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Remote Sensing in Developing Country-Nigeria: An Exploration

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Abstract

The paper examines remote sensing education, and research in Nigeria. Among the questions addressed in the paper are: (i) what is the situation of remote sensing education and research in Nigeria? (ii) what are the broad areas of research and topics that are addressed? (iii) what type of remote sensing and GIS software are used? (iv) what are the sources of satellite images used? (v) what are the institutional affiliation and departments of the researchers? (vi) what are the research coverage areas? and (vii) what are the major findings from the remote sensing images? The data used in the study is from extensive published article search from 2009 to 2013. Descriptive statistics is used to analyze the data. Descriptive statistics used include frequencies and percentages. Policy implications of the findings are discussed in the paper.

Keywords: remote sensing, education, developing counties, Nigeria

1. Introduction

Remote sensing is the collection of information relating to objects without being in physical contact with them. It is the process of acquiring data/information about objects/substances not in direct contact with the sensor, by gathering its inputs using electromagnetic radiation or acoustical waves that emanate from the targets of interest (Shaw & Burke, 2003; Teewu et al., 2005; Ali, 2010). The origins of remote sensing date back to a photography taken from a balloon in 1858, and by World War I the aeroplane had become the main platform from which aerial photography was collected (Areola, 1986; Teewu et al., 2005). Areola (1986) notes that the first aerial photographs taken from an aeroplane were those of Centocelli, Italy, in 1909 and that the first World War which began a few years later gave a great impetus to the development of aerial photographic interpretation, particularly for military purposes. Indeed aerial photographic reconnaissance of war fronts and enemy territories soon came to be regarded as being of utmost importance in the planning of both military offensives and counteroffensives; in assessing the military capabilities of the enemy; in safeguarding vital supply routes; and in making models of the terrain in order to plan troop movements and manoeuvres. In the preparation for and during the Second World War, the military intelligence establishments in Europe, Russia and America perfected their photographic interpretation techniques and developed better aerial photographic cameras and films (Areola, 1986). According to Areola, up to the end of the Second World War, aerial photographic interpretation was mainly developed for military intelligence, and most of the aerial photographs available then were classified documents. Nevertheless, significant advances had been made in the scientific and practical uses of aerial photography (Areola, 1986). During the inter-war period, film chemicals were developed that allowed colour and infra-red photograph: the latter was of particular interest to the military, as it highlighted camouflaged features (Teewu et al., 2005). Since the 1950s, and until in recent time, black and white aerial photography has been the basis of most Earth surface mapping: accounting for 99% of all topographic mapping (Petrie, 2000; Teewu et al., 2005). As observed in the literature, aerial photographs are no longer the only available type of imagery of the earth's surface; satellite and radar imagery are now very common. The techniques by which these other types of imagery are produced now constitute, together with aerial photography, the wider field of science known as remote sensing. Landsat Earth-observation satellites, operative since 1972, produce digital images in the visible and infra-red parts of the spectrum: each covers thousands of kilometers square, with sufficient detail to map many geo-ecological features (Teewu et al., 2005). Digital images have many advantages over photographs: digital data can be easily stored and processed by computers; perfect copies of an image can be made in a second. Teewu et al. (2005) notes that over 1999-2000 a new generation of satellites, utilizing 'spy-satellite' technology, began to provide commercially-available multi-spectral digital images that could rival the detail obtained by aerial photography. Other recent developments, such as millimeter-precision Global Positioning System (GPS) receivers, improved digital data compression software and internet transfers of remotely sensed data, have facilitated the use of remotely sensed data (Teewu et al., 2005).

Observation in the literature shows that remote sensing has some fundamental advantages at gathering information that make it a good tool in environmental monitoring and management. These have been listed by Barret and Curtis (1976) to include: a capability for recording more permanently detected patterns; play-back facility at different speeds; opportunity for informative (objective) analysis of observations to minimize personal peculiarities of observers; means of enhancing images to reveal or highlight selected phenomena; the synoptic view advantage offered by raise platform; ability to record data on otherwise inaccessible areas; ability to produce accurate data on large areas at desired time intervals and at relatively lower cost compared to the cost that would be incurred through ground survey methods; and, ability to record images in multispectral fashion at different stages, at different scale and spatial resolutions. To the developed world remote sensing is a cost saving method of acquiring raw data to update existing information, while for the developing countries especially those in Africa, it has provided an opportunity to obtain the first generations of information on some of their earth resources (Abiodun, 2000).

Observation from the literature shows that the greatest problems that have perhaps militated against the wholesome acceptance and application of remote sensing technology by most developing countries especially in Africa include lack of understanding of the role of space science and technology in the development process; shortage of trained manpower; financially related problems of remote sensing data; inadequate hardware and software facilities for image processing (Abiodun, 2000; Fagbami, 1993), and most importantly lack of contributory input to satellite launching and image acquisition processes. Table 1 shows the satellites in Africa. None of these satellites was launched by an African rocket or on an African soil. No African country has launch capability as of today. This paper examines remote sensing education and research in Nigeria.

Table 1. Satellites in Africa

S/N	Country	Year of first launch	First Satellite	Payloads in orbit as of January 2013
1	Egypt	1998	Nilesat 101	4
2	South Africa	1999	SUNSAT	2
3	Morocco	2001	Maroc-Tubsat	1
4	Algeria	2002	Alsat 1	1
5	Nigeria	2003	Nigeriasat 1	5

Source: Wikipedia Encyclopedia accessed: 21/10/2013.

2. Research Questions, Source of Data and Method of Data Analysis

The questions addressed in the paper are:

1) What is the situation of remote sensing education and research in Nigeria?
2) What are the broad areas of research and topics that are addressed?
3) What type of remote sensing and GIS software are used?
4) What are the sources of satellite images used?
5) What are the institutional affiliation and departments of the researchers?
6) What are the research coverage areas? and
7) What are the major findings from the remote sensing images?

The data used in the study is from extensive recent published article search (2009–2013). The total number of articles used in the study is seventy-seven (77). Descriptive statistics is used to analyze the data. Descriptive statistics used include frequencies and percentages.

3. Remote Sensing Education and Research in Nigeria – An Overview

Until recently, aerial photo-interpretation is what is available and taught in schools in Nigeria. Areola (1986) writing about the advance of aerial photograph in less developed countries notes that after the Second World

War, the advanced countries of Europe and America turned to the countries of the tropics for the much needed industrial raw materials to rebuild their damaged economies. In addition there were fears about possible world food shortages. In order to avert such food shortages plans were drawn up for agrarian and land use reforms in the overseas colonies of the European powers. It was in this spirit, for instance, that the World Land Use Survey was established in 1949 by the International Geographical Union through the influence of Sir Dudley Stamp. Although this project collapsed after some time, three countries, Cyprus, Iran and Sudan, were in fact, successfully surveyed. According to Areola, for many of these poor countries there were no maps at all so that, naturally, the survey groups had to turn to the use of aerial photographs. Also it soon became apparent to the colonial powers that maps were essential for development projects in the colonies. This meant that a programme of topographic mapping had to be embarked upon prior to, or simultaneously with, the development projects. The literature reveals that the failure of agricultural development projects in British East and West Africa during this period can in fact be linked at least in part, to the failure to survey and map the land initially (Areola, 1986). Most colonial powers after the war established topographic mapping, soil survey and land resource survey units in the colonies. In Britain, for instance, the Directorate of Overseas Surveys was created in 1946 to provide geodetic control and to map the colonial empire (Warren, 1969). According to Warren, by 1969 the Directorate had published maps, mostly to the scale of 1:50,000, covering more than 4.5 million square kilometers, over thirty different commonwealth countries throughout the world. According to Areola, the aerial photography was often obtained through special contacts with British firms specializing in aerial surveys, including Hunting Surveys and Aero Films Limited. The Land Resource, Division of the Directorate has been particularly active in Africa and other parts of the tropics. It has carried out land system mapping and land resource evaluation using aerial photographs in parts of Nigeria, the Gambia, Kenya, Malawi, Lesotho, Ethiopia, Zambia, Botswana, Tanzania, and the Seychelles. According to Areola (1986), in the French territories in Africa, many agricultural and soil survey organizations were very active under the general direction of the French Office de la Recherche Scientifique et Technique Outremer (ORSTOM). In the Congo, the Belgian Institut National pour L'Etude Agrnomique au Congo (INEAC) was the main survey organization. The United Nations Food and Agricultural Organization, sometimes in association with the United Nations Educational and Scientific Organization, have also applied aerial photographic interpretation techniques in soil, land use and land evaluation surveys in different parts of Africa.

As observed in the literature there is gross underutilization of aerial photo-interpretation techniques in Africa (Areola, 1986). According to Areola, inspite of the fairly wide coverage of aerial photography in Africa, aerial photo-interpretation techniques are not fully integrated into the routine data gathering system in many countries. This according to him is perhaps, because aerial photo-interpretation is still generally regarded as a highly specialized technique meant for the use of only a small group of specialists in the field. Areola also notes that aerial photo-interpretation is not taught in most schools and colleges. Among other reasons mentioned by him as being responsible for the gross underutilization of aerial photo-interpretation techniques in Africa include the prevailing high cost of aerial photographs and that aerial photographs are not made readily available for general use by the survey departments – the restriction on the circulation of aerial photographs being ostensibly for security reasons (Areola, 1986).

In an attempt at building remote sensing capabilities in Nigeria, in 1993, the National Agency for Science and Engineering Infrastructure (NASENI) set up a committee to formulate a National Space Science and Technology Policy for the country. The policy recommended among other things the creation of centres of excellence for the development of space science and technology; and the enhancement of the capabilities of institutions offering space related courses of study in the country. In 1999, the National Space Research and Development Agency (NASRDA) was established to pursue the development and application of space science and technology for the socio-economic benefits of the nation. In 2001, the government approved the National Space Policy and Programmes to serve as, roadmaps for transforming Nigeria from the status of a consumer nation to an active participant in space technology and allied fields. The objective of the National Space Policy and Programmes was to make space research and development activities part of the overall strategies for sustainable national development. The main thrust of the National Space Policy and Programmes were: development of human resources and capacity building in various areas of space science and technology; to develop and build competence in space technologies of direct relevance to national development; to develop strategies and space applications; to undertake national resource management; defence, national security and law enforcement; study of the earth environment; communication and information; education and training; provide support for universities and other academic institutions in space related research and development projects; promote private sector participation in the space industry; promote international cooperation. In order to achieve these, six centres were created to act as the operational limbs of the National Space Research and Development Agency (NASRDA). These NASRDA centres are:

a. Centre for Satellite Technology Development (CSTD): this centre has the primary focus on satellite technology development with indigenous critical mass of engineers and scientists in all rudiments of satellites technology – building, launching, telemetry, tracking and control of all kinds of satellites such as earth observation, communication, weather, scientific research, etc.

b. National Centre for Remote Sensing (NCRS): this centre is charged with the sole responsibility of harmonizing research and development in space science and technology application for sustainable socio-economic development in the country.

c. Centre for Space Science and Technology Education (CSSTE): this centre is affiliated to the United Nations African Regional Centre for Space Science. Its main function is to develop curriculum, skills and knowledge of university educators, research scientists and train other professionals and personnel in applications of satellite remote sensing, meteorology, communication and geographic information system to sustainable development.

d. Centre for Space Transport and Propulsion: this centre focuses on rapid advances in the science and technology of rocketry, which are the main transportation vehicles.

e. Centre for Geodesy and Geodynamics (CGG): this centre was established to facilitate capacity for geodetic surveying and mapping, as well as monitoring of coastal deformation and subsidence due to excessive oil and gas exploitation, floods and global mean sea level rise and other related seismic and geodynamic phenomena including implementation of international agreements with respect to satellite laser ranging (SLR), very long baseline interferometry (VLBI) and cooperative international GPS network.

f. Centre for Basic Space Science (CBSS): the centre is mandated to provide a sound education, research and knowledge in basic space science, astronomy/astrophysics, rocketry and balloons, geomagnetism, etc as well as designing and fabricating appropriate systems and instrumentations and telescopes.

To date, five satellites have been launched by the Nigerian government into outer space, one of these satellite was a failure. The NigeriaSat-1 (first satellite), NigeriaSat-2 (third satellite) and NigeriaSat-X (fourth satellite) were for world-wide Disaster Monitoring Constellation (DMC). The objectives of the satellites include: to give early warning signals of environmental disaster; to help detect and control desertification in the northern part of Nigeria; to assist in demographic planning; to establish the relationship between malaria vectors and the environment that breeds malaria and to give early warning signals on future outbreaks of meningitis using remote sensing technology; to provide the technology needed to bring education to all parts of the country through distant learning; and to aid in conflict resolution and border disputes by mapping out state and international borders. NigComSat-1 is the Nigerian second satellite ordered and built in China in 2004, was Africa's first communication satellite. It failed in orbit after running out of power and was replaced by NigComSat-1R (fifth satellite). Table 2 shows the description of Nigeria satellite.

4. Research Findings and Discussion

Table 3 shows the year of publication of the articles, number of the authors and percentage. This table shows that 7.8% of the articles are published in 2009, 10.4% are published in 2010, 19.5% are published in 2011, 28.6% are published in 2012 and 33.7% are published in 2013. This shows an increase in the publication on remote sensing in Nigeria. Number of authors publishing on remote sensing shows similar pattern. The percentages of authors in 2009 is 4.2%, in 2010, it is 14.5%, in 2011 it is 21.7%, in 2012 and 2013 it is 26.5% and 33.1% respectively. This observation of increasing trend in the volume of remote sensing publications and researchers in Nigeria is an indication of healthy development and suggest a growing interest in remote sensing in Nigeria. This suggests a future bright prospect for remote sensing and GIS business in Nigeria.

In remote sensing, there are diverse research areas, topics and topic applications. All these diverse areas of research can be broadly divided into two which are method development and analysis/application. The articles used in the study are sorted into these two broad areas of research. It is observed that all the seventy-seven articles focus on analysis/application and none of the article focus on method development (Table 4).

Table 2. Description of Nigeria satellite

Satellite	Description
NigeriaSat-1	Microsatllite for earth observations, the NigeriaSat-1 was the first Nigerian satellite and built by a United Kingdom based satellite technology company, Surrey Space Technology Limited (SSTL ltd) under the Nigerian government sponsorship for $30 million. The satellite was launched by Kosmos-3M rocket from Russian Plesetsk spaceport on 27th September 2003. NigeriaSat-1 was part of the world-wide disaster monitoring constellation system. It has 100kg mass and carries an optical imaging payload developed by SSTL to provide 32m ground resolution with an exceptionally wide swath width of over 640km. The payload uses green, red and near infrared bands equivalent to landsat TM+ bands 2, 3 and 4. Images are stored in a 1-gigabyte solid-state data recorder and returned via an 8-Mbit/s S-band downlink. NigeriaSat-1 can image scenes as large as 640 x 560 km, providing unparalleled wide-area, medium-resolution data. It has a revisit period of 3-5 days. The design lifespan was 5 years. As at 2009, total Scenes = 3,757 Scenes, data requests: government – 2,037 requests, private – 1,225 requests.
NigeriaSat-2	NigeriaSat-2 is the third satellite, with 300 kg mass was built as a high resolution earth satellite by SSTL for DMC system. It has 2.5-metre resolution panchromatic (very high resolution), 5-metre multispectral (high resolution, NIR red, green and red bands), and 32-metre multispectral (medium resolution, NIR red, green and red bands) antennas.
NigeriaSat-X	NigeriaSat-X is the fourth satellite. NigeriaSat-X is based on the SSTL-100 and is developed by SSTL in association with a team of Nigerian trainee engineers at SSTL's facilities in England under their supervision. The key features of the NigeriaSat-X include: 22 m next generation imager with improved resolutions and optics over the same swath areas as DMC+, Swath of 600 km @ 8 bit, High rate X-band downlink set to 20 Mbit/s, Low rate S-band at 8 Mbit/s, 2 x 2 GByte data recorders. The NigeriaSat-X sensor provide 22 m multi-spectral (R, G, NIR) imagery. The data volume is estimated to be a handful of images per day. The onboard storage is different between NigeriaSat-X and NigeriaSat-2; NigeriaSat-X uses SSDRs (Solid State Data Recorders), while NigeriaSat-2 uses HSDRs (High Speed Data Recorders).
NigComSat-1	A Geostationary Satellite, NigComSat-1, built in China in 2004, was Nigeria' second satellite and Africa's first communication satellite. It was launched on 14th May 2007, aboard a Chinese Long March 3B carrier rocket, from the Xichang Satellite Launch Centre in China. It was over 5 Tons Wet Mass. It was based on the Chinese DFH-4 satellite bus, and carries a variety of transponders: 4 C-band; 14 Ku-band; 8 Ka-band; and 2 L-band. It was designed to provide coverage to many parts of Africa and Middle East, and the Ka-band transponders would also cover Italy. It has a lifespan of 15 years. NigComSat-1 failed in orbit after running out of power due to an anomaly in its solar array. On 10th November 2008 (0900 GMT), the satellite was reportedly switched off for analysis and to avoid a possible collision with other satellites. The satellite was a total loss.
NigComSat-IR	NigComSat-IR replaces the lost NigComSat-1, launched by China on 19th December 2011 with no cost to Nigeria.

Source: Mohammed (2010), Wikipedia Encyclopedia accessed: 21/10/2013; eoPortalDirectory https://directory.eoportal.org/web/eoportal/satellite-missions/n/nigeriasat-x accessed 11/12/2013

Table 3. Year of the publication of the articles used in the study, number of authors and percentage

Year of the publication	No (n=77)	%	Number of Authors (n=166)	%
2009	6	7.8	7	4.2
2010	8	10.4	24	14.5
2011	15	19.5	36	21.7
2012	22	28.6	44	26.5
2013	26	33.7	55	33.1

Table 4. Broad areas of research

Broad Areas of research	No. (n=77)	%
Analysis/Application	77	100.0
Method Development	0	0.0

Observation from the literature show that there has been low scientific research output contribution from African countries. In East African countries, in the field of GIS and remote sensing, the greatest knowledge, skill and productivity gap identified is developer that is, remote sensing and GIS method development (Simons, 2013). It is also observed from a concept note of a recent workshop on "expanding and sustaining excellence in doctoral programmes in Sub-Saharan Africa: what needs to be done?" organized by South Africa's National Research Foundation and the Carnegie Corporation of New York held in South Africa that while rapidly expanding economies elsewhere had more than doubled their rates of scientific publication in the past decades, Sub-Saharan Africa contributed only 0.7% to World scientific output and this percentage was decreasing and only three countries in Africa – South Africa, Egypt and Nigeria – produced three quarters of Africa's output (McGregor, 2013).

When these articles are further sorted into broad areas of topic (Table 5) and topic applications (Table 6), three broad areas of topics are identified which are land use/land cover, socioeconomic and disaster management, while nine topic applications are identified which are change detection/use and cover patterns, damage assessment/vulnerability, population, urban and regional planning, agriculture, health, geology, climatology and energy. Majority of the researches are on land use/land cover (87.0%) followed by disaster management (7.8%) and socioeconomic (5.2%). Also most of the topic applications are on change detection/use and cover patterns (42.9%) followed by urban and regional planning (18.2%), geology (11.9%), damage assessment/vulnerability (9.0%), agriculture (7.8%), climatology (6.5%), population (1.3%), health (1.3%), and energy (1.3%) in that order.

Table 5. Broad topics

Broad Topics	No (n=77)	%
Land use/land cover	67	87.0
Socioeconomic	4	5.2
Disaster Management	6	7.8

Table 6. Broad topic applications

Broad topics applications	No (n=77)	%
Change detection/use and cover patterns	33	42.9
Damage assessment/vulnerability	7	9.0
Population	1	1.3
Urban and regional planning	14	18.2
Agriculture	6	7.8
Health	1	1.3
Geology	9	11.7
Climatology	5	6.5
Energy	1	1.3

Table 7 shows the remote sensing and GIS software used by the researchers. The table shows that ILWIS software was the most used software (35.4%), ArcGIS 9 software (19.5%), Arcview 3 software (18.3%), Idrisi software (13.4%), Erdas Imagine Software (8.5%), ArcGIS 10 software (2.4%), and ENVI software (2.4%). In some of the articles more than one type of software were used (that is why the total frequency number of software used is 82) while in 19.5% of the articles, the software used was not mentioned.

Table 7. Remote sensing and GIS software used by the authors

Software used	No. (n=82)	%
ILWIS	29	35.4
Arcview 3	15	18.3
ArcGIS 9	16	19.5
ArcGIS 10	2	2.4
ERDAS IMAGINE	7	8.5
Idrisi	11	13.4
ENVI	2	2.4
Did not mention the software used (n=77)	15	19.5

Table 8 shows that the sources of images used by the researchers are from diverse sources prominent among which are Global Land Cover Facility (GLCF) of the University of Maryland, Maryland, USA (18.5%); Google Earth (18.5%); National Space Research and Development (NASRDA) Abuja, Nigeria (16.7%); and National Centre for Remote Sensing (NCRS) Jos, Nigeria (13.0%).

Table 8. Sources of satellite images used by the authors

Sources of satellite images used	No (n=54)	%
United States National Aeronautical and Space Administration (NASA)	3	5.6
National Centre for Remote Sensing, Jos, Nigeria	7	13.0
Global Land Cover Facility (GLCF) of the University of Maryland, Maryland, USA	10	18.5
National Space Research and Development (NARSDA), Abuja, Nigeria	9	16.7
Google Earth imagery	10	18.5
www.digitalglobe.com	2	3.7
Institute of Food Security, Environmental resources and Agricultural Research (IFSERAR), University of Agriculture, Abeokuta (UNAAB)	1	1.9
National Population Commission of Nigeria	1	1.9
Ministry of Agriculture and Rural Development, Federal Department of Forestry (FORMECU), Nigeria	4	7.4
Regional Centre for Training in Aerospace Surveys, (RECTAS) Obafemi Awolowo University, Ile-Ife, Nigeria	2	3.7
Department of Geography, Ahmadu Bello University, Zaria	1	1.9
Department of Geography, Obafemi Awolowo University, Ile-Ife	1	1.9
United States Geological Survey EROS Data Centre	2	3.7
National Emergency Management Agency (NEMA)	1	1.9

Tables 9, 10 and 11 show the department of the researchers, institutional affiliation of the researchers and the type of the university institution of the researchers. Table 9 show that majority of the researchers are from Department of Geography/ Geography and Environmental Management/ Geography and Planning/Geographic Information System (47.0%), followed by those from Research Institutes/Agencies/Centres (12.1%), Department of Urban and Regional Planning (9.0%), Department of Geology and Mineral Sciences/Applied Geology/Earth Science/Geoscience (9.0%), Department of Environmental Management/Environmental Management &

Toxicology (4.8%), Department of Surveying and Geoinformatics (4.8%), and Department of Physics and Solar Energy/ Pure and Applied Physics (2.4%).

Table 9. Department of researchers

Departments	No (n=166)*	%
Department of Urban and Regional Planning	15	9.0
Department of Geography/ Geography and Environmental Management/ Geography and Planning/ Department of Geographic Information System	78	47.0
Department of Environmental Management/ Environmental Management & Toxicology	8	4.8
Department of Surveying and Geoinformatics	8	4.8
Department of Geology and Mineral Sciences /Department of Applied Geology/ Earth Science/Geoscience	15	9.0
Department of Physics and Solar Energy/ Pure and Applied Physics	4	2.4
Research Institutes/Agencies/Centres	20	12.1
Others	18	10.8

* Number of the authors.

Table 10 show that majority of the researchers are from University institution (81.3%), followed by those from Research institutes/Agencies/Centres (12.1%), and Polytechnic institution (1.8%).

Table 10. Types of Institutional affiliation of the authors

Types of Institution	No (n=166)*	%
University	135	81.3
Polytechnic	3	1.8
College of Education	0	0.0
Research Institute/Agences/Centres	20	12.1
Others	8	4.8

* Number of the authors.

Table 11 show that most of the researchers are from Federal universities (45.0%), followed by those from State universities (26.3%), and then private universities (9.8%). The table further shows that 25.6% of the total universities in Nigeria featured out of which 14.0% are Federal universities, 7.8% are State universities and 3.9% are private universities.

Table 12 shows the research coverage area, publication numbers and percentage as well as some of the major findings from the remote sensing images. Appendix 1 shows the list of the articles by research coverage area, year of publication and the name of the author(s). Table 12 shows that the highest percentages of researches are on South West area of Nigeria (24.7%) followed by researches on North Central area of Nigeria (22.1%), North West area (19.5%), South South (Niger Delta) area of Nigeria (16.9%), North East area of Nigeria (7.8%) and South East area of Nigeria (6.5%). South west area of Nigeria comprises of the following states Lagos, Ogun, Oyo, Osun, Ondo, and Ekiti states. In the South West area of Nigeria, findings from the images revealed a steady decline in forest area and the expansion in farmlands, fallow ground and built up/residential areas. North Central area of Nigeria comprises of the following states Kwara, Kogi, Plateau, Nassarawa, Benue, Niger and Federal Capital Territory (FCT). In the North Central area of Nigeria, findings from the images revealed that while the built-up area increased, vegetation cover decreased at an alarming rate. Urbanization process is observed to be responsible for land use/land cover change. North West area of Nigeria comprises of the following states Sokoto, Zamfara, Kebbi, Kaduna, Katsina, Kano and Jigawa states. In the North West area of Nigeria, findings from the images revealed significant rapid growth in city/residential land use while the vegetation is diminished. Open spaces constituted the most extensive type of land use/land cover. Cultivated land is also observed to be decreasing. South South area of Nigeria comprises of the following states Edo, Delta, Rivers, Bayelsa, Cross River and Akwa-Ibom states. In the South South and the Niger Delta areas in general, findings from the images show high rate of land use/land cover change. Oil spill area is increasing, area covered by mangrove forest is declining, and urban land use is increasing in area extent. Determinants of forest dynamics are observed to include the variations in state forest management policies and the influence of the oil and gas industry on the economies of the states. North East area of Nigeria comprises of the following states Taraba, Adamawa, Borno, Yobe, Bauchi and Gombe States. In the North East area of Nigeria, findings from the images show increase in built up areas/land areas put under man's use and decrease in woodlands the only natural vegetation cover in the area. Factors observed to be responsible for land use/land cover change include extensive agriculture, animal grazing, intensive agriculture, tree crop farming, irrigation agriculture, wood cutting, bush burning and road construction. South East area of Nigeria comprises of the following states Anambra, Enugu, Ebonyi, Imo and Abia states. In the South East area, findings from the images show that high forest and agricultural land has been decreasing, built-up area has been increasing.

Table 11. Type of university institution affiliation of researchers

Type of University Institution affiliation of Researchers	Number of University Institution affiliation of Researchers by type	% of the total number of such Institution in Nigeria	% of the total number of University in Nigeria (n=129)*	Total % of the University in Nigeria (n=129)*
Federal University (n=40)*	18	45.0	14.0	
State University (n=38)*	10	26.3	7.8	25.6
Private University (n=51)*	5	9.8	3.9	

*The source of this figure is from National University Commission of Nigeria web site.

Table 12. Publications by research coverage area and some of the major findings from the remote sensing images

Research coverage area	Publication Numbers	% (n=77)	Some of the major findings from the remote sensing images
South South	13	16.9	Findings from the images show high rate of land use/land cover change. Oil spill area is increasing, area covered by mangrove forest is declining, and urban land use is increasing in area extent.
South West	19	24.7	Findings from the images revealed a steady decline in forest area and land use intensification with the expansion in farmlands, fallow ground and built up/residential areas.
South East	5	6.5	Findings from the images show that high forest and agricultural land has been decreasing, built-up area has been increasing.
North Central	17	22.1	Some of the major findings from the images revealed that while the built-up area increased, vegetation cover decreased at an alarming rate.
North West	15	19.5	Some of the major findings from the images revealed significant rapid growth in city/residential land use while the vegetation is diminished. Open spaces constituted the most extensive type of land use/land cover. Cultivated land is also observed to be decreasing.
North East	6	7.8	Some of the major findings from the images show increase in built up areas/land areas put under man's use and decrease in woodlands the only natural vegetation cover in the area.
Others	2	2.6	

5. Summary, Policy Implications and Conclusion

This study examined remote sensing education, research and utilization challenges in Nigeria. It is observed in the study that there have been an increasing numbers of researchers and publications on remote sensing in Nigeria. This is an indication of healthy development and suggests a growing interest in remote sensing in Nigeria. This also suggests a bright future prospect for remote sensing and GIS business in Nigeria. The study shows among other things that most of the remote sensing researches in Nigeria are on analysis/applications, most of the broad research topics are on land use/land cover, most of the broad topics applications are on change detection/use and cover pattern, most used remote sensing and GIS software is ILWIS followed by ArcGIS 9, Arcview 3, Idrisi, Erdas Imagine, ArcGIS 10, and ENVI. Sources of images used are from diverse sources prominent among which are Global Land Cover Facility (GLCF) of the University of Maryland, Maryland, USA, Google Earth, National Space Research and Development (NASRDA) Abuja, Nigeria, and National Centre for Remote Sensing (NCRS) Jos, Nigeria in that order. The study reveals that majority of the researchers are from Department of Geography/Geography and Environmental Management/Geography and Planning/ Geographic Information System, majority of the researchers are from university institutions and especially Federal universities. The study reveals that few university institutions in Nigeria featured out of which most are Federal universities. The study show that the highest percentages of researches are on South West area of Nigeria followed by researches on North Central area of Nigeria, North West area, South South (Niger Delta) area of Nigeria, North East area of Nigeria and South East area of Nigeria. Among the findings from the remote sensing images include high rate of land use/land cover change, steady decline in vegetation areas, and increasing area extent of built-up areas. Findings of this study show that there is the need to encourage and promote indigenous technology, industries and firms particularly on remote sensing and GIS method development. To achieve this, there is the need to strengthen the research capabilities of educational institutions and research centres/agencies in Nigeria. Research laboratories and libraries in various educational institutions should be equipped with state of the art research equipments and adequate funds should be provided for the maintenance of the research laboratories and for training and re-training of staff.

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Appendix

Appendix 1. List of the articles by area of coverage, year of publication and name of the author(s)

S/N	RESEARCH COVERAGE	RESEARCH TITLE	YEAR PUBLISHED	AUTHOR(S)
1	Niger Delta	Remote sensing and geographic information techniques: veritable tools for land degradation assessment	2012	Abbas, I. I., & Fasona, M. J.
2	Niger Delta	An assessment of land use/land cover changes in a section of Niger Delta, Nigeria.	2012	Abbas, I. I.
3	Niger Delta	Application of remote sensing (RS) and Geographic Information Systems (GIS) to Environmental Impact Assessment (EIA) for sustainable development.	2009	Abbas, I. I., & Ukoje, J. A.
4	Niger Delta	Trends in vegetation cover changes in Bonny area of the Niger Delta.	2013	Akuro, A.
5	South South	An assessment of the threats to global warming in Akwa Ibom State, Nigeria.	2013	Ekpenyong Etim Robert
6	Niger Delta	An Assessment of Recent Changes in the Niger Delta Coastline Using Satellite Imagery	2010	Jimmy, O. A., Mofoluso, F., Godstime J., and Ganiyu, A., Ologunorisa, T. E.
7	Niger Delta	Landuse and Landcover Change Analysis Using Satellite Remote Sensing: A case Study of the Upper Niger Delta Region of Rivers State, Nigeria.	2013	Monte, J. & Farhan, A.
8	South South	Spatial image data mining using K-Means analysis: a case study of Uyo Capital City, Nigeria.	2013	Ndehedehe Christopher, Ogunlade Simeon and Akwaowo Ekpa
9	South South	An integrated remote sensing and GIS approach in monitoring urban expansion in Benin City, Nigeria.	2013	Ogunbodede Emman Funmilayo and Balogun Toju Francis
10	South South	Interpretation of structural features based on Nigeriasat1 imagery of Benin City and its environ.	2012	Okereke, C. N., Nwagbara, J., Onyekuru S., Okoro, R., Chinemelu, E. S.
11	South South	Analysis of the rate of change of Mangrove Forest Ecosystem in Calabar South, Nigeria.	2013	Okpilya, F. I., Effiong, E. B., & Udida, A. A.
12	Niger Delta	Forest transition in an ecologically important region: patterns and causes for landscape dynamics in the Niger Delta.	2011	Onojeghuo, O. Alex & C. Alan Blacburn
13	South South	An assessment of the physical impact of oil spillage using GIS and Remote Sensing technologies: Empirical evidence from Jesse town, Delta State, Nigeria.	2013	Oyinloye, M. A., & Olamiju, O. I.
14	South West	Disposal sites and transport route selection using geographic information system and remote sensing in Abeokuta, Nigeria.	2012	Achi, H. A., Adeofun, C. O., Ufoegbune, G. C., Gbadebo, A. M., & Oyedepo, J. A.

15	South West	Geospatial analysis of deforestation and land use dynamics in a region of Southwestern Nigeria	2012	Adeoye, N. O., Abegunde, A. A., & Adeyinka, S.
16	South West	Assessment of deforestation, biodiversity loss and the associated factors: case study of Ijesa-Ekiti of Southwestern Nigeria	2011	Adeoye, N. O., & Ayeni, B.
17	South West	An assessment of the growth of Ile-Ife, Osun State Nigeria, Using Multi-Temporal Imageries.	2013	Ajala, O.,A., & Olayiwola, A. M.
18	South West	Fracture distribution within Bowen University permanent site and its hydrogeologic implication.	2013	Alagbe, O. A., Sunmonu, L. A., & Adabanija, M. A.
19	South West	Tectono-Hydrological Study of Akure Metropolis, Southwestern Nigeria.	2012	Anifowose, A. Y. B., & Kolawole, F.
20	South West	Waste disposal site selection using remote sensing and GIS: A study of Akure and its environs, Southwest-Nigeria.	2011	Anifowose ,Y. B., Omole, K. E., & Akingbade, O.
21	South West	Spatial analysis of soil fertility estimates and NDVI in south-western Nigeria: a new paradigm for routine soil fertility mapping.	2013	Fabiyi, O. O., Ige-Olumide, O., & Fabiyi, A. O.
22	South West	Spatial and social dimensions of post conflict urban reconstruction programme in south-western Nigeria: The case of Ile-Ife, Nigeria.	2012	Fabiyi, O., Thontteh O. E., & Borisade, P.
23	South West	Delineation of groundwater potential zones in the crystalline basement terrain of SW-Nigeria: an integrated GIS and remote sensing approach.	2013	Fashae, A. Oluwatoyin, Moshood, N. Tijani, Abel, O. Talabi & Oluwatola I. Adedeji
24	South West	Impact of climate change on sea level rise in Lagos, Nigeria.	2011	Fashae Adeola Olutoyin and Olumide David Onafeso
25	South West	A Study of Land Degradation Pattern in the Mahin Mud-beach Coast of Southwest Nigeria with Spatial-statistical Modelling Geostatistics.	2011	Mayowa F., Ademola O. & Alabi S.
26	South West	Developing natural resources database with Nigeriasat-1 satellite data and geographical information systems.	2012	Ogunbadewa Yemi Ebenezer
27	South West	Resultant land use and land cover change from oil spillage using remote sensing and GIS.	2013	Omodanisi E.O.
28	South West	Urban expansion and urban land use in Ado Ekiti, Nigeria.	2013	Oriye Olusegun
29	South West	Geospatial analysis of urban growth – The case of Akure, Nigeria.	2013	Oyinloye M.A.
30	South West	Analysis of Landuse, Landcover change and urban expansion in Akure, Nigeria.	2011	Oyinloye M.A. and Kufoniyi O.
31	South West	Status of flood vulnerability area in an ungauged basin, southwest Nigeria.	2013	Sobowale A. and Oyedepo J.A.
32	South West	The application of remote sensing and geographic (GIS) information system for monitoring deforestation in Southwestern Nigeria.	2012	Yohanna P., Innocent R., and Emmanuel B.

33	South East	Application of Geographic Information System in Mapping of Groundwater Quality for Michael Okpara University of Agriculture Umudike and its Environs, Southeastern Nigeria.	2012	Akaninyene O.A. and Magnus U.I.
34	South East	The role of satellite remote sensing data and GIS in population census and management in Nigeria: A case study of an enumeration areas in Enugu, Nigeria.	2009	Chijioke G.E.
35	South East	Changing Pattern of Land Use in the Calabar River Catchment, Southeastern Nigeria.	2011	Efiong J.
36	South East	Detection and Mapping of Land Use and Land Cover Classes of a Developing City in Southeastern Region of Nigeria, using Multi-band Digital Remotely-sensed Data.	2010	Njoku J.D., Ebe T.E., and Pat-Mbano E.C.
37	South East	Detecting changes in landuse/cover of Umuahia, South-Eastern Nigeria using remote sensing and GIS technique.	2011	Ujoh, F., Ifatimehin, O. O., & Baba, A. N.
38	North Central	Characterization of Structural Composition and Diversity of Vegetation in the Kpashimi Forest Reserve, Niger State, Nigeria.	2013	Abdullahi, J., & Idris, A. J.
39	North Central	Monitoring urban sprawl in the Federal Capital Territory of Nigeria using remote sensing and GIS techniques	2013	Ade, M. A., & Afolabi, Y. D.
40	North Central	Spatio-Temporal Analysis of Land Use/Cover Change of Lokoja – A Confluence Town.	2012	Adeoye, N. O.
41	North Central	Geological investigation of Tagwai Dams using remote sensing technique, Minna Niger State, Nigeria.	2012	Akinrinmade, A. O., Ibrahim, K. O., & Abdurrahman, A.
42	North Central	Urban sprawl, pattern and measurement in Lokoja, Nigeria	2009	Alabi, M. O.
43	North Central	Spatial Growth Assessment with Remote Sensing Data for Central Nigeria.	2011	Alaci, D. S. A., Amujabi, F. A., Baba A.N., & Daniel, O.
44	North Central	Remote sensing and GIS assessment of flood vulnerability of Nigeria's confluence town.	2012	Dukiya, J. J.
45	North Central	GIS Analysis of Peri-Urban Agricultural Land Encroachment in (FCT), Nigeria.	2013	Etim, N. E., & Dukiya, J. J.
46	North Central	An analysis of temperature variations using remote sensing approach in Lokoja Area, Nigeria.	2010	Ifatimehin, O. O., Ishaya, S., & Fanan, U.
47	North Central	Application of Remote Sensing and GIS Techniques in Mapping Fadama Farming Areas in a part of Abuja, Nigeria.	2009	Ishaya, S., & Ifatimehin, O. O.
48	North Central	Using Remote Sensing Data to Improve Rice Production in Kutigi, Niger State, Nigeria.	2012	Jibril, M., & Yunusa, M. B.
49	North Central	Geospatial techniques for the assessment and analysis of flood risk along the Niger-Benue basin in Nigeria.	2013	Nkeki Felix Ndidi, Philip John Henah and Vincent Nduka Ojeh

50	North Central	Agricultural land use in sub-urban Lafia of Nasarawa State, Nigeria.	2013	Nuhu Zainab and Ahmed M.
51	North Central	Geospatial application in mapping gully erosion sites in Jos, Plateau State, Nigeria.	2013	Ogwuche Jonathan and Bulus Joshua
52	North Central	Structural analysis the ropp complex, North Central Nigeria, using magnetic anomaly and Landsat ETM imagery.	2012	Olasehinde A., Ashano E.C., & Singh, G. P.
53	North Central	Applications of geographic information system and remote sensing in road monitoring in Minna and environs, Nigeria.	2013	Onuigbo, I. C., & Orisakwe, K. U.
54	North Central	Urban Expansion and Vegetal Cover Loss in and around Nigeria's Federal Capital City.	2011	Ujoh F.1, Kwabe I. D. & Ifatimehin O.O.
55	North West	Application of remote sensing and geographic information system in parcel mapping for irrigation farm scheme in Pampaida millennium village, Ikara, Kaduna State, Nigeria.	2012	Abbas, I. I., & Anger, R. T.
56	North West	Green area mapping of Ahmadu Bello University main Campus, Zaria, Nigeria using remote sensing (RS) and geographic information system (GIS) techniques.	2012	Abbas, I. I., & Arigbede, Y. A.
57	North West	Sustainable land management in Zaria using remote sensing and GIS techniques.	2011	Abbas, I. I., & Arigbede, Y. A.
58	North West	Mapping land use-land cover ad change detection in Kafur Local Government, Kastina, Nigeria (1995-2008) using remote sensing and GIS.	2010	Abbas, I. I., Muazu, K. M., & Ukoje, J. A.
59	North West	Analysis of land use/land cover changes to monitor urban sprawl in Keffi-Nigeria	2012	Abubakar Mahmud and Anjide Simon Achide
60	North West	Assessment of Revised Universal Soil Loss Equation (RUSLE) in Katsina Area, Katsina State of Nigeria using Remote Sensing (RS) and Geographic Information System (GIS).	2010	Adediji, A., Tukur, A. M., & Adepoju, K. A.
61	North West	Mapping the spatial distribution of Rabies in Kaduna State, Nigeria (1999-2009) using geographic information system technology.	2012	Asabe, A. D., & Abbas, I. I.
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74	North East	Application of remote sensing and geographic information system (GIS) in revising township map: a case study of Mubi metropolis, Adamawa State, Nigeria.	2011	Yohanna, P., & Nuhu, H. T.
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