

*Full Research Paper*

## **Using Geospatial Information Technology in Natural Resources Management: The Case of Urban Land Management In West Africa**

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**Abstract:** In the past several decades, Lagos Metropolis emerged as one of the fastest urbanizing cities in the West African Sub-region. In the absence of a regular use of geospatial information management systems, limited effort had been made to keep track of changes in the natural environment in the rapidly growing city for policy making in land administration. The ubiquitous energy radiated by the rapid urbanization rate in the area not only created unprecedented consequences by diminishing the quality of the environment and natural resources but it raises serious implications for land management in the region. The factors fuelling the land crisis in the area which are not far fetched consists of socio-economic, ecological and policy elements. To tackle these issues in a mega city, up-to-date knowledge would be required to capture and analyze land information trends. Such an effort will help manage the city's expansion as well as infrastructure development through the right choices in planning and (spatial) designs using the latest tools in geospatial technologies of Geographic Information Systems (GIS) and remote sensing. This study investigates the spatial implications of the rapid expansion of metropolitan Lagos for land management using GIS and Remote sensing technology. The result of the research provides a valuable road map that can enable planners contribute to improved land administration necessary for effective management of natural resources.

**Keywords:** Urbanization, natural resources management, Land Management and Administration, GIS and Remote Sensing

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## 1. Introduction: Background Information and the Issues

In the last several years, Lagos Metropolis emerged as one of the fastest urbanizing areas in the West African Sub-region. Considering its population of over 13 million [8], Lagos share the attributes of emerging mega-cities of the 21<sup>st</sup> century [10, 7]. As a major urban center, Lagos experiences abundant problems in the domain of land administration. The problems include an unreliable and chaotic land market in which the poor inventory of land records and inadequate update of the topographical mapping of Metropolitan Lagos hinder effective planning for both real estate and other urban services [20, 8]. This has been worsened by the lack of essential databases for accurate land information for planning and development purposes [8]. In the absence of a regular use of land information management system limited efforts were made to keep track of change in the rapidly growing city for policy making in land administration. The ubiquitous energy radiated by the rapid urbanization rate in the area not only created unprecedented consequences by diminishing the quality of the environment but it raises serious implications for land management in the state [15, 10, 14].

The factors fuelling the land crisis in the area which are not far fetched, consist of socio-economic, ecological and policy elements. The establishment of sophisticated remote sensing centers, with advanced hardware and software packages and highly equipped remote sensing aircraft demands significant investment, high level training, numerous years of committed effort to attain most efficient means of operation in the use of such sophisticated equipment [1]. However, in such places as Lagos the use of information technologies in land administration is marred due to lack of spatial information tools and infrastructure, inadequate training, lack of coordination between agencies [10]. There have also been widespread concerns about the activities of registered land surveyors who rubber stamp land documents carried out by inexperienced survey assistants without proper supervision on the job [4]. Additionally, the departments of survey still rely on obsolete land management approach not designed in meeting the current challenges of sustainability and management of land resources. More so, the centralized style of land administration in force since 1978 under the Land use act operates under a process that vests land controls in the hands of the state governor [9, 22, 18]. This legislation that overlooked the use of geospatial information systems as decision support system for land managers, not only inhibits public participation but it hampers efforts to promote public access to land information system.

Being a mega city and to tackle the issues [21,25], up to date knowledge and skill would be required to capture and analyze land information in order to steer and control the city's expansion through infrastructure development. This will enable planners to make the right choices in planning and (spatial) designs [12, 10, 16]. Because the basic land-use management problems are unsolvable without considering the basic geo-spatial approaches [19, 3], the Lagos Government is launching a trademark electronic devise for accessing land titles in an attempt to end current difficulties in ascertaining the authenticity of titles [16]. The expectation is that the proposed approach will eradicate several difficulties including an environment for the perpetuation of fraud on land title documents; an

inability to meet the demands of the prospective land owners, and an inefficient administrative process which causes long queues. Accordingly, the Association of Professional Surveyors in the state of Lagos has expressed interests in modifying land information systems for meeting the needs of planning. The belief is that access to digital maps and detailed geographic information technologies will enable the association confront the challenges facing land administrators in the area of physical planning involving infrastructure, roads, environment and others [4].

In this setting, remote sensing and Geographic information systems (GIS) have the capacity to provide valuable and timely information about natural resources, urban change and the extent of environmental change being experienced in Lagos as an important basis for sustainable planning for land management and decision making in the state. While both devices can provide effective tools for decision makers, they are important geometric tools, which are used extensively in land management [1]. With the type of problems currently faced by land administrators in the state of Lagos coupled with the rapid pace of urbanization leading to environmental decline [15, 10, 14], a GIS and remote sensing approach is a highly favored approach to the effective management of land use and land resources in the state. With spatial information technology tailored in such a way to suite a particular geographic area, critical indicators of change from activities like agriculture, housing, road design can visually be captured for use in land administration and policy [19]. Considering the benefits of spatial technologies, it is therefore paramount that such an improved approach be designed for land management in the Lagos area.

### *1.1. Purpose and Organization*

This study investigates the implications of the rapid expansion of metropolitan Lagos for land administration using Geographic Information Systems (GIS) and Remote sensing technology. This is intended to enable planners and policy-makers contribute to improved land administration and enhance their competence in decision-making. The study contains three sections. Section one offers a description of the methodology and the study area. Section two presents the results and data analysis while section three discusses findings and their significance to land administration. The fourth section offers recommendation for change in land administration policy. The final section summarizes the importance of the study to the future of land management in the study area. This study has three objectives. The prime objective is to update the literature while the second objective is to design a decision support tool for land administration. The third objective is to demonstrate how latest advances in geo-spatial information technology can guide planners and policy makers towards an improved land administration.

## **2. Materials and Methods**

### *2.1. The Study Area: The State of Lagos*

Lagos state is situated in the South Western Nigeria within latitudes 6 degrees 23'N and Longitudes 2 degrees and 3 degrees 42 E (Figure:1). The state is bounded from the North and East by Ogun State, in the West by the Republic of Benin and the South by the Atlantic Ocean. The total land mass of the

state stretches over 3,345 kilometers. While the state appears physically smaller, it is ranked as the most highly populated state in the country with an estimated population of about 10 million inhabitants representing 10 % of the total population of Nigeria. Because water is the most significant topographical feature in Lagos State, water and wetlands cover 40% of the total land area in the state. Other notable features in the state consist of Lagoon and creeks, wetlands, barrier islands, beaches and estuaries [14].



**Figure 1.** Map of Study Area.

Lagos consists of two main regions, namely the Lagos Island and mainland, the original city and Ikoyi, Victoria Island, and the Lekki corridor areas are referred to as Lagos Island while the mainland encompasses other parts of the state. The more built up mainland and Lagos Island, which make up what is referred to as the Metropolitan Lagos is inhabited by about 80% of the population of the state. Major developments on the area in the middle of last century show that the area not only experienced a rapid expansion, but it engulfed adjacent towns and villages [2, 14, 17]. Considering the previous growth trends, Metropolitan Lagos at present extends to over 1,068 (km<sup>2</sup>).

Current projection in 1996 regarding the hierarchy of Global cities ranks Lagos as the fifth largest city with 12 million inhabitants. At the same time, other studies put future population of Lagos by 2015 at 24.6 million as third largest city of the world with implications for international capital and Sub Saharan Africa [24, 5]. Based on this concept, global capital utilizes urban areas such as Lagos as the organizing node in the spatial organization of international production and markets [11]. The population of the Lagos urban agglomeration stayed at 10.3 million in 1995 at a growth rate of 5.8% annually. It went up by more over 300,000 persons per year during the 1980's and 1990's [24]. The population density along the built-up metro section also ranges from 20,000 persons/sq km. The rapid

expansion of Metropolitan Lagos with its role as a center of global capital seems to have surpassed efforts in physical planning as well as the development of infrastructure facilities in meeting the needs of the inhabitants. See Table 1a for the population monitor of the state.

Under this setting, the area's rapid expansion continues at an alarming rate with sporadic engulfment of adjacent towns and villages through dredging of land previously covered by water and mangrove swamps. This in turn puts enormous strain on the areas scarce land base and the aquatic ecosystem. This is evident considering the growing discharge of wastewater into the Lagoon due to a growing population [14](Table 1b). While previous efforts to address land management resulted in land reclamation, which was used in providing thousands of hectares of land in Lagos, and housing for many residents (Table 1c and 1d). Insufficient attention was paid to periodic geo-spatial inventory and assessment of available scarce land resources for policy and sustainable management of these lands with the latest advances in management information systems for land administration. To keep track of the rate of urban expansion onto available land area in the state, there is a need for the use of latest advances in spatial information technologies such as GIS and Remote sensing technologies in order to guide policy makers towards effective land management in the state [10, 19,8].

**Table 1a.** Lagos State Population Monitor.

Year	Population	Global Ranking
1997	11.5	12 <sup>th</sup>
1998	12.1	10 <sup>th</sup>
1999	13.4	8 <sup>th</sup>
2015	24.5	3 <sup>rd</sup>

Source: United Nation World Population Monitor 1998/1999

**Table 1b.** Wastewater Flows From Metro Lagos to The Lagoon 1995-2010.

Environmental Indicators	Year	
	1995	2010
Population in million	7.01	27.6
Domestic Wastewater	437,490 (54%)	?
Total Waste Water (m <sup>3</sup> /dy)	811,300( 115.71/ c/d )	1,663.087

Source: Lagos Ministry of Environment and Physical Planning 1996

## 2.2. 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 came from The United States National Aeronautical and Space Administration (NASA). This information was analyzed with ARC View GIS and remote sensing technology.

**Table 1c.** Planned housing schemes in metropolitan Lagos.

Housing Agency	Scheme	Remarks
Lagos Executive Development Board, 1955 - 1975	Slum clearance of Central Lagos, 1955 to early 1960s, Olowogbowo Relhousing Scheme, Lagos Housing Scheme	1,847 families housed in Surulere. 1,337 families resettled in low-income rented houses. Subsidized by Ministry of Lagos Affairs
	Other housing schemes in Surulere	14,537 family units (dwellings) provided. In all, 128,800 people were provided with housing
Lagos State Development and Property Corporation (LSDPC), 1972-1979	Resettlement of slum dwellers from Central Lagos to Ogba and low-income housing in Isolo	1,000 families housed
Federal housing LSDPC, 1979 to date	Under 1975-1980 and 1981-1985 plan periods Low-income housing Medium-income housing	6,000 housing units <sup>a</sup> 16,878 housing units 1,790 housing units

Source: Lagos State Development and Property Corporation Various Years

**Table 1d.** Units of Planned Houses For State.

Units	Locations
1,500	Abraham Adedsanya Estates -Aja
152	Ayangburen Phase II Ikorudu
112	Lekki Phase 1 Oba Adeyinka Oyekan
336/304	Ojokoro Housing Schemes Phases I and II
79	Lekki II
56	Amunwo-Odofoin
150	Ibeshe

Source Lagos State Government 2004

### 2.3. Data Acquisition and Processing

Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) data pair of December 18, 1984 and February 6, 2000 covering Lagos, Nigeria was acquired from the University of Maryland free Online Data Services. The images were imported into ERDAS Imagine Image Processing Software for further processing. Since the images were in single bands, layer stack technique was performed to group the bands together. The process was continued by performing geometric corrections of the images to remove few scattered clouds in the image. Both images were projected to the Universal Traverse Mercator (UTM) coordinates zone 31. The spheroid and datum was also referenced to WSG84. Histogram Equalization enhancement technique was performed on all the images, and subset to an area of approximately 2,383.994 km<sup>2</sup> to cover Lagos and its vicinity. The

images were later displayed as false-color composites with band combination of red as band 7, green as band 4, and blue as band 2. All the images were later categorized using unsupervised classification technique.

### 3. Results and Discussion

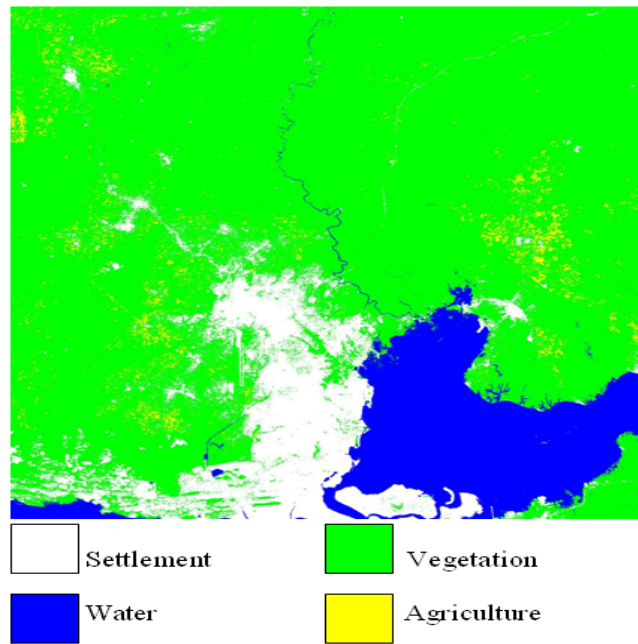
Table 2 and figures 2 and 3 shows the results of the classification for 1984 and 2000 images. From table 2, land area under water declined from the initial estimate of 29,040 hectares (ha) in 1984 to 24,708 in 2000. This represents an overall decrease of 14.91 percent. The size of area covered by vegetation, which include coastal mangrove, forest and grassland areas experienced a significant decline from 180,384 ha in 1984 to 140,568 ha in 2000. While the area of Lagos containing water and vegetation were experiencing a decline, agriculture and settlement was increasing. For example, between 1984 and 2000, agricultural activities increased from 4,615 ha to 9,806 representing an overall change of 112.48 percent. The size of land designated as settlement also showed a change of 159.02 percent in the same time.

Figures 4 and 5 also show the results of the false-color composites for 1984 and 2000 images. In these images, the relatively dark-brown areas represent the built up and heavily populated area, whereas greenish areas are vegetation. The deep blue regions are the water bodies. While these figures show the tremendous rate of urban expansion between 1984 and 2000, it is safe to say also based on figures 1-4, that the population of the Lagos seems to have doubled between 1984 and 2000. This not only puts a tremendous pressure on the resources of the city, but it has the potentials to aggravate flooding of the Lagos area due to its location on a floodplain.

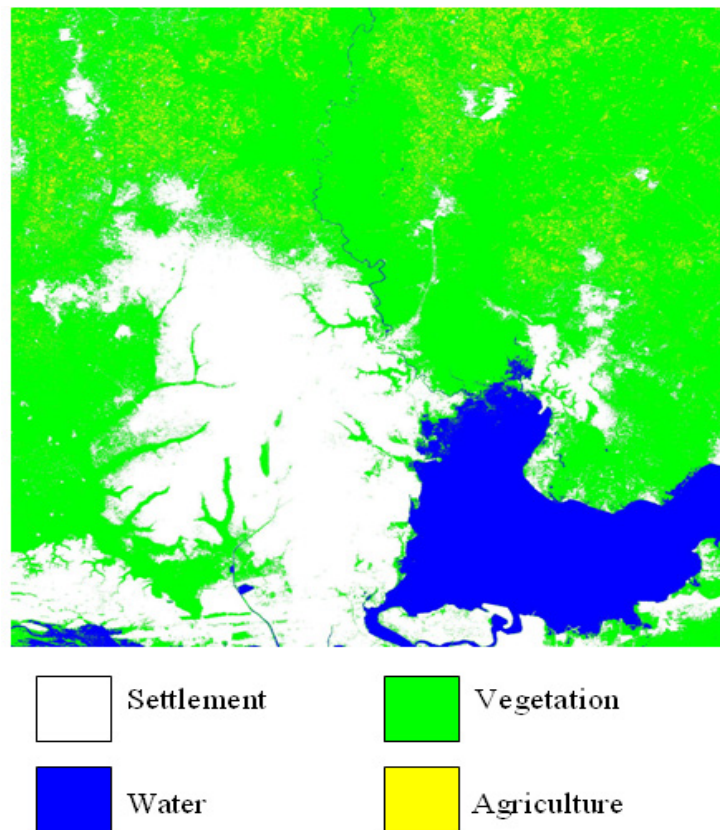
These results suggest that the state and national administration should adopt policies that would protect the land mass of this vulnerable city by taking advantage of the latest advances in geospatial information technologies given their usefulness as advanced warning information devices for boosting decision support system in land management in the area. The results also indicate that geospatial information technologies are the key to planning, management and administration of land in areas such as Lagos. This study serves as a road map towards the development of the much needed geospatial information infrastructure for the effective administration of land areas under the pressures of urbanization.

**Table 2.** Results of the classified 1984 and 2000 images.

<b>Classes</b>	<b>Area (ha) in 1984</b>	<b>Area(ha) in 2000</b>	<b>% Change (1990-2000)</b>
Water 14.91	29,040	24,708	-
Settlement	24,360	63,317	159.92
Vegetation 22.07	180,384	140,568	-
Agriculture	4,615	9,806	112.48

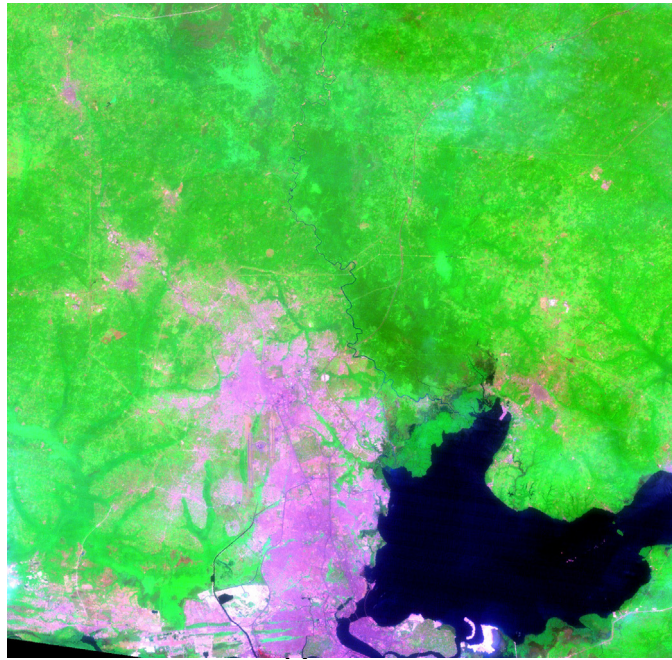


**Figure 2.** 1984 Classified Landsat Image of Lagos and its Vicinity.

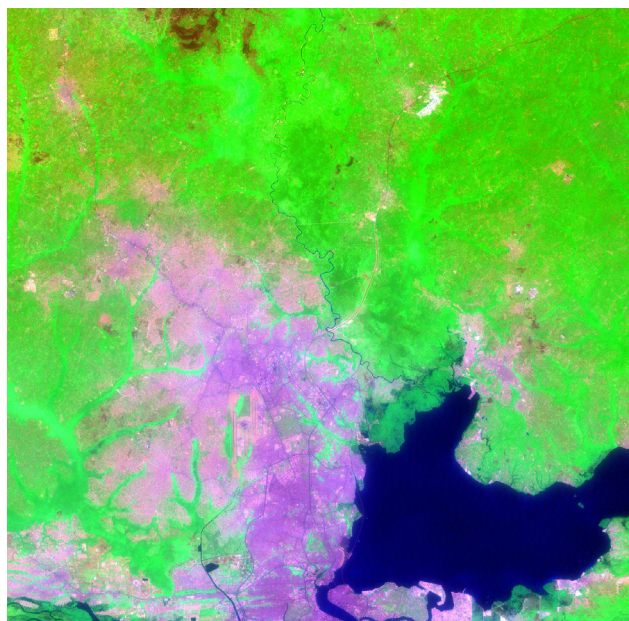


**Figure 3.** 2000 Classified Landsat ETM+ Image of Lagos and its Vicinity.





**Figure 4.** 1984 False-Color Composite (742) Landsat Image of Lagos and its Vicinity.



**Figure 5.** 2000 False-Color Composite (742) ETM+ Image of Lagos and its Vicinity.

### *3.1. Policy Recommendations*

Five recommendations for land management strategies and decision-making are listed below

#### **1) Encourage Community Involvement in Land Management and Administration**

Experiences show that communities are most often at the receiving end of land problems confronting the state of Lagos. This is evident with the pace at which the rapid expansion of Metro

Lagos into rural communities has affected community land base over the years. Because communities are much closer to these problems, efficient land management under the current circumstances demands active involvement of local communities in matters associated with land administration. This is attainable through the provision of technical assistance that gives local entities and community organizations such as non-profit organizations real involvement in planning and implementation of novel land programs on areas adjacent to their communities.

## **2) Provide Support for the Education and Training of Land Administrators**

With too few trained people to upgrade obsolete spatial data infrastructure, land administrators are unable to carry out their assigned tasks. As a result, decision-makers lack access to valuable information and the appropriate decision support tools for land administration. To tackle these issues, up-to-date knowledge and skills through education for land administrators would be required to capture and analyze spatial information in order to steer and control the city's expansion. This will enable land managers make the right choices in planning and (spatial) designs associated with land use. In light of this, there is a need for training in order to boost the skill acquisition that is necessary in meeting the challenges facing land administrators. Modest investment in education of land administrators can make big improvement in the capability of decision makers in tackling complex land issues.

## **3) Allocate Funds For Upgrading Spatial Data Infrastructure**

The current assessment of the state of land information data in the state and other parts of the country point to a continuous reliance on obsolete data infrastructure that serves little purpose in the information age. With the socio-economic relevance attached to land under the aegis of global cities, the state of Lagos should encourage funding programs that promote the rapid upgrade of spatial data infrastructure for the efficient management of land information. Government funds should be directed at the procurement of sophisticated modern technologies to sustain decision making in the land sector for the public.

## **4) Strengthen Existing Policy With Emphasis on Periodic Geospatial Inventory of Land**

For decades, land managers operated under a command and control mechanism which vests authority on allocation on the state executive branch. This made the modernization of land information system difficult. Accordingly, insufficient attention was paid to a periodic geo-spatial inventory and assessment of available scarce land resources for policy and sustainable management with the latest advances in management information systems. Considering the defects in policy and concerns about the unreliability of land information system, and the current move to boost land management, this paper suggests that the state of Lagos strengthen its current programs with policy emphasizing the commissioning of periodic geospatial inventory of land resources in order to evaluate the current and future needs.

### 5) Design a Regional Land Information System for Monitoring of Change

In recent years, the United Nations through its document Agenda 21 reiterated the essence of geospatial information system for planning and development in developing nations. However, the recourse to geospatial information as suggested in Agenda 21 of the United Nations has not fully been integrated into the administrative framework of land management in state of Lagos. Yet considering the rapid urbanization of the state, the design of a regional land information system along the lines of Agenda 21 is highly needed. Monitoring the extent of change and keeping track of land use trends in the state must be the main aim of the proposed Regional Land Information System. This will not go a long way in sustaining land management, but it will augment the decision support system guiding land administration with the latest advances in spatial information technologies. This approach supplements the current efforts of Government of Nigeria towards the development of NigeraSat.

## 4. Conclusion

This paper has shown that Geospatial information technologies are the key to planning, management and administration of land in areas such as Lagos. The tools and methods used in the study serves as a road map to the development of the much needed geospatial information infrastructure for the training of land managers and the effective administration of land areas under the pressures of urbanization. Geospatial information technology as used in this paper also stands as a necessary tool in the design of decision support systems in sustainable management of land resources and policy development. Not only is the combined use of GIS and remote sensing technologies essential for the development of an innovative spatial data infrastructure, it is an indispensable device for decision making across all sectors of land management and the environment in the area. Other findings in the paper point to the pace at which insufficient attention were paid to a periodic geo-spatial inventory and assessment of available scarce land resources for policy and sustainable management of these lands with the latest advances in management information systems for land administration. To deal with these problems the paper offered several recommendations such as community involvement, support for education and training, allocation of funds, strengthen existing policy and design of a regional land information system. The idea behind the emphasis on education stems from the relevance of up-to-date knowledge and skills that would be required to capture and analyze information in order to steer and control city's expansion as well as infrastructure development so that land administrators can make the right choices in planning and (spatial) designs in the area.

## References

1. Abdel Rahman, S.I. *The Use of Geoinformation Technology For Agriculture Application In Egypt*; FAO: Rome, Italy, 2005; page 1.
2. Abiodun, J. O. *The urban challenge in Africa: Growth and Management of its large cities*; United Nations University Press: Tokyo, 1997; Part 2, page 1.

3. Adeoye, A.; Okunlande, B. National Geographic Information Infrastructure for Sustainable Development in Nigeria. In *Proceedings of FIG XXII International Congress*, Washington, DC, Apr 19-26, 2002; page 3.
4. Alao, T. *Surveyors Tackle Challenges of Mapping and Land Administration*. The Guardian; Newspapers, 2005; page 1-2.
5. Alkali, J. Planning Sustainable Urban Growth In Nigeria: Challenges and Strategies. In *Proceedings of the Conference on Planning Sustainable Urban Growth and Sustainable Architecture*, United Nations: New York, June 2005; page 2.
6. All Africa. *Lagos Launches E-Registry*. All Africa: Lagos, November 2005; p. 1-2.
7. Brockerhoff, M.P. *An Urbanizing World*. Population Bulletin, 2000; p. 10.
8. Chiazor, Maxwell.; *Developing Land Information Systems In Nigeria; The Lagos Experience*; 2<sup>nd</sup> Global conference, Ecological Justice and Global Citizenship, Denmark, Feb 13-15, 2003.
9. Fajemirokun, B. Land and Resource Rights: Issues of Public Participation and Access to Land In Nigeria; In *Proceedings of the First Workshop of the Pan African Programme On Land and Resource Rights (PAPLRR)*, Cairo, Egypt, Mar 25-26, 2003.
10. Fajuna M.J.; Omojola A.S. GIS and Remote Sensing For Urban Planning: A Case of Festac Town, Lagos Nigeria; In *Proceedings of 12th International Conference On Geoinformatics*, University of Gavle: Sweden, 2004.
11. Friedmann, J. The World Cities Hypothesis. *Development and Change* 1986, 17-69-84.
12. Ikhuaiah, I. Professionalism and Manpower Issues In Geographical Information Systems In West Africa. *Transactions in GIS* 1999, 3(4), 343-358.
13. January Spatial Data Infrastructure. *Africa News Letter* 2005, 1-21, 4(1).
14. Iwugo, K. Aspects of Land Based Pollution of African Coastal Mega City of Lagos; In *Proceedings of the Diffuse Pollution Conference*, Dublin, 2003; p. 14-122
15. Merem, E. The Impacts of Globalization On The City of Lagos (unpublished manuscript); The Department of Urban and Regional Planning, Jackson State University, Jackson, Mississippi, 2003.
16. Mursu, A. Information Systems Development In a Developing Country: Theoretical Analysis of Special Requirements In Nigeria and Africa. In *Proceedings of The 33<sup>rd</sup> Hawaii International Conference On Systems*, 2001.
17. Ogunleye, D.A. *Settlement Geography*; University of Lagos Press, Lagos, 2001; page 1.
18. Omoweh, D. *The State, Land and Resource Rights and the Prospects of Sustainable Development in West Africa*, Paper Presented at 2<sup>nd</sup> Workshop of the Pan African Programme on Land and Resource Rights Lagos, July 15-16, 2002
19. Sodeinde, O.R. ; *Software For Land Use Management: Modeling With GIS* ; In *Proceedings of FIG XXII, International Congress*; Washington D.C , April 19-26, 2002
20. Speer, E. Implementing GIS Applications. In *Proc. Third World ESRI User Conference*, 1997.
21. Strom, S. The Growth Explosion: Why Smart Growth In the Third World is so Important. *The Next America City*, Feb 2003, Issue 1.

22. Taylor, R. *Urban Development Policies In Nigeria: Planning, Housing and Land Policy*; Center For Economic Research On Africa Montclair State University: Upper Montclair, NJ, 1988.
23. The South's Urban Revolution. UNESCO Courier, June 1999, 52:6:1-4
24. United Nations (UN). *United Nation Department of Economic and Social Affairs Population Division Urban Agglomeration*; United Nations: New York, NY, 1996; p. 18
25. United Nations (UN). *The State of The World's Cities Report*. United Nations Center for Human Settlement: Nairobi: KY, 2001; p. 1-4.

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