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Environmental Challenges with a Focus to Vegetation and Hydro-Ecological Vulnerability in Nigeria: Why Earth Observation Research and Education Matter?

Sa'ad Ibrahim[1]
[1]Department of Geography
Adamu Augie College of Education
PMB 1012, Argungu, Kebbi State, Nigeria

Abstract:- Despite recent development in Earth observation technology, in Nigeria, the vulnerability of environmental resources in the natural ecosystems aggravated by man-induced environmental transformations and climate change have been a subject of concern among scientists and policy makers. The country is still facing enormous challenges in the area of environmental protection which is prompting the need for the development of a strong internal capacities in Earth observation. The effects of deforestation, land degradation, hydro-ecological dynamics, their temporal repeatability and magnitude, for example, require an effective evaluation through accurate analyses that would provide evidence-based information that is urgently needed otherwise the goal of environmental protection and sustainability will remain elusive. In Nigeria, specifically, the vegetation and hydro-ecological vulnerability couple with lack of appropriate technology for policy implementation resulted to change in microclimate, endanger wildlife, flooding, food insecurity, soil erosion, drought and conflict between herders and farmers. These developments have heightened the needs for a paradigm shift in research and education in Earth observation to encourage biodiversity mapping, environmental monitoring and sustainability. This paper reviews the short-coming of the environmental policies with specific reference to vegetation and water resource development in the context of vulnerability assessments and the potential application of remote sensing. The paper also highlights the challenges facing remote sensing/ Earth observation research and education in Nigeria and therefore proffer numerous recommendations to address those challenges.

Keywords:- *Earth observation; Remote sensing; Vulnerability; Vegetation; Hydrology; Education; Research; Environment; Policy; Nigeria.*

I. INTRODUCTION

Vegetation and water resources are becoming vulnerable due climate change and human activities such as logging, the clearing of natural vegetation for agriculture, irrigation and degradation of marginal semi-arid to arid ecosystems by excessive grazing or cultivation (Chen, Huang, Wang, & Li, 2018; Y. Z. Ibrahim, Balzter, & Kaduk, 2018; Ippolito, Sala, Faber, & Vighi, 2010; Smith et al., 2014). Hence, the vulnerability assessments in spatial and temporal magnitude is very useful to resource managers, policy makers and environmentalists for changing land use decisions. There have been trends to consider ecological vulnerability by the International Biological Program (IBP) in the 1960s, the Man and the Biosphere Program (MAB) in the 1970s, and the International Geosphere-Biosphere Program (IGBP) starting in the 1980s (Hong et al., 2016). Moreover, the United Nation Summit held in Rio de Janeiro (1992), UN Framework Convention for Climate Change (UNFCCC, 1992), Kyoto Protocol (KP- UNFCCC 1992) and programme on Reducing Emission from Deforestation and Degradation (REDD) have also emphasized on measures against climate change, deforestation, global warming and carbon emission (Andersson, Evans, & Richards, 2008; Dam, 1999; Putz, Sist, Fredericksen, & Dykstra, 2008). More recently, Earth observation for biodiversity and ecosystem assessment is one of the key areas identified by Group on Earth observation, an intergovernmental organization (Nigeria is a member country) working to improve the availability, access and use of Earth observations for the benefit of society.

While People are worried about how to control the pristine nature of the environment to ensure continued existence of human lives and biodiversity, current understanding of the extent and rate of vegetation change and water availability on ecosystems, is largely inadequate(Rogan, 2006). For a good political acceptance and proper implementation of climate policies to manage environmental resources, there is the strong need for resolution of scientific challenges (Gibbs, Brown, Niles, & Foley, 2007). One of the most critical elements in understanding climate is the proper assessment ecological vulnerability (Le Toan et al., 2004). Although, traditional methods (e.g. field surveying) of assessing ecosystems vulnerability yield accurate results, they are very expensive and impractical to monitor large and inaccessible areas. To overcome these limitations, the remote sensing scientists have since embraced analytical measures to detect, characterize, parameterize and monitor land variables using space observations. The past forty years have seen increasingly rapid advances in the field of Earth observation/remote sensing. Remote sensing collects data across different regions of electromagnetic spectrum at wide temporal (e.g. the Landsat programme/missions- for over 40 years) and spatial scales (e.g. the recent Copernicus programme/Sentinel missions- which provides data down to 10 m). The use remote sensing in vulnerability studies, is

therefore, an intriguing option not only for policy makers to make a wise decision about our environment but also to enrich the methodological system of ecosystem vulnerability assessment (Hong, et al., 2016; Peter, 2004).

In Nigeria, for example, despite recent development in technology, the vulnerability of environmental resources in the natural ecosystems aggravated by man-induced environmental transformations has been a subject of concern among scientists and policy makers. However, the country not yet established strong internal Earth observation capacities to overcome its environmental challenges. The effects of deforestation, land degradation, hydro-ecological dynamics, their temporal repeatability and magnitude therefore require an effective evaluation through accurate analyses that would provide evidence-based information which is urgently needed otherwise the goal of environmental protection and sustainability will remain elusive. For example, current population explosion in Nigeria is leading to pressing pressures on the available resources particularly on land (e.g. deforestation) due to extreme poverty, demand for food, shelter and development of agro-industries. Yet, a systematic quantitative assessment of landscape response at the country level is still lacking. The lack of frequently-updated monitoring and forecasting systems (e.g. fires, drought, flood warning) such those from the Earth observation (remote sensing), only shows how stakeholders are unprepared for catastrophes.

The recent developments in Earth observation have heightened the needs for research and education in this field to encourage biodiversity mapping and environmental monitoring. So far, the relevance of Earth observation is well recognized by the scientific community as a valuable instrument for disaster management and vulnerability assessments. Earth observation data offer unparalleled opportunity for time series analysis and forecasting of ecosystem processes. The effects of deforestation, land degradation, hydro-ecological dynamics and their temporal repeatability and magnitude can be evaluated and predicted in the context of environmental change and vulnerability to help policy makers to design and implement mitigation options for environmental protection and sustainability. Haacka and Ryerson (2016) who discuss the challenges and strategies for improving and facilitating remote sensing research and education in developing countries (Haack & Ryerson, 2016). Drawing on an extensive range of sources, the authors set out the different ways in which developing countries can advance research and education in the field of remote sensing. This paper is specific to Nigeria as one of the developing countries. The paper reviews the short-coming of the environmental policies with specific reference to vegetation and water resource development, the concept of vulnerability, the potential application of remote sensing to vulnerability assessments and what needs to done by the government of Nigeria in the area of remote sensing education and research so as to minimize challenges in environmental protection and disaster management.

II. ECOSYSTEM VULNERABILITY

Vulnerability is a dynamic and context-specific (Beroya-Eitner, 2016; Oppenheimer M, 2014). Oppenheimer et al. (Oppenheimer M, 2014) defined vulnerability as the "propensity or predisposition to be adversely affected. It encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt". Vulnerability is the set of properties of an ecosystem that determine its potential for being damaged by a specific stressor (Ippolito, et al., 2010). Hong et al. (Hong, et al., 2016)explained that sensitivity, responsiveness, resilience, and adaptive capacity are the major components of vulnerability. This indicates a need for a more holistic approach if an environmental problem is being addressed in the context of change and vulnerability.

Villa and McLeod (Villa & McLeod, 2002) pointed a theoretical framework through which an ecological research gap could be addressed. These are: (1) a vulnerability model, the components and their mutual dependencies of which are identified in terms of properties that can be associated to indicators; (2) a system model that defines a way to map system characteristics onto the identified components of vulnerability; and (3) a mathematical model for use in the aggregation of information defined by the system model into a hierarchically organized set of indicators (Beroya-Eitner, 2016). Although, ecosystem vulnerability is a significant challenge to environmental change and protection, there have been few empirical investigations on its application to ecosystems (Beroya-Eitner, 2016; Weißhuhn, Müller, & Wiggering, 2018). In Africa, for instance, there is still a significant communication gap (in terms of policy making and its implementation) between the ecologists and policy makers (Lawal & Ibrahim, 2015). To communicate the results of the vulnerability research to other researchers, policy-makers, and the community at large, Weißhuhn et al. (2018)emphasized that it is important to provide spatially explicit map of vulnerability distributions such that hotspot areas that may require attention are easily identified (Weißhuhn, et al., 2018). For example, the spatial distribution of vegetation disturbance, the duration and frequency of the disturbance. Satellite remote sensing assessment of vulnerability is therefore useful due its consistency and repeatability at a wide spatial scale (at local, regional or global scale).

A. Remote of Vegetation Change and Vulnerability

The rapid development of remote sensing, over the past few decades has seen increased in data acquisition for landscape characterization from regional to global scales. Remote sensing data are acquired from airborne and space-borne sensors, from multispectral sensors to hyperspectral, at different wavelengths from visible to microwave, and at a range of spatial and temporal scales (Xie, Sha, & Yu, 2008). This study provides an exciting opportunity for large area measurement, time series analysis to assess vegetation change and susceptibility of ecosystem to disasters (Ustin & Gamon, 2010).

Large spatiotemporal information on the vegetation composition of a landscape can reveal ecological processes leading to vegetation fluctuation and succession to assess ecosystem vulnerability to environmental change (S. a. Ibrahim, Balzter, Tansey, Tsutsumida, & Mathieu, 2018). Verbesselt et al., (Verbesselt, Hyndman, Newnham, & Culvenor, 2010)identified three forms of changes in an ecosystem: (i) seasonal change which is mainly determine by annual rainfall and temperature (ii) gradual change occurring mainly due to inter-annual climate variability and land management (iii) and abrupt change usually due disturbances (e.g. fires, floods, deforestation etc.). Difficulties arise, however, when an attempt is made to study vegetation change or vulnerability using remote sensing data mostly due to differences in sensor characteristics (e.g. spatial resolution, sensor viewing geometry), cloud cover or signal contamination and habitat type. Trade-offs therefore exist for these datasets in terms of their applicability and usage (Thomas Lillesand, Ralph W. Kiefer, & Chipman, 2015). Despite the limitations of remote sensing data for vegetation assessments, studies on the assessments of vegetation change and vulnerability have been widely published (Balzter et al., 2007; Propastin, Fotso, & Kappas, 2010; Smith, et al., 2014).

There are different approaches used in remote sensing for vegetation change and vulnerability assessments. Liu et al. (Liu, Liu, & Yin, 2013) studied the global pattern of NDVI while making attempt to find out the impact of precipitation extremes to vegetation which could capture the vulnerability of ecosystems. Results contradict the hypothesis that vegetation in water-limited semi-arid and semi-humid regions might be adapted to drought. The study suggests that more attention should be paid to precipitation-induced vegetation changes than to temperature-induced events. However, the influence of environmental drivers of vegetation change in savannah ecosystems is context dependent (Levick & Rogers, 2011). Propastin et al. (Propastin, et al., 2010) investigated the vulnerability of vegetation over Africa to El-Nin˜o Southern Oscillation (ENSO) events for the period 1982-2006 using the moving window statistical correlation analysis technique. The sensitivity of vegetation to ENSO events were assessed using Normalized Difference Vegetation Index (NDVI) data from Advanced Very High-Resolution Radiometer (AVHRR) and ENSO indices. Results indicated that the vulnerability of vegetation in Africa depends to a large extent on the vegetation type. The grassland, closed shrubland and woodland exhibit the largest share of areas with both moderate and high vulnerability based on their assessment. The evergreen broadleaved forest and deciduous broadleaved forest areas were significantly less affected than the other land cover types during the study period 1982–2006. Overall, there seems to be some evidence to indicate that savannah ecosystems are more susceptible to environmental change than other ecosystems.

B. Remote Sensing of Hydrological Dynamics and Vulnerability Assessments

Hydro-ecological dynamics resulting due to anthropogenic or natural factors (such as non-extreme precipitation) can have a strong effect on ecosystems, agriculture and resource management. The implications to resilience of ecosystems and for agriculture and water resource planning are more severe where the rate of change exceeds the adaptive capacity, this makes environment susceptible to collapse (Roque-Malo & Kumar, 2017). While there is the need to study hydrological dynamics, it is important to note that such phenomena can be very hard to document probably due to lack of data, monitoring sites and intricate nature of the underlying forces. Remote sensing offers opportunities to explore, for example, river systems using RADAR, multispectral, hyper spectral, and LiDAR data (Bizzi, Demarchi, Grabowski, Weissteiner, & Van de Bund, 2016). Stampoulis et al. (Stampoulis et al., 2016) assessed the hydro-ecological vulnerability using microwave radiometric measurements from WindSat. They highlight the spatial patterns and characterized the inter-relations among the three hydrologic variables, as well as the sensitivity and resilience of vegetation water content and soil moisture, derived from WindSat.

III. ENVIRONMENTAL POLICIES ON LAND USE/CONSERVATION AND WATER RESOURCES DEVELOPMENT IN NIGERIA

To manage and control the widespread environmental degradation, since 1915, Nigeria is formulating and reviewing environmental protection policies (e.g. Environmental Impact Assessment Act of 1992 and National Environmental Standards Regulation Agency (NESREA) Act 2007) to ensure sustainable development ((NESREA), 2017; Akamabe & Kpae, 2017; Eneh & Agbazue, 2011). Threat to environmental sustainability is captured in the call to secure the quality of environment adequate for good health and well-being, to conserve and use the environment and natural resources for the benefit of present and future generations and restore, maintain and enhance the ecosystems and ecological processes essential for the functioning of the biosphere to preserve biological diversity. Strategies for implementations are directed to all sectors of the economy and problem areas of the environment. Most important areas in this context are the land use/conservation and water resources development. For land use, the strategies should encourage among others the compilation of detailed land capability inventories, comprehensive land classifications, assessment of the current land use practices, causes and extent of land degradation and regulatory framework for sustainable land use. In water resource management, the policy encouraged among others the consideration of the impacts of climate change on water resources, environmental impact studies of water resources development, and comprehensive inventory of national water resources and application of appropriate analysis and prediction techniques capable of minimizing the impacts of natural disasters((NESREA), 2017).

However, despite this policy development in Nigeria, little effort is made towards environmental protection and management (Eneh & Agbazue, 2011). Akamabe and Kpae (Akamabe & Kpae, 2017) emphasized that the major drawback in the policy guidelines is the lack of appropriate technology for implementation. For instance, agricultural yields and irrigation requirements can be affected by changes in precipitation. Roque-Malo and Kumar (2017) observed that " If precipitation magnitude is unchanged but precipitation events last longer and are less intense and more frequent, the effect on agricultural management could be different than if precipitation fell in shorter but more intense and infrequent bouts" Today, in many parts of Nigeria (e.g. Kebbi State), we are experiencing massive deforestation and changes in precipitation extremes couple with depletion in the amount of water available to rivers and streams leading to extreme hydrologic conditions posing severe implications to food security, environment and economic development.

It was reported that out of the 415 designated grazing reserves in Nigeria, only few are officially gazette. Most of the federal and the states are illegally farmed on or built on. Previous researchers have drawn the attention of policy makers on the status of protected areas and environmental sustainability. Environmentalists estimated that Nigeria loses about 3000 ha of vegetation per year through bush-burning, tree-felling, and desertification. It was also estimated that about 96 % of the pristine forests of the country have been cut down in the past four decades. It was pointed out that government de-reservation of protected areas is one of the major problems affecting the sustainability of protected areas. Several projects in the country have led to massive deforestation in the country. For example, the Ajaokuta forest reserve in Kogi State lost about 18,390 ha for the Steel Development Company.

In the area of space policy, the country has developed some capacities through the National Space Research and Development Act which establishes the National Space Research and Development Agency (NASRDA) and the National Space Council. So far, the NASRDA embarks on a multi-institution strategy by established six space centers in the country. These are:

- The Centre for Basic Space Science and Astronomy
- The National Centre for Remote Sensing
- The Centre for Satellite Technology Development
- The Centre for Geodesy and Geodynamics
- The African Regional Centre for Space and Technology Education
- The Centre for Space Transport & Propulsion

Despite progress on space policy, several authors lamented that much need to be done (Asiyanbola, 2014; Peter, 2004). This because little is known on the extent of resource vulnerability and it is not clear what factors are responsible for these processes. A well-developed system which could tract the devastating consequences of human activities and natural hazards to ecosystems, socioeconomic and political structure of the society is not in place yet. It is annoying that the country has no even a single land use/cover map despite recent development in Earth observation and remote sensing. Advances in Earth observation have improved reliable remote sensing measurements to study environmental change and vulnerability. For proper implementation of this policy guidelines, science and technology become the integral part. Information and data could be used by scientists and decision makers to support environmental technological research. The application of remote sensing can address some of these gaps by assessing the vulnerability of vegetation and hydrological dynamics using Earth observation data.

IV. CHALLENGES FACING REMOTE SENSING/OBSERVATION RESEARCH AND EDUCATION IN NIGERIA

- Development in Earth observation research and education require an effective scientific knowledge in remote sensing data such as microwave (e.g. synthetic aperture radar such as the recent Sentinel-1 sensor launched by the European Space Agency (ESA) and optical sensing (e.g. airborne LiDAR; passive multispectral such as Landsat (from the joint (National Aeronautics and Space Administration)/USGS (United State Geological Survey), the spatial and radiometric resolutions of the data. The state-of-the-art techniques in remote sensing data analytics (e.g. model development/validation of EO products, machine learning algorithms and big data analytics) is also necessary for image processing. Asiyanbola (2014) who explored the state of remote sensing education and research based on published work by Nigerians from 2009 to 2013, discusses that the few researchers who conducted research in the area of remote sensing do not only concentrated in the narrowest of geographical regions, but also a greater proportion studied land cover change. A recent study have emphasized on the need for a paradigm shift from change detection to monitoring with remote sensing (Woodcock, Loveland, Herold, & Bauer, 2019). Asiyanbola (2014) observed that only very few research were conducted in the area of environmental monitoring (e.g. vulnerability assessments and risk reduction). Out of the total 166 papers examined, only 3 were published by the staff in Polytechnics and none by the Colleges of Education in Nigeria (Asiyanbola, 2014). There is lack of sufficient expertise needed to prepare and effectively utilize the

remote sensing data. However, the African Regional Centre for Space Science and Technology Education in English (ARCSSTE-E), which was established as a result of the efforts of the Programme on Space Applications (PSA) of the United Nations Office for Outer Space Affairs (UNOOSA), is making tremendous contribution to remote sensing education in Africa (Agbaje G, Alabi O, & E., 2019).

- NASRDA as one of the most important space agencies in the country is still facing funding issues. Although the Nigerian government have invested hugely for this agency and part of the expectation were that agency would generate its own revenues by now, NASRDA is still clamouring for funding to executive research projects.
- Remote sensing data have already exceeded petabytes scales. Data accessibility/download in most developing countries is therefore difficult to researchers and students. This is simply due to poor data infrastructural facilities such internet access, hardware and software. The size of remote sensing data of a typical small study are may run into 100s of Megabytes. This makes it difficult for our researchers to download even the freely available data.
- The significant cost of materials needed to store and process Earth observation data. Remote sensing data and software are significantly costly. In Nigeria, therefore, researchers with interests in remote sensing application struggle to conduct research because of the particular structure of the data and its requirements.
- Most government agencies in Nigeria, whose mandate has strongly link to environmental management and socio-economic development lacked a section Earth observation and personnel with relevant expertise in this field. They do not know what Earth observation application can do to help to address some of their challenges.

V. RECOMMENDATIONS

It is apparent that Earth observation research and education in Nigeria is facing myriad challenges. The following suggestions are offered to address some of the challenges:

- Remote sensing education in the country require a complete overhaul.
- The current curriculum for university undergraduate and postgraduate students should be updated to encompass the practical based approach for problem solving. The curriculum design should involve local universities, professional in the industry and the foreign nationals. strategize and understand that there is need for change of paradigm
- University management should encourage postgraduate programmes (MSc., PhD) in remote sensing where the courses are not presently being offered.
- Institutions of higher learning in the country need to collaborate with the industries especially international companies who manufacture the software, hardware and other material needed for teaching and research in remote sensing.
- Institutions of higher learning where remote sensing is being offered should be well-equipped with state of the art research equipment. and adequate funds should be provided
- There should be adequate funding for training and re-training of staff.
- Teaching staff in the higher learning need to by embracing aspects of Earth' observation where programmes and use of open-source where is possible. This will help to cut cost and reduce heavy reliance on commercialized software.
- Postgraduate diploma should be encouraged to motivate people with background in computing, land surveying, environmental management etc. to embrace remote sensing applications.
- There is the need to introduce remote sensing education in colleges of education in the country.
- To provide scholarship for students to study courses in remote sensing abroad. The scholars should be bonded to make sure they return after the completion of their programmes. There should be provision to automatically employ the scholar on their return.
- There is need for the management of universities and colleges to cover the cost of software and hardware which are needed in Earth observation teaching and research.
- There is need for government to be proactive on space technology and investments so that the country can reap the benefits of its investment. There should be adequate funding for the existing research agencies, especially the ones with the sole responsibility for research in the area of space technology so that government can benefit from the available human resources in these institutions. There is need for a pragmatic approach in this direction.

- Satellite observation data from the Nigeriasat-1 and 2 should be made free available to students and researchers in Nigeria
- Environmental agencies (e.g. NESREA) should collaborate with the universities' (and other tertiary institutions of learning) departments of remote sensing, geography, environmental, science, and engineering among other.
- National Earth observation center should be established with the designated centers in some the universities in the country. This center should be saddle with the responsibility to champion the Earth observation for biodiversity assessment programmes mainly designed to improve biodiversity assessment and conservation
- State government should encourage Earth observation research by establishing local centers and funding to ensure research projects are carried and subsequent research outcome are truly implemented.
- The federal and state governments should provide budgetary allocations to environmental agencies under them so that they can fund projects through collaboration with the higher institution of learning and other non-governmental organizations to enable them to accomplish their policy targets.
- There should be a registered national society for Earth observation that could serve as a medium through which researchers can collaborate and network through conference, seminars and presentations.
- There should be a section of Earth observation under scientific services of each of the federal and state national parks. This section should be responsible for the monitoring changes driven by natural and anthropogenic disturbances affecting the park's biodiversity using space and field observations.
- Most biodiversity laws available for this country were formulated during the pre-colonial period. There is need for the amendment of these laws to help the country to keep pace with the recent environmental management challenges.
- Water resources monitoring is one the most challenging aspects of water management in the country. This probably due to lack of data, monitoring sites around rivers, lakes, and oceans. The Nigerian Meteorological Agencies should create more sites for ground data collection around watershed areas.

VI. CONCLUSION

In this study, the environmental challenges with a focus to vegetation and hydro-Ecological vulnerability in Nigeria was reviewed. It was revealed major drawback in the policy guidelines, in Nigeria, is the lack of appropriate technology for implementation. For example, facing remote sensing/observation research and education in Nigeria is currently facing significant challenges. The relevance of Earth Observation Research and Education was emphasized as tool for addressing vegetation and hydro-ecological vulnerability. The study therefore, proffer numerous recommendations to address those challenges.

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