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Prospects of satellite–Enhanced Forest Monitoring for Nigeria.

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Abstract— Comprehensive and effective forest monitoring for efficient forest management requires adequate information and accurate estimate on forest cover. In spite of the significance of forests and forestry sector to Nigerians and Nigeria's economy, reliable database that gives accurate extent and quality of forest resources in the country is seemingly not available due to the techniques used in creating the database, and other salient factors. This result in various estimates for forest size and quality, which are characterized by uncertainty and inconsistencies in literature. Consequently, the goal of this paper is to review the prospects of satellite–based forest monitoring for Nigeria. Selected issues were addressed including the significance of forest monitoring for Nigeria, status of forest resources in Nigeria, and current advancement in satellite–based forest monitoring. The review indicates that, deforestation and forest degradation is apparent in Nigeria, and that the subsisting management strategy is rudimentary at best. Of course, the traditional approach of forest monitoring is no longer sufficient to serve the urgent demand of forest information users. Hence, satellite remote sensing application in forestry for Nigeria is justifiable.

Keywords— Forest, LULC, Management, Monitoring, Nigeria, Remote sensing, Satellite Imageries.

1 Introduction

Forest ecosystems are very important habitats in terms of the biological diversity they contain, and ecological functions they serve. They are multi–functional ecosystems, providing material and intangible services such as carbon sinks, enhanced regional biodiversity, environmental services, and forest–based economies [1]. The large number of organisms that forests contain helps to sustain many environmental functions upon which humanity is dependent [2]. However, pressures on forest, especially in the tropical world, to provide economic resources have been increasing rapidly as a consequence of burgeoning population in the region [3]. In Nigeria for instance, there is an increasing pressure on the land resources basically as a result of the spike in the population rate as well as the economic problem that arises when every individual tries to secure the greatest benefit from the resource at the expense of others; a concept known as the "Tragedy of the Common" [4]. The level of deterioration of forest resources is a factor of uncoordinated land–use policy and other forms of land–use such as agriculture, grazing, industrialization, urbanization and water management leading to formation of deserts, bare surfaces and general environmental degradation [5].

Nigeria is richly endowed with abundant forest resources [6] as a result of its variable climatic conditions and physical features [7]. Yet, both naturally and anthropogenically motivated factors have manifestly caused unprecedented transformation in its forest biomass and a concomitant alteration in the ecosystem and ecological process in recent decades. In spite of the importance of forests and forestry sector to Nigerians and the economy, reliable database that gives accurate extent of forest in the country is not presently available, and therefore, various estimates for forest size exist in literature [8]. Beside the insufficiency of information on spatiotemporal extent or quantity of Nigerian forests, comprehensive information about its quality on temporal basis is equally lacking. For the gains from forest resources to be sustained for times to come, then our forest has to be guided diligently in order to avoid excessive and unauthorized exploitation of forest resources, thus ensuring that its conservation must be balanced [4].

Effective management of forest resources involving, policies and planning, prioritization, valuation, efficient investments, and accountability is a function of information and monitoring systems for the forest sector. Of course, monitoring systems rely on adequate Landuse/Land–cover information (LULC) [9]; thus, data on land–use change are of value to planners in monitoring the consequences of changes occurring within the region [10]. Information on LULC and also vegetation changes is the basis on which the past and present human interactions and the impacts of such interactions with the natural resources and the environment can be understood [11]. Lack of adequate information on forest resources, and appropriate monitoring system especially in the tropical region impedes proper forest management. Although a number of forest inventories have been carried out in tropical forests, there re-

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main large areas in the tropics where such inventories are out of date, incomplete, or entirely lacking [12]. Monitoring forests from the space– or airborne platforms can provide relevant information quickly, as well as repeatedly and at regular intervals of time [13]. The growing accessibility to multi–resolution and mult–isource remotely sensed data result in the rise in proficiency to derive timely and accurate maps of forest configuration. Therefore, the goal of this paper is to review the prospects of satellite–based forest monitoring for Nigeria.

2 Significance of Forest monitoring for aNigeria

As environmental degradation and its consequences come clearly into focus, we are faced with the prospect that the non–renewable forest resources may be exhausted and that the nation stands a greater risk of destroying her environment if appropriate measures are not taken to checkmate the pressure and impact of deforestation [4]. Forest in broad and tropical forest in particular is important at both global and local levels, in providing many benefits to nature and humans. It harbours salient potentialities that are economically, socially, financially, nutritionally and medically beneficial to man [14]. By sequestering and storing atmospheric carbon, global forests occupy a significant spot in the global carbon cycle and in balancing atmospheric greenhouse gases, thereby, regulating the Earth's climate. Similarly, Nigeria's forests provide critical environmental services, ranging from water protection to climate moderation [15]. The Nigerian Federal Ministry of Agriculture and Natural Resources submitted that: forest is an important source of re–investible capital and a source of income, and serves as a foundation for industrialisation and enhances the stability of the rural population [16]. Summarily, forest provides habitats to diverse animal species; they form the source of livelihood especially for the rural people [17]. Efforts in forest conservation and environmental management are therefore crucial to Nigeria's economy especially at this time when the nation has seen the need to diversify to other sectors; basically the agricultural sector and this is due to the downturn in the oil sector which has been the major source of revenue for the nation [4].

In Nigeria, studies and experiences have shown that the major factors contributing to deforestation and forest degradation are logging, removal of forest for developmental purposes such as infrastructures like road, among others, and conversion of forestland to small–scale permanent agriculture, with investment in large–scale agriculture also predicted to become a major contributor in the future [8]. Trees are seen as obstacles to development and their removal is viewed as the first stage in development, hence deforestation has prominently become one of the most important environmental issues of the century [11]. Consequentially, the process of deforestation leads to annihilation of carbon sources, which in turn enable the release of stored carbon into the atmosphere, depending in part on how much of the biomass or wood is damaged. Of course, deforestation and forest degradation is recognised as a serious factor responsible for a significant percentage of global greenhouse gas emissions.

According to Houghton [12], knowing the spatial distribution of forest biomass is important for at least two reasons. First, a knowledge of biomass is required for calculating the sources (and sinks) of carbon that result from converting a forest to cleared land (and vice versa). While average biomass values have been used in most calculations of carbon flux to date, the possibility that deforestation occurs in forests with biomass that is significantly different from the average, suggests that linking specific locations of disturbance with geographically specific estimates of biomass would improve estimates of flux. What is the biomass of the forests actually deforested? A second reason to know the spatial distribution of biomass is to enable measurement of change through time. Furthermore, reliable information on global trends in forest area is of great help to international agencies, governments, non–governmental organizations and the commercial sector when they make decisions on policies and investment, and to scientists whose research also informs these decisions [18]. This information responds to a pressing need for scientific research and support for policy formulation and implementation at national and international levels–in particular, the United Nations Framework Convention on Climate Change (UNFCCC) process for the Reduction of Emissions from Deforestation and Forest Degradation (REDD+) and the protection of habitat for biodiversity conservation, as defined in the Convention on Biodiversity [19].

3 Status of Forest Resources in Nigeria

The distribution of forest in Nigeria spreads from the rainforest zone in the south and decreases in density and structure as one moves up north which is predominantly of savannah nature characterized by grasses and sparsely populated tree cover [17]. Regrettably, Nigeria has one of the world's highest rates of deforestation of primary forests, where more than 50% of such forests have been lost in the past decades through unsustainable logging, agriculture, as well as fuel wood collection" [4] . The progressive decline in the country's forest cover over the last three decades pose the utmost intimidation to the conservation of its wild biotic resources, as it continue to experience loss of natural habitats [7]. Though, various assessments demonstrate that the Nigeria's forest is diminishing in extent and quality, the rate of degeneration and current extent and quality of the country's forest is seemingly unpredictable. The reason for this is perhaps due to inconsistencies and in most cases, contradicting data that subsist. For instance, one record indicates that Nigeria land mass is 910,770 km^2, out of which the forest occupies 110,890 km^2 which represents 12.8% of the total land mass [4], while another shows that the land mass of Nigeria is 997,936 km^2, and that only 10% is under forest reserve [20], [21]. Also an account claimed that Nigeria, once in the heart of the tropical rainforest belt, has lost about 95% of her total forest cover and now has to import 75% of the timber she needs for her own purposes [8]. Nigeria is presently losing about 351,000 square kilometres of its landmass to the desert, which is advancing southward at the rate of 0.6 kilometres annually [5].

Nigeria's forest cover in 2000 was estimated at 13.5 million hectares compared to 17.5 million hectares in 1990, indicating a forest cover loss of close to 400 thousand hectares per annum, or a decline of about 2.6% [4]. Between 2000 and 2004, the country lost 55.7% of its primary forests, and the rate of forest change increased by 3.12% per annum [4]. Also, a report by UN–REDD shows a range from 3.5 to 3.7% per annum, translating to a loss of 350,000– 400,000 hectares of forest land per annum, and a loss of 21% of the global estimate [21]. Nigeria loses 139067Ha of forest area yearly, from the period 1990 – 2005. This means that Nigeria has lost 35.7% of her forest cover [4]. It also means that Nigeria's total forest cover as of 2005 was 7130227Ha [4]. Projecting at the same rate, Nigeria's forest cover by the year 2020 will only be 4584735.961Ha, which represents 4.963% of her entire landmass, and this suggests that unless something decisive is done, and urgently, the country will lose all her forest areas by the year 2052 [4]. The prevailing rate of deforestation has been suggested to be at 3.5% annually [22], [5] due to encroachments, excisions and outright de–reservations. Of course, forest area in the country has decreased from 14.9 million hectares in 1980 to 10.1 million hectares in 1990 and to 9.5 million hectares in 1996 [23].

4 Remote Sensing–enhanced forest Monitoring

The Information on forest biomass and alteration in flora is important for effective monitoring and management of physical changes that occur on forests. Forest managers require timely and accurate geospatial information on forest conditions and management practices at site specific and regional scales [24]. Generally, information about the alteration in landscape may be acquired by various means or techniques. Aerial photography and field surveys have been the traditional methods used in monitoring forest resources [9]. Yet, the information needs are not met entirely by traditional techniques because they were not practical or economically sound to devote more effort to human intensive mensuration activities [25]. Also, topographic maps are significant input in generating maps for monitoring and management of the wild habitats. Maps are information in graphic communication, and are very important in monitoring and management of natural and artificial resources. Such information should accurately reflect and record spatiotemporal reality. Unfortunately, the terrestrial landscape is constantly changing; such that, maps produced oftentimes do not match with the landscape dynamism. Hence, they become obsolete by the time the products are available, as recent features are not depicted. For this reason, map revision is inevitable in order to incorporate recent variations in the landscape. The traditional methods of map revision have numerous shortcomings that make them exorbitant for application in operational basis.

Remote sensing offers an important means of detecting and analysing spatiotemporal dynamics on geographical entity. Since the early 1970s, satellite data have been commonly used for detecting these changes over large landscapes [13]. Many studies have demonstrated the effectiveness of using remotely sensed data as a powerful tool to detect land–use change for critical environmental areas, vegetation dynamics and urban expansion [10]. Since the launching of the first earth–observing civilian Landsat satellite in 1972, satellite remote sensing has been used for gathering synoptic information on forests [26], and generally of the surface area of interest, thereby capturing the spatial variability in attributes of interest like tree height, crown closure, etc. [27]. Initially, remotely sensed data were used by cartographers and geographers to make forest maps based on digital spectral data without incorporating ground–based digital information such as topography and other important ancillary data. More recently, ecologists have joined the geographers in utilizing satellite technology for a variety of forest–related applications detecting landscape change over time, relating landscape patterns to biological or physical phenomena, evaluating physiological processes of forest canopies, and quantifying forest cover, biomass, or productivity over varying scales of spatial resolution [26]. Monitoring forests from the space–borne or air–borne platforms can provide relevant information quickly, as well as repeatedly and at regular intervals of time, resulting in swift and efficient change detection on forest cover. This is due to the effectiveness of space–borne and air–borne remote sensing platforms and sensors that facilitate observation of biophysical attributes over extensive areas at multiple spatial, spectral and temporal scales [28].

Remotely sensed data have in the past four decades steadily become invaluable information source for ecological characterization and survey [29]; eventually making remote sensing to form a significant fragment of most forest management scheme. The most common methods of forest monitoring using remote sensing are wall–to–wall mapping and sampling. Wall–to–wall mapping involve a technique with which the entire country or forest area is monitored. On the other hand, sampling approach is especially appropriate when deforestation is concentrated in some areas of a country or region. Nonetheless, both approaches does not eliminate each other: a sampling approach in one reporting period can be extended to wall–to–wall coverage in the subsequent period; similarly, wall–to–wall mapping in one reporting period can be followed up by hotspot analysis (stratified sampling) in the subsequent period.

Current trends in ecological studies have dictated the integration of remotely sensed digital spectral data into Geographic Information Systems (GIS) [26]. Ancillary data, such as topography, soil, road, and census data, may be combined with remotely sensed data to improve classification performance [30]. This merger has repositioned satellite spectral data beyond customary image processing and allows the use of remotely sensed spectral data in conjunction with ancillary data including elevation, slope aspect, vegetation type, and soils etc. The integration of image processing systems and multi–layered spectral data with GIS and digital geographic databases enables the development of more sophisticated models of landscape scale variables such as regional forest cover.

5 Current Advancement in Satellite–Based Forest Monitoring

As the problem of environmental change places the world in the middle of many crossroads, new frontiers of environment related knowledge continue to emerge in ways that advance new human passions and curiosities [4]. The advantages of remote sensing include the ability to obtain measurements from every location in the forest, the speed with which remotely sensed data can be collected and processed, the relatively low cost of many remote sensing data types, and the ability to collect data easily in areas which are difficult to access on the ground [31]. Satellite remote sensing has obviously had a generational advancement. For instance, the earliest Landsat Multisensor Scanner (MSS) has a spatial resolution of 80m, which was improved upon by Landsat Thematic Mapper (TM) with a spatial resolution of 30m.

The Nigerian satellite system, NigeriaSat–1 which has a spatial resolution of 32m is in the same category with Landsat TM. These types of images are suitable for studies involving geological formation, land–use and land–cover mapping, mapping effect of natural disasters, monitoring agricultural crop, forest monitoring, and a host of other important task covering extensive areas for human benefits. subsequent technological advancement in remote sensing has resulted in satellite imaging systems with enhanced resolutions and geometric properties, enabling finer features to be identified and analysed, as well as enhancing the mapping capabilities of the systems, thus, making them useful for many additional types of applications. For example, Landsat ETM+ and the French SPOT have resolutions of 15m and 10m respectively.

There are many sensors available with different characteristics of spectral, spatial, and temporal res olutions used for biomass estimation based on availability, efficiency and cost. Optical remote sensing, radar and light detection and ranging (LiDAR) sensors provide the three main sources of remotely sensed data for biomass estimation [27]. One of the most important developments in remote sensing technology in recent years has been the advent of hyperspectral remote sensing or imaging spectroscopy. Hperspectral remote sensing is the acquisition of images where for each spatial resolution element in the image, a spectra of energy arriving at the sensor is measured. These spectra are used to generate information based on the signature of the interaction of matter and energy expressed in the spectrum. Hypespectral sensors are capable of recording data in tens, or hundreds of wavelengths or spectra channel in a very narrow and contiguous nature. Hence they have been applied in diverse areas of interest including forestry, since they are capable of providing better–quality discrimination of forest cover and physiological attributes.

One major advance in remote sensing has been the increased availability of high–spatial– and high–spectral–resolution remote sensing imageries from an extensive continuum of sensors and platforms including photographic and digital cameras, video capture, and airborne and spaceborne satellite sensors. NigeriaSat–2 is in the second generation Disaster Monitoring Constellation (DMC), and contained a set of encouraging properties including a swath width of 300k for 32m Medium Resolution Imager (MRI), 20km for 2.5m panchromatic, and 5m multispectral GSD or Very High Resolution Imager (VHRI). Therefore, NigeriaSat–2 imagery has the capacity to provide improved discrimination of forest cover and physiological attributes, but are not yet widely utilised for forest monitoring. Similarly, the NigeriaSat–X has a host of attractive characteristics that allows its usage for enhanced forest cover assessment and other operations. Thus, the Nigerian satellite systems are highly reccomended for forest monitoring in Nigeria.

Current scientific advancement in remote sensing application in forestry has led to more reliable procedures for monitoring forest resources. Beside aerial photography, other systems such as radar, LiDAR, thermography and optical sensors, provide cost–effective methods of spatial data collection for forest monitoring and management. The two–dimensional (2–D) nature of optical remote sensing data confines its use to direct quantification of some vegetation features such as tree height, canopy height, and volume, etc whereas, the recent developments in airborne light detection and ranging (LiDAR) open a vista for measurements of topography and the three–dimensional structure of vegetation at high spatial resolution and throughout large areas. LiDAR has been used to provide estimates of forest biomass, height, and the vertical distribution of forest structure with unprecedented accuracy [32]. Also, Radar applications in forestry are used to penetrate the forest canopy to reveal characteristics of the forest fl oor.

6 Conclusion

Terrestrial ecosystem is frequently subjected to rapid conversion as a result of anthropogenic and natural effects. Deforestation and forest degradation has become a disturbing phenomenon in the recent past as they are responsible for significant threats on forests resources. The highest pressures on forest cover, especially in the tropical ecosystem results from deforestation, which is the gradual removal of forest cover. To fully appreciate the physical and human impact on forest cover, it is important that forest variations be detected and accurately quantified. This is because, comprehensive and effective forest monitoring for efficient forest management requires adequate information and accurate estimate on forest cover. Unfortunately, dependable database that gives accurate spatial extent and quality of forest resources on temporal basis in Nigeria is lacking. The traditional approach of forest monitoring which involve ground–based measurement is no longer sufficient to serve the urgent demand of forest information users. Hence, remote sensing application in forestry for Nigeria is tenable, because it embeds several pluses encompassing cost effectiveness, extensive spatial coverage, data availability and dissemination in time and regular manner. Furthermore, remote sensing is prominently effective in determining the areas from which forest product can be sustainably harvested for human needs, and ite effective abilities can be expoited in the enhanced mapping of forest cover with appropriate precision for forest management.

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