirms that moisture loving crops can be cultivated on the lower terrain. Specifically Bacita sugar plantation is sited on the terrain less than one hundred meters above sea level. Enhanced utilization of this abundant natural resource across the country is necessary for any meaningful development as agricultural activities employ high proportion of the population. This also may contribute to environmental friendly agriculture, promote sustainable use of the ecosystem, ensure food security and reduce poverty. Stoneham et.al (2002) demonstrates that despite degradation of the natural resource base, agricultural sector is more productive now than in the past.

TTVI analyses eliminate the use of negative values in the quantitative assessment of ecosystem in the study area also; standard class image class is a vital tool for assessing environmental change over space and time. Vegetation degradation of wetland ecosystem was observed in 2000 compared to 1986; this may lead to increase in soil erosion and degradation of the ecosystem. It was clearly shown that within 15 years wetland ecosystem, shallow lake and reservoir have degraded. These areas are ecologically tempered with by human interference and more areas have been opened to erosion since land is mostly laid bare by deforestation for agricultural purposes and other attributes. Progressive vegetation degradation, increase in spread and intensity of flood in recent years have escalated ecological degradation of wetland ecosystem and have made inhabitants of this ecosystem highly vulnerable to flood, thereby promoting malnutrition, sickness, hunger, famine, food insecurity and poverty.

As a result, unless there are a measure towards mitigation of the above and ways for better management of land and water resources, the poverty level of the inhabitants may be on increase and food insecurity may be aggravated. Hence, there is the need to promote planting of moisture loving plants and other economic trees like palm trees, kola nuts, shear butter, mango, oranges to check degradation of the natural ecosystem and enhance utilization of wetland ecosystem for sustainable agricultural activities. This will enhance the nutritional level, standard of living and reduce poverty in the rural communities. Moreover, these will also check flooding, promote infiltration and percolation of moisture, since emphasis of the community may be on afforestation for commercial benefit rather than deforestation. Hope (2004) observed that asset creation from incremental stream flow is economically efficient.

Finally, the analysis and field observation confirm general increase in the amount, spread and intensity of discharge in recent years coupled with degradation of natural vegetation and wetland ecosystem. These make the inhabitants of this natural environment highly vulnerable to flood. There is the need for enhanced and sustainable management of excess water resources from the dam, for sustainable agricultural production and poverty eradication in the rural communities. This may be achieved through construction of small scale dams downstream of Jebba for agricultural activities, especially during the period of low runoff, drought and even dry season agriculture on this abundant wetland ecosystem across the country. Akinyemi (2003) observed that most of the years, rainfall is adequate for all year round crop production if provision for rainfall storage is carried out during the rainy season. This may promote cultivation of crops with large scale small irrigation system, increase fish production, enhanced utilization of water resources that is usually wasted annually, check problem of flooding downstream and promote productivity thereby eradicating poverty and enhanced food security.

6. CONCLUSIONS

Flood is a natural phenomenon of wetland Ecosystem. However, increased dam inflow and gauge height are responsible for higher discharge recorded in the recent years. These have escalated the intensity and spread of flood. Vegetation degradation of the moderate and lower terrain is a very clear sign of ecological degradation which are accelerated by increased runoff which may be a function of changed pattern of rainfall and landuse influencing the river hydrology. As a result, this human interference has resulted in the shrinkage or dryness of wetland ecosystem soil moisture, sedimentation of the reservoir (storage capacity), and it is generally shrinkage. This justifies the need for afforrestation to enhance infiltration, percolation thereby reducing runoff. The inflow and discharge trend generally tend towards higher intensity in terms of spread and amount. In 1989, the discharge was at its peak for two months, September/October; three months in 1991 and 1994; four months in 1998 and five months in 1999, thus, necessitating conservation of these vital resources and enhanced utilization of the resources that remain inevitable for any civilization.

There is a need to understand, develop and apply the best practicable tools possible to tackle the challenges of boosting sustainable development (Adigun, 2000). TTVI analysis and Standardize image class are vital for wetland ecosystem assessment and change detection over time and space. The findings indicate that high rate of population growth coupled with abundant arable land along the river courses in Nigeria may be used to promote agricultural activities through enhanced conservation and management of water resources. These can be used for all year round cultivation of diversified crops that may promote food security and eradicate poverty in the rural areas and the country at large. This study used flood vulnerability assessment to identify mitigation measures for adaptation to natural changes such as small scale dam construction downstream of Jebba reservoir, recovery of wetland ecosystem, cropping calendar and types of crops to be cultivated as a pathway towards achievement of food security to enhance rural livelihood in Nigeria.

AKNOWLEDGEMENTS

I sincerely acknowledge University Net-Work for Disaster Risk Reduction in Africa (UNEDRA) for their effort towards capacity building, Harold John Annegarn, University of Johannesburg and Dr. Usman M. T for their unique counselling and stimulation.

References

[1] Abubakar A. S. and Yisa C. (2004), "Flood Frequency of the Lower Niger at Jebba", *Gurara Journal of Humanity Studies*, **2**, 129-135.

[2] Adigun A. A. (2000), "Remote Sensing Technology Today and Tomorrow"; *Viable Tool for National Development,* Paper Presented at Federal University of Technology, Minna, Nigeria.

[3] Akinyemi J. O. (2003), "Rainfall Analysis for Irrigation Management in Ibadan South Western Nigeria", *Proceeding of Regional Conference on Climate Change and Food Sustainability in the 21st Century,* 8-11.

[4] Ambastha, K., Hussain, S. A. and Badola, R. (2005), "Resource Dependence and Altitude of Local People Towards Conservation of Karbatal Wetland: A Case Study from Indo-Gangetic Plains", *Ecological Engineering,* **24**(4): 391-401.

[5] Conway, G. (1997), "The Doubly Green Revolution", Cornell University Press, New York.

[6] Conway, G.R. (1997), "The Doubly Green Revolution", Penguin, London, UK.

[7] Food and Agriculture Organization (FAO) (1989), "Sustainable Agricultural Production: Implications for International Agricultural Research", *Research and Development Paper No. 4.* FAO, Rome, 131 pp.

[8] Freebairn D.M. and King, C.A. (2003), "Reflections on Collectively Working Toward Sustainability: Indicators for Indicators", *Australian Journal of Experimental Agriculture,* **43**(3), 223-238.

[9] Haase, R. and Haase, P. (1995), "Above-ground Biomass Estimate for Invarsive Tree and Shrubs in the Pantanal of Mato Grosso", *Forest Ecology and Management*, **73**(1-3): 29-35.

[10] Hamilton S.K. (1999), "Potential Effects of a Major Navigation Project (Paraguay-Paraná-Hidrovia) on Inundation in the Pantanal Floodplains", *Regul. Rivers. Res. Manage.,* **15:** 289-299.

[11] Hope, R.A. (2005), "Water Workfare and Poverty: The Impact of the Working for Water", *Hydrological Engrg,* **11**(2): 165-172.

[12] Junk, W.J. (2002), "Long-term Environmental Trends and the Future of Tropical Wetlands", *Environ Conserv.,* **29:** 414-435.

[13] Junk, W.J., Soares, M.G.M., Saint-Paul, U., 1997. The fish. In: Junk, W.J. (Ed.), "The Central Amazon Floodplain", *Ecology of a Pulsing System*, Springer, Berlin, 385-408.

[14] Kloub, N., Matouq, M., Krishan, M., Eslamian, S. S. and M. Abdelhadi, 2010, "Monitoring of Water Resources Degradation at Al-Azraq Oasis", Jordan Using Remote Sensing and GIS Techniques, *International Journal of Global Warming*, **2**, (1): 1-16.

[15] Kvist, L.P. and Nebel, G., (2001), "A Review of Peruvian Flood Plain Forests: Ecosystems, Inhabitants and Resource Use", *For. Ecol. Manage.,* **150**, 3-26.

[16] Nebel, G., 2001, "Minquartia Guianensis Aubl.: Use, Ecology and Management in Forestry and Agroforestry", *For. Ecol. Manage.* **150**, 115-124.

[17] Ngai, W.R.C. (1995), "Flood Disaster Management in Malaysia: An Evaluation of the Nigeria", *Proceeding of Regional Conference on Climate Change and Food Sustainability in the 21st Century*, 8 -11.

[18] Olofin, E.A. (1990), "Some Effects of the Tiga Dam on the Environment Down Stream in the Kano Rriver Basin", *Unpub. Ph.D. Thesis*, Bayero University Kano.

[19] Peng, D., Guo, Sh., Liu, P. and Liu, T. (2006), "Reservoir Storage Curve Estimation Based on Remote Sensing Data", Effectiveness of Government Resettlement Schemes. *J. Disaster Environ. Res. Public Health.*, **4**(2): 173-184.

[20] Rao, N.H. and Rogers, P.P. (2006), "Assessment of Agricultural Sustainability", *Current Science*, **91**(4): 439-448.

[21] Roger, J. R. and Li., SW (1985), "Preliminary Results of Anthropogenic Albedo Changes Over the Past 15 Years in Eastern Canada", *Proceedings of ISLSCP Conf., Rome*, 497-499.

[22] Loiselle, S., Bastianoni, S., Bracchini, L. and Rossi, C. (2005), "Neotropical Wetlands: New Instruments in Ecosystem Management", *Wetlands Ecology Management.*, **12** (6): 587-596.

[23] Sivakumar M.V.K. (2007), "Interactions Between Climate and Desertification", *Agricultural and Forest Meteorology*, **142**(2-4): 143-155.

[24] Stoneham G., Eigenraam M., Ridley A. and Barr N. (2002), "The Application of Sustainability Concepts to Australian Agriculture: An Overview", *Australian Journal of Experimental Agriculture,* **43**(3): 195-203.

[25] Yaw A.T. and Edmund C. M. (2007), "Using Remote Sensing and GIS in Analysis of Ecosystem Decline Along the River Niger Basin: The Case of Mali and Niger", *Int. J. Environs. Res. Public Health*, **4**(2): 173-184.