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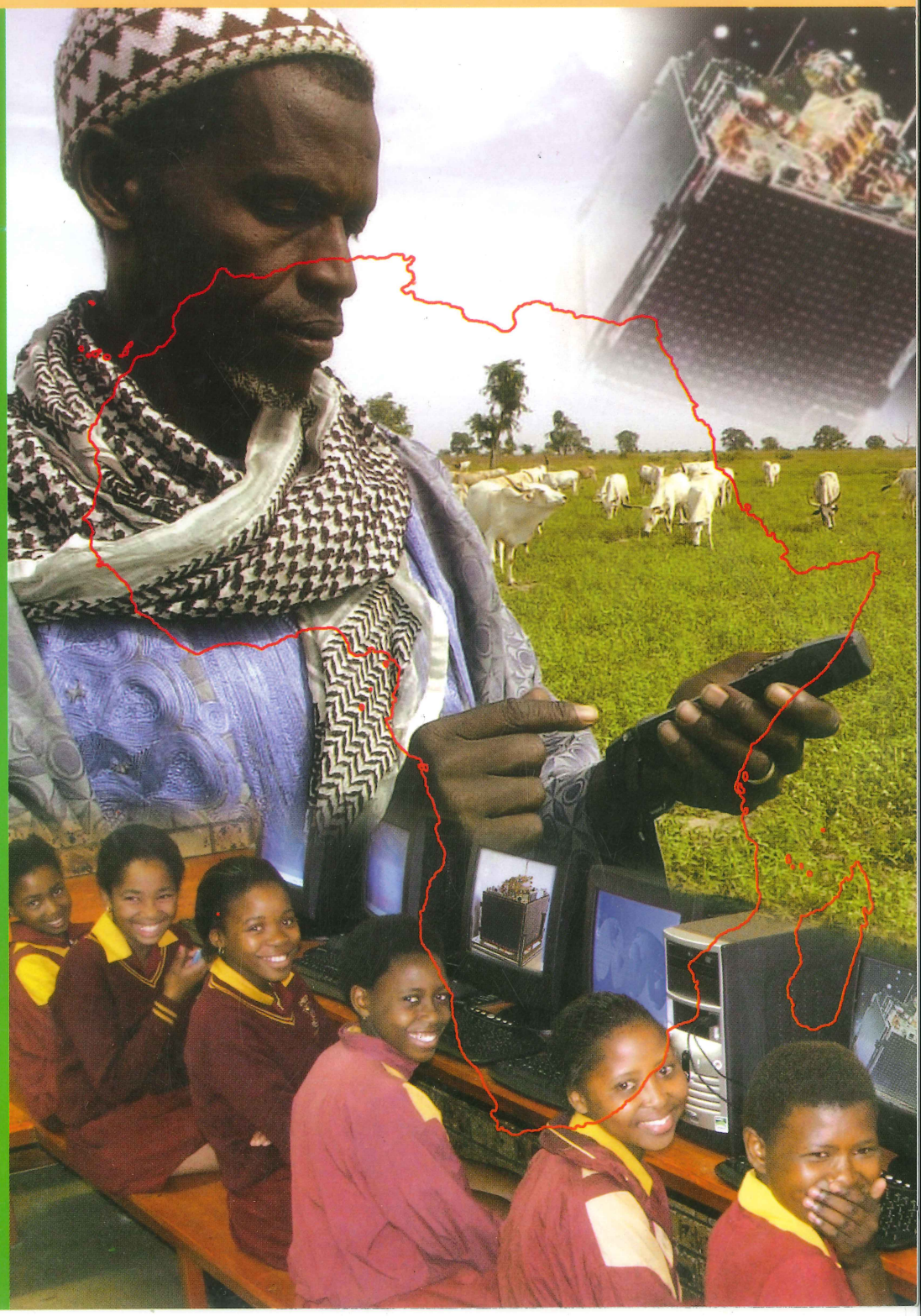

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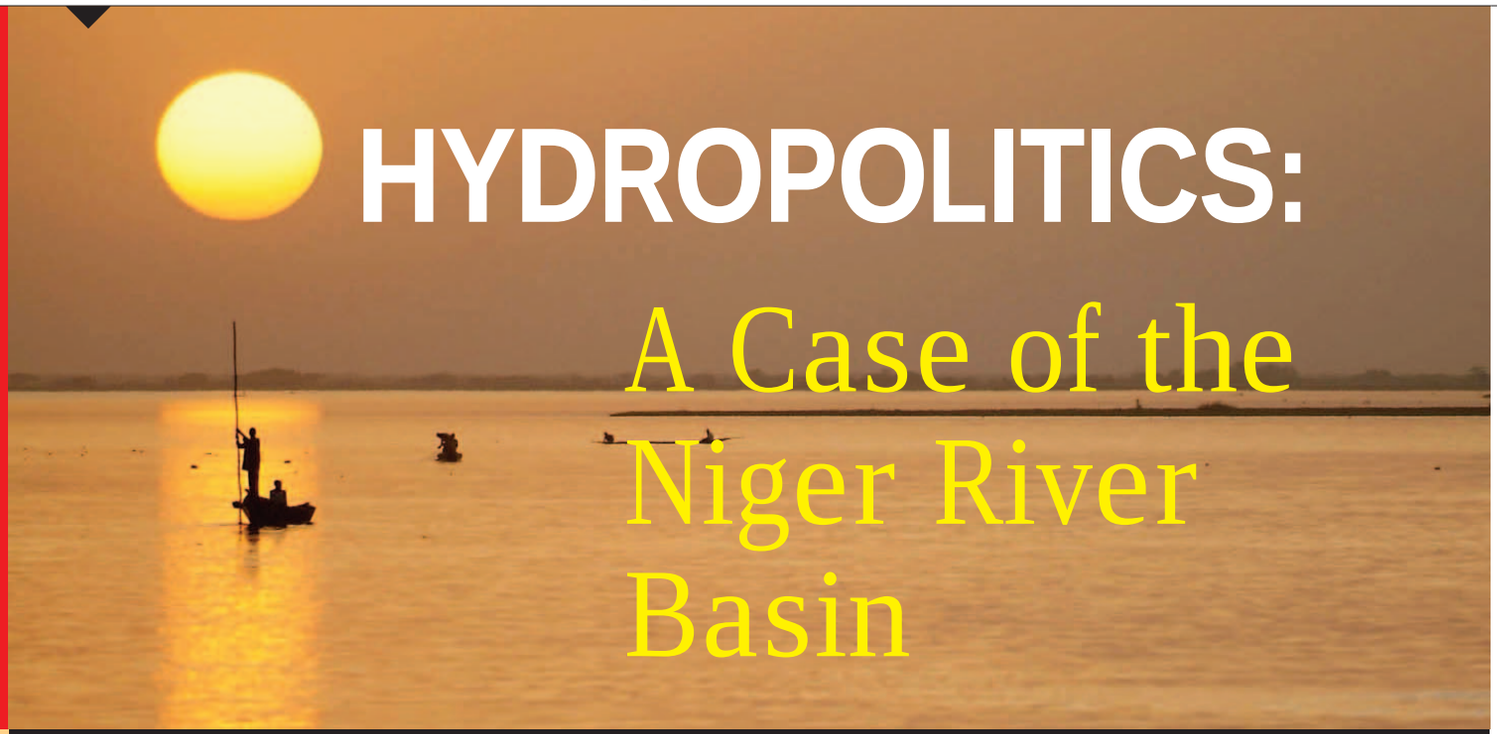

HYDROPOLITICS: A Case of the Niger River Basin

This paper is a case study of River Niger Basin highlighting environmental analysis and efforts towards regional water sharing.

Edmund C. Merem, Yaw A. Twumasi

In the Sub-Saharan African region of River Niger Basin, where none of the major rivers is fully contained within the borders of a single nation, transnational water sharing is essential for survival. Even the globally proclaimed goals of sustainability and environmental security are unattainable in the absence of bilaterally negotiated water agreements.

Yet the systematic study of the nature, conduct of conflict, and cooperation between states over shared water resources in troubled areas of the Middle East continues to dominate the literature with minimal coverage of the Sub-Saharan Africa experience and the role of GIS and remote sensing in monitoring the problem. Considering the intense ecosystem stress inflicted on River Niger by human activities and natural forces emanating from upstream and downstream nations. Researching the growing potential for acute conflict and the need for negotiated water sharing agreements and environmental cooperation among nations of River Niger Basin with the latest advances in spatial information technology as a decision support tool not only helps in averting conflicts, but it has the potentials to bring nations much closer through information exchange. From a geopolitical standpoint, the nature of hydropolitics embodies the complex arenas of interactions between states that share river basins. While this complexity remains compounded due to the depletion of nationally available water resources, the lack of hydropolitical cooperation extracts socioeconomic, political and environmental costs from all players. This is essential as the Niger Basin nations move towards a multi-national watershed management as a conduit for sustainability and equity.

This paper uses GIS and remote sensing technologies in the analysis of hydropolitics of West Africa by focusing on the River Niger Basin with emphasis on the issues and the nature of water politics. Other aspects of the paper cover a regional case study of the River Niger Basin highlighting environmental analysis in Nigeria, Niger and Mali and efforts towards multinational water sharing. The paper has four objectives. The first aim is to update the literature on multinational sharing of water. The second objective is to analyze the current issues in transnational water management. The third objective is to apply the latest methods and advances in geospatial technologies in the study of hydropolitics. The fourth and last objective focuses on the design of geospatial decision support tools in the manage-

ment of shared waters in arid environments of West Africa. The paper is divided into four sections. The first section highlights the methods. The second section presents the results of environmental and hydrological analysis of the trends in the three selected nations of the Niger Basin. Section three focuses on the remediation efforts while section four discuses the findings and some recommendations. The last section outlines a summary of the paper and the future of geo spatial analysis of the hydropolitics of the river Niger basin.

MATERIALS AND METHODS

Study Area: The River Niger Basin

The River Niger as the principal river of West Africa extends over an area measuring 2500 miles (4000 km). It is the third longest river in Africa after the Nile and the Congo river and the most important in West Africa. The basin's catchments area entirely situated between latitudes 4 and 17 North meridian 12 West and meridian 15 covers a total surface area of nearly 1,471,000 km2 shared among nine countries.

The River Niger takes its course from the Fouta D Jallon mountains in Guinea at an Altitude of about 800m and flows North East towards the fringes of the Sahara which it reaches after having traversed its own delta, a vast spreading of 89,000km2 that dissipates an appreciable portion of its potential hydraulic by absorption and evaporation. At the fringe of the Sahara, the River Niger turns back forming a great bend flowing South East towards the Gulf of Guinea which it reaches after being joined by the its largest tributary, the Benue, which brings the great River into contact with the heavy equatorial rainfalls. The Benue River, flows west from Cameroon and joins the Niger at the city of Lokoja in Nigeria. From this confluence, the River flows, North Southward and empties its waters into the Atlantic Ocean through the numerous branches of its Delta. Each year the River supplies the Atlantic Ocean with 180 billion cubic meters of water.

The River Niger and its tributaries boosts of enormous biodiversity made up of mammals and numerous species of birds, plant resources, natural sites and parks. The inland delta is internationally considered as one of the most important wetlands of the planet and an exceptional biotope of the in the Sahel zone. The extensive wetland ecosystems of the inland delta in Mali and the Atlantic Delta in Nigeria have been identified as important centers of biodiversity in the Niger River Basin (Bourn 1992). However, oil industry and agricultural developments in the Atlantic Delta region are increasing the pace of environmental change in the region. Because the Niger River stands as the lifeline of West Africa supporting rich and varied biodiversity, the basin's fresh water wetlands remain highly productive and supportive of millions of resident and migratory birds in the area. The river basin links together the three World Wildlife Federation priority ecoregions.

The population living in the basin estimated at 100 million inhabitants with the Nigerian side of the basin being the most populous. The growth of the population reaches 3% per year with a relatively larger density more than other riparian regions. The region has high susceptibility to climatic hazards and had been affected serious droughts specifically those of 1963-1973, 1982-1985, and 1990-1991 during which Niger Basin Authority (NBA) member nations experienced star-

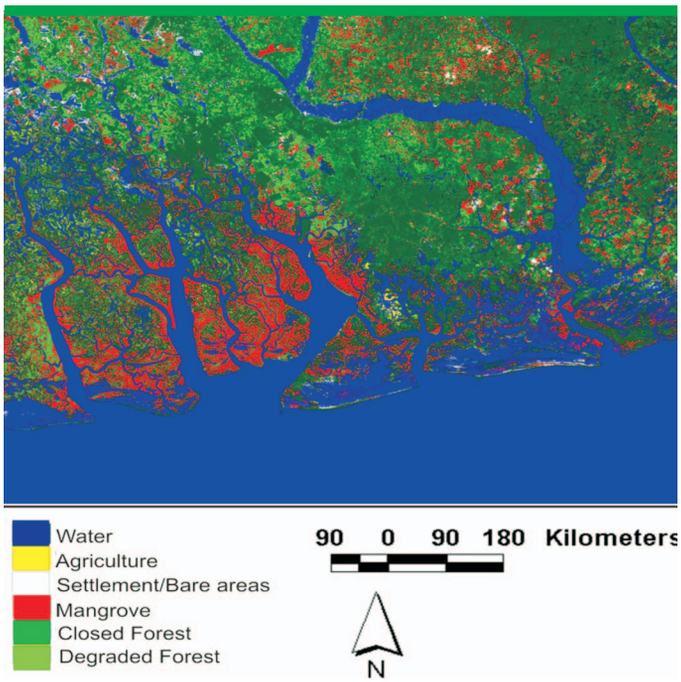

Fig. 2.1 Classified image of Landsat TM, May 20, 1986

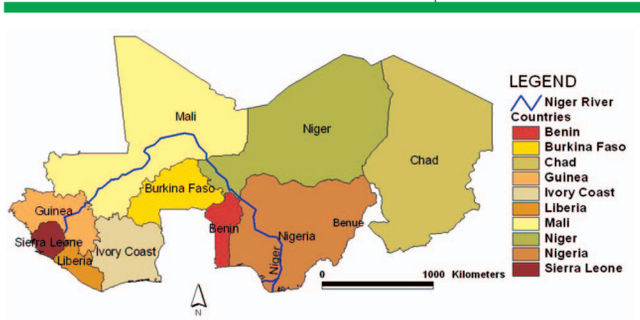

Fig. 1 Map of the Study Area

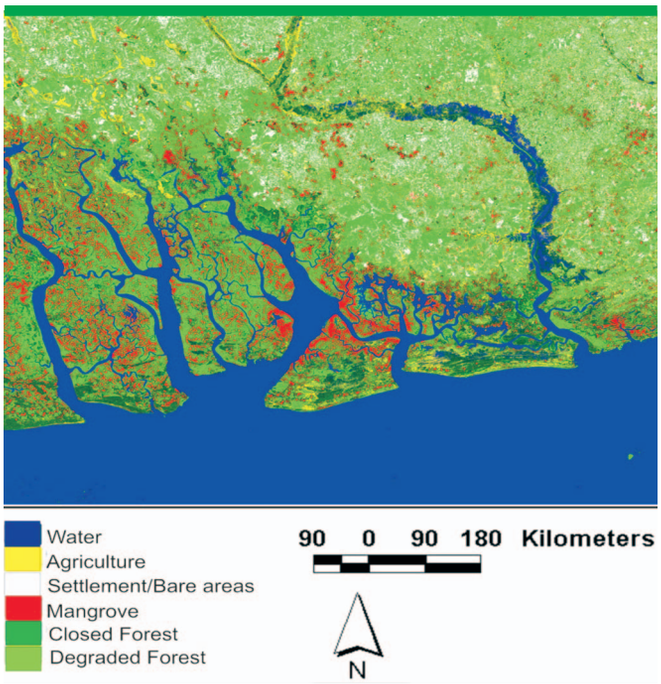

Fig. 2.2 Classified image of Landsat TM, June 19, 2000

vation. Each drought period heightened desertification, over population, inadequate cropping practices, overgrazing, soil erosion and deforestation (NBA 2006). The persistent drought and desertification since the 1970s, makes navigation and fishing impossible during certain periods of the year. Between 1985 through 1990, the river essentially stopped flowing in Niamey, the capital of Niger. Because of continuous drop in its quantity, climate change and water experts estimate that the volume of the Niger has shrank by one- third over the past thirty years alone. In the face of shrinking water supply, competing land use practice involving irrigation and the expansion of cultivable areas with water thirsty crops at the expense of fallow lands at pastoral zones often constitutes the source of conflicts between herdsmen and farmers in the area. In the Urban areas, residues from industrial and domestic activities seep into the river without prior processing and generally through open channels. For example in the Malian capital of Bamako located on the Bank of the Niger River, nearly all the cities commercial and residential effluents drain into the river untreated. By the time the river water gets to Burkina Faso, the waters are highly polluted and certainly unsafe to drink. With the current pace of water table shrinkage caused by yearly decrease in rainfall, pollutants have become increasingly concentrated in the river. In these circumstances river fishing becomes highly vulnerable.

Considering all the potentialities, the various environmental challenges and the capacities of member states, it became necessary in 1964 to create an organization to oversee an equitable management of thee resources (Davis 2003). The authority of the River Niger Basin authority now extends to ensuring the integrated development of the basin, including the use of surface and ground water. However, the Niger basin authority has been unable to formulate a viable master plan. Part of the defects stems from the continuous accumulation of action plans with implementation. Furthermore, member nations have most often disagreed over the fiscal requirements of equal financial contribution. Chad with just only 80,000 basin inhabitants believes it should pay less than Nigeria with more than 60 million inhabitants along the basin. The disagreement over financial contribution worsened with the economic downturn that hit the region in 1994, during which most members ceased to honor their financial obligation to the basin's authority. Only recently, has the United Nations Environment Program (UNEP) proposed a financial plan among member states to strengthen the basin's institutional capacity. Even if these restructuring plans by UNEP may ultimately redress the basin's long standing institutional capacity in financial and infrastructural resources, it is uncertain whether such plans will be able to resolve imbalances in size and power among member states or strengthen regional cooperation when casual conflict breaks out (Milich 1998). Considering the projected water demands in the area the region faces a daunting task in meeting the needs of competing users.

Notwithstanding these challenges, the analysis of water politics is in the region

TABLE 1: Results of the classified 1986 and 2000 images

Classes	Area (ha) in 1986	Area (ha) in 2000	% change (1986-2000)
Water	399,346	305,207	-24
Agriculture/economic activities	17,810	16,092	552
Settlement / bare areas	10,968	31,839	190
Mangrove	114,266	101,326	-11
Closed forest	357,657	108,759	-70
Degraded forest	73,097	309,921	324

is essential as the Niger Basin nations embark upon international management of shared waters as a preamble for sustainable development and equity. Accordingly, transboundary water resource use as conceptualized in hydropolitics join all the countries sharing the Niger basin into a network of mutual dependencies in which no nation can get out from. The economic and environmental complexities inherent in the hydropolitical network binding these nations can be improved by drawing from the current advances in geo spatial information systems in the West Africa sub region.

Methods Used

This paper stresses a mix scale approach involving the integration of primary and secondary data provided through government sources and data bases from other organizations. The raw spatial data and satellite images used in the research were procured through The United States National Aeronautical and Space Administration (NASA) and the United States Geological Survey

Step 1: Data Acquisition

The first step involves the identification of the variables needed to assess environmental change at regional level. The variables consist of socioeconomic and environmental information, including amount of cropland, human settlement, water bodies, forest and population. This process continued with the design of data matrices for the variables covering the various periods from 1986 and 2000 and beyond. In addition, to the design stage, access to databases and abstracts that are presently available within the Federal archives in Nigeria, The United States Geological Survey Department, online images from the University of Maryland website and host of other organizations helped facilitate the search process. The spatial data acquired from NASA consists of two Satellite images covering the Niger Delta area of Nigeria for the separate periods of 1986 and 2000 while the data for Niger and Mali for the periods of 1987 and 2000 came from the University of Maryland free online images.

Step 2: Geo Spatial Data Acquisition and Processing

For the Nigerian area, two Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) multi-seasonal images of 20 May 1986 and 19 June, 2000 were obtained for this study. The path was 188 and 189; and 57 for the row. Similar Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) data pair of 13 October 1987 and 23 September 1999; 18 November 1986 and 12 October 2000, and 12 November 1985 and 20 October 2000 covering Mali and Niger were also assembled. The path and rows of the scenes used covering the same area of

TABLE 2: Results of the classified 1986 and 2000 images

Classes	Area (ha) in 1987	Area (ha) in 2000	% change (1987-2000)
Water	158,702	138,010	-13.04
Shrubs	620,042	471,026	-24.03
Settlement	53,290	127,859	140.00
Plateau Surface	406,552	220,240	-46.00
Plateau Vegetation	233,175	255,065	9.39
Agricultural Fields	107,996	223,988	107.40
Bare Areas	200,110	343,679	72.00

> Complexities of hydropolitical network can be improved by advances in GIS.

Mali and Niger were: (193, 051, (193, 051), (194, 048), (194, 050) and (195, 049).All the images were processed using ERDAS IMAGINE 8.7 image processing software. The images for Mali and Niger were imported into ERDAS as single band while the Nigerian images were housed into ERDAS using ERDAS native file format GEOTIFF. All the bands for the three countries were group together by employing ERDAS Layer Stack modules. This was followed by geometric correction of the images to remove, haze, scan lines and speckles. The scenes were mosaiced using ERDAS Mosaic Tool. Image matching techniques was applied on all the images in order to achieve uniform color on all the images. A linear stretch enhancement technique was performed on all the images, and later subset using ERDAS Area of Interest Tool (AOI) to emphasize the study area. In the case of the Nigerian data, the 1986 image was co-registered with the 2000 image and later geo-linked to allow for the subset of the both images to the study area. Finally, image categorization was also performed using unsupervised classification techniques. The remaining procedure involves spatial analysis and output (maps-tables-text) covering the study period, using ARCVIEW GIS. The spatial

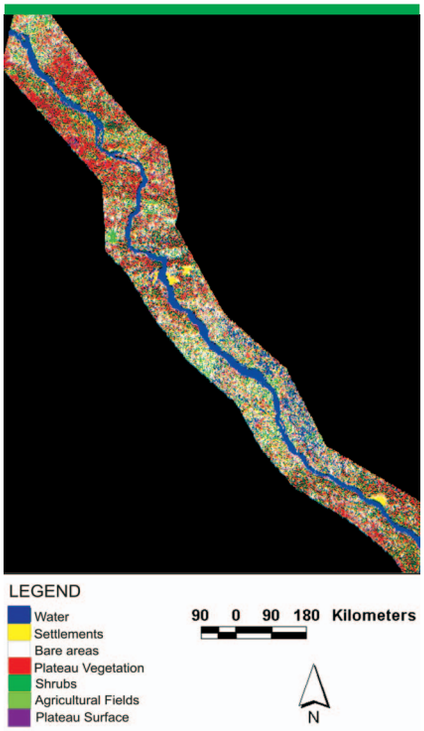

Fig. 3.2 Classified image of Landsat TM, 20 October 2000

units of analysis consisted of the states located in the delta region. Outputs for the region were mapped and compared cross time. This process helped show the extent of temporal-spatial evolution of ecological change induced by human activities along the Niger River watershed.

Environmental Change in the Niger Delta

Overall land cover change for the duration of 14 years between 1986 and 2000 is given in Table 1 and Figures 2.1 and 2.2. The accuracy of the results was compared to government statistics and available information on the area. From Figures 2.1 and 2.2 and Table 1, water bodies experienced slight decline from 399,346 to 305,207 hectares. Mangrove also posted an overall decline of 11 percent. The biggest decline in the area was the closed forest. It declined from an initial estimate of 357,657hectares in 1986 to 108,759 hectares representing an overall decrease of 70 percent. While mangrove, water bodies and closed forest were decreasing, settlement, agricultural and economic activities were increasing as well. Agricultural and economic activities increased from 17,810 hectares to 116,092 hectares representing a change of 552 percent. Settlement also shows an overall change of 190 percent from 10,968 hectares in 1986 to 31,839 hectares in 2000. A number of forest areas degraded also increased during the 14 years' period. For example, from the initial estimate of 73,097 hectares in 1986, it increased to 309,921 hectares in 2000 representing an overall increase of 324 percent.

Environmental Change In Niger and Mali

The results of 1987 and 2000 classified images are shown in Table 2 and Figures 3.1 and 3.2 The accuracy of the results was compared with the available information on the area. In Figures 3.1 and 3.2, and Table 2, water bodies experienced slight decline from 158,702 to 138,010 hectares. Shrubs and plateau surface also posted a decline from an initial estimate of 620,042 hectares in 1987 to 471,026 hectares for shrubs; and from 406,552 hectares in 1987 to 220,240 hectares for plateau surface representing an overall decrease of 24.03 and 46 percent respectively. While shrubs, water bodies and plateau surfaces were declining, settlement, agricultural fields and bare areas were increasing as well. For instance, between 1987 and 2000, agricultural activities increased from 107,996 hectares to 223,988 hectares representing a change of 107.40 percent. Plateau vegetation also posted a slight change from 233,175 hectares in 1987 to 255,065 hectares in 2000, an increase of 9.39 hectares. Settlement had the highest increase in the area. For example, from the initial estimate of 53,290 hectares in 1987, it doubled to 127,859 hectares in 2000 representing an overall increase of 140 percent. The overall decline of the water bodies, development of bare areas and decline of the prime vegetation in the area might be attributed to the seasonal changes in the rainfall patterns and increase in population from the 1970s to 2000 (Manu et al. 2003; Twumasi et al. 2005).

EFFORTS

The Niger River Basin Authority serving the nine nations using the basin's waters has undertaken several initiatives to promote cooperation and support among member states in the use of the river. The initiatives range from the design of development plan to the provision of technical support for the needy nations.

- The Design of Development Plan and International cooperation
- Acquisition of Technological Infrastructure To Boost Riparian Water Rights
- Establishment of New Administrative Structure For Water Management
- Technical Support Through Monitoring and Evaluation

Using remotely sensed satellite imagery and GIS modeling, quickened the analysis of the geographic diffusion of environmental change

RECOMMENDATION AND CONCLUSIONS

To address some of the concerns raised in this paper five recommendations are provided as the strategies to boost multinational management of the Niger Basin waters.

- Encourage Regular Update of Environmental Trends with Geo Spatial Information
- Support Cooperation and Negotiation on Water Issues
- Adopt Sustainable Water Management Strategies
- Involve Local Communities in Multinational Water Management Decisions
- Reform Current Policy of Financial Contribution
- Encourage More Research on Water Issues of the Niger Basin

CONCLUSIONS

This paper has presented the applications of GIS and remote sensing tools in the analysis of the hydro-politics of West Africa with a focus on the assessment of multinational management of shared waters of the River Niger basin. The paper outlined an overview of the concepts and issues in the literature and the driving of water politics along shared water basins at the multinational level. This was followed with the outline of the situation in the River Niger Basin of West Africa with some emphasis on the attributes of Niger Basin region, the essence of GIS and remote sensing based approach, the analysis of environmental and hydrological change and the efforts of the Niger Basin Authority in mitigating the problem.

Notwithstanding the gravity of the trends in the region and continued negation of the water politics of area by mainstream literature, there has not been any major effort among decision makers aimed at analyzing water issues of the Niger region by using geospatial information systems. Considering the growing pressures mounted by human activities and natural process in the region, the results from the data analysis reveal that the study area experienced some significant changes in its environments especially on the surrounding ecology of River Niger forests, land cover and waterbodies. These changes are attributed to socioeconomic and environmental variables and host of other factors.

The results point to a decline in waterbodies, mangrove forests, and increase in human settlement, mixed forests, cropland and agricultural intensification as well as the potentials of drought and desertification due to increases in bare surfaces in both Niger and Mali. There were also declines in plateau surface, shrubs and minor gain in plateau vegetation in Niger and Mali. Other interesting findings touch on the potentials for population growth due to the expansion of human settlements.

This will not only threaten the carrying capacity of an already fragile ecosystem, but it poses enormous challenges for environmental and water managers and policy makers in the region if not confronted with dispatch. To deal with these problems, the paper offers some recommendations as part of the strategies for the region. The recommendations range from an update of geospatial information systems to policy reforms.

The practical applications of a mix scale approach involving GIS and remote sensing in analyzing multinational water politics coupled with the assessment of environmental and hydrological changes showed some valuable results in case of the River Niger Basin of West Africa. GIS technology as used by scientists for mapping of spatial data stands as an effective tool for effective monitoring of multinational water management and the provision of information regarding the extent and nature of water sharing and stress facing River Niger Basin ecosystem. Using remotely sensed satellite imagery and GIS modeling, quickened the analysis of the geographic diffusion of environmental change involving land use, land cover classification, forest cover and hydrology and human settlement expansions threatening the River Niger Basin nations.

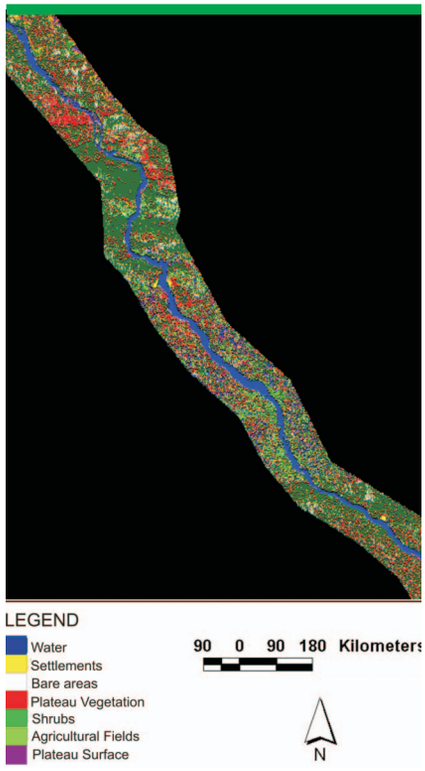

Fig. 3.1 Classified image of Landsat TM, 13 October 1987

In closing, the expectation is that successful implementation of some of the strategies outlined herein could lead to effective management in the Basin. Furthermore, the paper serves as a valuable tool for enhancing decision support systems that are necessary in maintaining the Basins' ecological health.

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