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Space Science Development in Nigeria and Emerging Possibilities for Sustainable Landuse Management

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Abstract

Space technology has been a major driving force behind rational and sustainable environmental management in the developed countries. However, access to affordable, real-time, and reliable space-derived data has been a major problem in most developing countries. After the articulation and approval of a space policy, Nigeria launched her first Earth Observation Satellite (EOS) in 2003 and this has offered new possibilities for environmental management in the country. This paper therefore demonstrates the importance of this development for sustainable environmental management in the country. The discussion in particular is focused on the relevance of space-derived historical data (such as land use, forestry, biomass stock etc) as essential variables for either climate change modeling and/or monitoring climatic variations on a continuous basis.

Introduction

Efforts at space science development dates back to the 5th Century B. C. when Socrates noted that "man must rise above the earth to the top of the atmosphere and beyond, for only thus will he fully understand the world in which he lives". The space age eventually began with the launch of the Soviet Union's Sputnik 1 on October 4, 1957. This 60 cm diameter sphere satellite weighed 83 kg, circled Earth once every 96 minutes and transmitted radio signals that could be received on Earth; providing the first space views of our planet's surface and atmosphere. This development was quickly followed by Explorer 1 that was launched by the United States on January 31, 1958 through the U.S. Army Ballistic Missile Agency using its Jupiter C rocket. Since then many remote sensing satellites have been launched. Today, the advent of space technologies has changed the way we live our lives and care for our environment (Agbaje, 2006).

Space science development has now given humanity a new perspective of Earth and resulted in a lot of scientific discoveries. With the advent of Earth Observation Satellites (EOS), which are satellites specifically designed to obtain data about the earth while in orbit, scientists now have the opportunity of rapid response with respect to disaster management and environmental monitoring. The technology can now be used for monitoring a wide range of natural and anthropogenic events such as, tsunamis, landslide, earthquake, forest fires, deforestation, flooding, oil spill, erosion and desertification. The focus of this paper is to examine the development of space science in Nigeria and discuss how it can be used for sustainable environmental management with a specific case study on the application of space technology for landuse management and the implications for climate change monitoring.

Development of space science in Nigeria

For a very long time, Nigeria was a consumer nation of space-derived products. This led to limited application of space technology for environmental management. This is partly due to the cost of the imagery required for such assessment, except where external funding for such exercise was available. But even if and where external funding was available, monitoring beyond the project era was a major problem. For sustainable environmental evaluation therefore, regular access to image data sources is a prerequisite. On May 5, 1999, the National Space Research and Development Agency was established with a broad objective of pursuing the development and application of space science and technology. This effort culminated in the launching of NigeriaSat-1 in 2003 and this constitutes a watershed of history; signifying a major scientific and technological achievement.

NigeriaSat-1 has 3 spectral bands namely; Green: 0.52-0.62µm, Red: 0.63-0.69µm and NIR: 0.76-0.9µm and a ground resolution of 32m. This satellite is in constellation with ALSAT-1 (owned by Algeria), BILSAT (belonging to Turkey), U.K-DMC and China-DMC+4. The revisit cycle is 3-5 days while the swath width is 600 km (Salami and Balogun, 2006). With NigeriaSat-1 currently in its orbit and NigeriaSat-2 being planned for 2009, as well as a Ground Receiving Station now operational in Abuja, the problem of availability of image data source for sustainable environmental monitoring seems to have been solved in the country.

NigeriaSat-1 has great potentials especially for environmental monitoring because its multi-spectral imagers are similar to SPOT HRV and bands 2, 3 and 4 of Landsat TM with an added advantage of better temporal resolution than either SPOT XS or Landsat TM. Table 1 provides a summary of some technical characteristics of NigeriaSat-1 in comparison with some other earth observation satellites. This reveals that NigeriaSat-1 has about 3 times the swath width of Landsat ETM+ and 10 ten times that of SPOT. The implication of this is that NigeriaSat-1 is expected to be highly effective for inventory as well as for rapid and timely assessment, monitoring and overall management of the environment.

Table 1: Comparison of Characteristics of NigeriaSat-1 with other EO Satellites

Satellite (Instrument)	Landsat ETM+	SPOT (HRV)	NigeriaSat-1 (DMC Imager)
Swath	185km	60km	600km
Typical Revisit	16 days	26 days	3 – 5 days
Spatial Resolution	30m	20m	32m
Spectral Resolution	0.45-12.5µm	0.5-0.89 µm	0.52-0.90µm
Pixels	6000	3000	19000

Source: Salami (2007).

Landuse and climatic situation in Nigeria

Climatic variability in Nigeria is governed by the atmospheric systems over the West Africa. These are Subtropical High Pressure Systems, Tropical Easterly Jet (TEJ), African Easterly Jet (AEJ), African Easterly Waves, the Monsoon systems, Intertropical Discontinuity (ITD) Surface, Hadley and Walker Circulation Systems and Desert and Ocean Influences. The components of the atmospheric circulation are affected by extensive bush burning (which introduce greenhouse gases into the atmosphere) and massive deforestation along the West African Coast (Balogun and Salami, 1995).

Nigeria is one of the countries with an extensive coverage of tropical rainforest. According to World Resources Institute (2003), forest/woodlands originally covered approximately 45% of the Nigerian landmass about 8000 years ago. By 2000, the tropical forest and woodlands had been reduced to about 15% of the country's landmass. On the global scale, the rate of tropical deforestation is not known with any accuracy, but is estimated by the Food and Agriculture Organization (FAO) as around 15.4 million ha per year. Its destruction has many serious long-term environmental implications and hence there is need for proper monitoring of this invaluable resource.

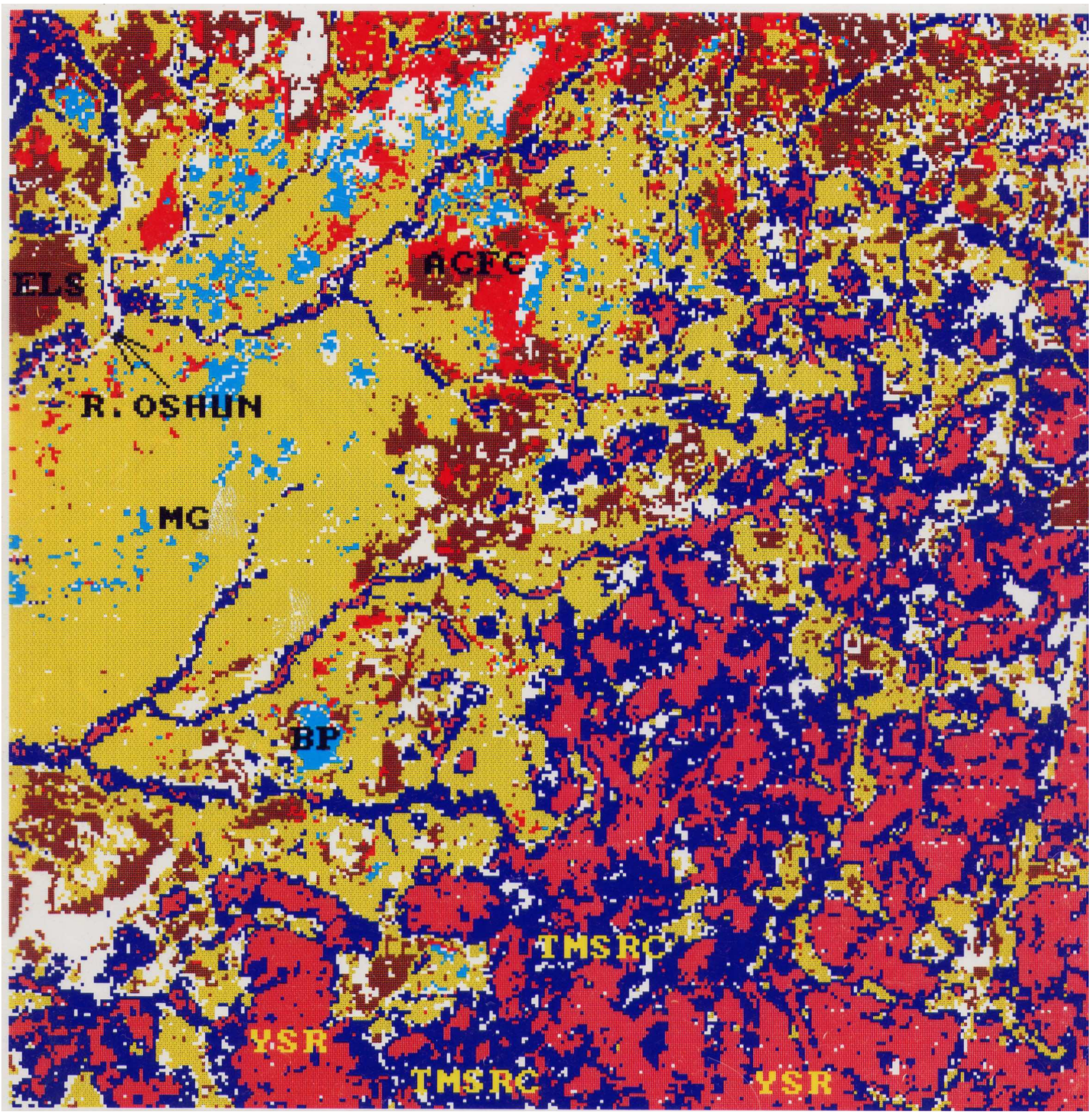
Several studies in Southern Nigeria have shown that areas previously characterized by a continuous cover of forest are being converted to secondary regrowth vegetation, mainly as a result of intermediate shifting cultivation and lumbering. Climatologists are of the opinion that the declining precipitation in the Sudan zone is caused by diminishing water transport of the monsoon (Fricke, 2004). It has been noted that decrease in precipitation in the Sahel and Sudan savanna zones of northern Nigeria is a result of disturbance of the atmospheric circulation south of them. Zheng and Eltahir (1998) submitted that about 60% of the water content in the clouds in the middle and northern Nigeria originates from evapotranspiration of the humid rainforest and the adjacent semi-humid rainforest. Meteorological records of Maiduguri (near Lake Chad) show over 20% decrease in precipitation between 1905 and 1995 and isohyets have shifted more than 100 km south of those for the period 1949-1961 (Fricke, 2004). This fits into the general picture of climate change in West Africa as discussed by Olajiran (1999) and Nicholson *et al.* (2000). The effect of deforestation is not only in terms of declining rainfall in the north, but the exposed surface arising from deforestation leads to increased run-off rate and reduced evapotranspiration in the south. This reduces the amount of water available for atmospheric circulation. The resulting increase in atmospheric dust prevents the rain-producing monsoonal winds from moving north of Nigeria.

There seems to be an increasing pressure on the tropical rainforest in Nigeria, just like in the rest of tropical Africa. For instance, a study by UNIFECS (1991) showed that fuel wood consumption, on average, accounts for over 50% of the total annual energy consumption in Nigeria. This places an additional stress on the forest apart from the pressure generated by cultivation and logging. The need for appropriate management of the forest estate is better appreciated when we consider the impact on the climatic variability. Deforestation is an important factor in climatic change via its influence on surface *albedo* and its disruption of the regional and global balance of carbon (Ward and Robinson, 1990). Akinbami *et al.* (1996) acknowledged that low level of water at Kainji and Jebba Power Stations is a major constraint in the supply of hydro-electric power in Nigeria and some later studies (Balogun and Salami, 1995; Adejuwon *et. al.*, 1990; Akinbami *et. al.*, 2003) have shown that deforestation plays a major role in such changes in water level. Adequate measures are therefore required to manage the remaining forest in a sustainable manner and this should be integrated into climate change programme for the country.

Nigeria has been actively involved in climate change issues. For instance, the country is involved in Clean Development Mechanism (CDM) and is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), which gives guidance for addressing the greenhouses gases (GHGs) in the atmosphere. However, attention has not been given to specific issues that could assist in climate change control and adaptation. For example, historical data on environmental parameters and anthropogenic activities such as land use, forestry, biomass stock etc that are essential variables are either available in an unorganized and uncoordinated format or not available at all. This is thus an area in which recent development in space science in Nigeria can be put into practical use. Adesina (2005) laments that forest destruction is going on unabated in Nigeria and it is difficult to believe that there is hardly any law protecting forest reserves in the country. The country at the moment relies on empirical information on the rates of deforestation provided by international organizations such as FAO and World Bank which are sometimes conflicting (depending on the source) and generally do not reflect the reality on ground.

Space technology and land cover mapping/monitoring

Adejuwon *et al.* (1990) reported that while there is need to monitor the landuse changes and assess the implications of the shift in boundaries of ecological zones on climate change, details of such significant changes are lacking. Reliable data base for such assessment and monitoring are simply not available. A case for the development of a geo-spatial framework for such monitoring is demonstrated by recent studies of forest-savanna boundary in Southwestern Nigeria (Salami 1999; 2000; Salami and Balogun, 2004). The studies assess landuse dynamics on the forest-savanna fringes between 1963 and 2003, using remotely sensed data and supervised classification of the multi-temporal images (see Table 2 and Figures 1 and 2).



TMSRC: Tree Crop/Mature Secondary Regrowth **BP:** Burnt Patches
YSR: Young Secondary Regrowth **ACFC:** Arable Cropland/Fallow Complex
MG: Mixed Grassland **ELS:** Exposed Land/Settlement
Figure 1: Supervised Classification of Forest-Savanna Boundary in Southwestern Nigeria from Landsat TM (1991)
Source: Salami, 2000.

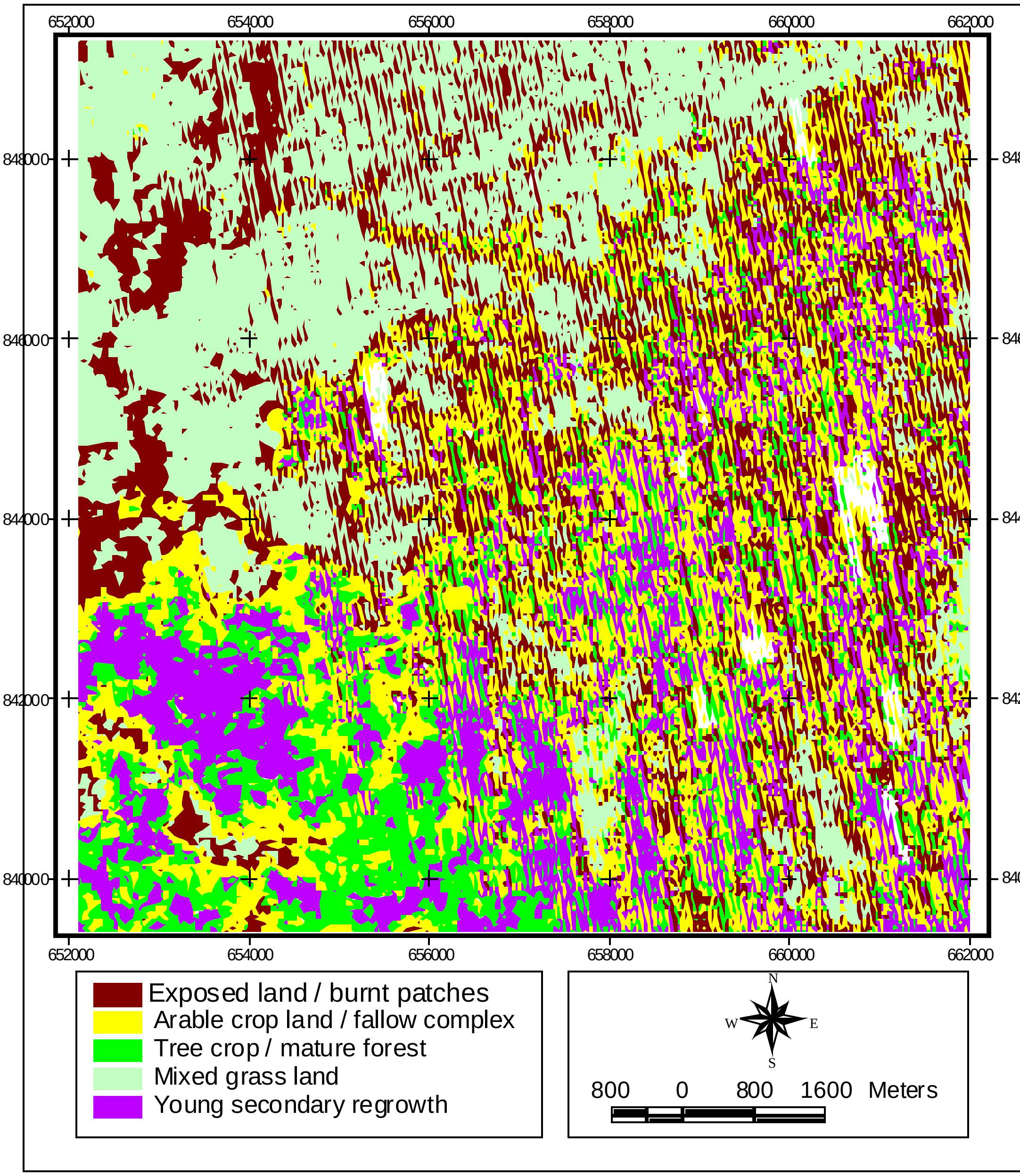


Fig. 2: Supervised Classification of Forest-Savanna Boundary in Southwestern Nigeria from NigeriaSat-1 (2004)

Source: Salami and Balogun (2004).

Table 2: Changes in forest cover of study area between 1963 and 2003

COVER TYPE	Areal Extent (in ha)				Annual Rate of Increase/Decline (1963-2003)
	1963*	1973*	1991**	2003***	
Mature forest/Tree Crop Complex	3460	2550	1830	2465	-0.72
Young Secondary Regrowth	4566	2236	2761	2355	-1.21
Arable Farmland	1370	2414	794	1160	-0.38
Mixed grassland	574	2733	3380	2509	8.43
Exposed Land/Burnt Patches	30	67	1235	1511	12.42

**Derived from aerial photos (Salami, 1999) **Derived from SPOT XS (Fig. 1)*
****Derived from NigeriaSat-1 (Fig. 2)*

Fig. 1 shows the landuse situation in the area as at 1991 while Fig. 2 presents the classification of landuse types in the area from NigeriaSat-1 of 2003. The results from the interpretation of these satellite images were completed with the earlier results obtained from interpretation of 1963 and 1973 aerial photographs of the area. Table 2 shows that farmland increased at a high rate between 1963 and 1973 while it experienced a decline between 1973 and 1991. This reinforces the study of Salami (1995), in which progressive edaphic degradation in the area is described. When soil fertility decreases, a farmer is likely to reduce his investments in the farming enterprise, especially if chemical fertilizers are not used and, since savanna elements were already present in the area, it becomes easier for grass layer to take over the abandoned farmlands (Salami, 1999). The increased coverage of mature forest/tree crop complex in 2003 indicates the maturation of some parts classified as young secondary regrowth in 1991.

Implications for climatic variability

Figs 1-2 show that there has been a steady savannization of the forest in Southwestern Nigeria. The secondary forest is receding at the rate of 1.21% per annum while the mature forest is declining at the rate of 0.72% annually (Table 2). This gives an empirical average rate of deforestation of 0.97 per annum between 1963 and 2003. This is higher than the rate of 0.76% derived for Nigeria by FAO (1990) but relates to the global rate of 1.0-2.0% given by World Bank (1991). Significant uncertainties surround predictions of regional climate changes in general but predictive models rely on landuse data as part of the variables. Inaccurate landuse data therefore increases the unreliability of such models. Adaptation strategies are easier formulated when the future directions are known with a high level of certainty. Landuse pattern is indicative of future vulnerability to climate change as well as adaptive capacity of the society. Attention needs to be focused on feedback from landuse in Nigeria. This has been a major problem that requires urgent attention. The example presented herein shows the significance of geo-information system in capturing landuse data.

New Economic Foundation (2005) noted that African countries must give serious attention to climate change issues. There is a consensus among researchers that although climate is not a static phenomenon, the scales of changes being witnessed are largely due to the composition of the atmosphere and landuse. It is expected that climate change may spell doom for the developing countries in future. The likely impacts of such changes are uncertain and there has been a heavy reliance on predictive models.

It is against this background that this paper advocates the development of a geo-spatial framework for historical data on environmental parameters and anthropogenic activities including data compilation, storage, retrieval, analysis and display in Nigeria. This will ensure that climate change programme in Nigeria takes advantage of the recent development in satellite technology in Nigeria (specifically with the launch of NigeriaSat-1).

Conclusion

Available evidence shows that many human activities especially with respect to landuse, are causing the emissions of increasing quantities of polyatomic molecules into the atmosphere. A number of evidences have been gathered to show that there is a steady increase in greenhouse gases (GHG) due to man's industrial and agricultural activities which is capable of initiating spatio-temporal variations in climate (Ramanathan, 1990). This has triggered off some remarkable changes in climate which has been a subject of concern that needs continuous monitoring and documentation. In Nigeria, just like in most other African countries, rainfall is the only parameter available with continuous data sufficient to infer climate changes during the instrument era of many researchers (Adejuwon *et. al.*, 1990; Tyson, 1993). But the landuse pattern over the years has triggered off some changes in the rainfall regime. This paper has demonstrated the importance of space technology for regular monitoring of landuse pattern in Nigeria.

There is a global apprehension that a new kind of climate change is now under way and that its impacts on people and ecosystems are likely to be drastic especially in the less developed countries. IPCC (2001) predicted a rise of 1.4 to 5.8^{o}C in global mean surface temperatures over the next 100 years while temperature increases of about 0.2-0.3 ^{0}C per decade have been reported for Nigeria (Ojo, 1985; Olayanju, 1991). Human activities, such as clearing of tropical forests in Central and Western Africa alters local climate and rainfall patterns and increases the risk of drought (FAO, 2001). The tracking of such human activities has now been facilitated by the data from NigeriaSat-1. Specifically, experts have demonstrated that the natural vegetation destruction and degradation severely affects the microclimate, hydrological cycle, precipitation dynamics, *albedo* and energy budget of the atmosphere (IPCC, 1990). The feedback from the landuse therefore needs to be empirically investigated through the space-based data, documented and properly organized for regular update and monitoring.

The launching of NigeriaSat-1 constitutes one of the major enduring legacies of the recent years. Relevant agencies in the country such as Nigerian Emergency Management Agency (NEMA) and Nigerian Meteorological Agency (NIMET) need to develop strong collaborations with NASRDA before the country can derive the maximum benefit from the satellite program. NigeriaSat-2 if implemented in 2009 as proposed (2.5m panchromatic, 5m and 32m multi spectral in 4 bands) will offer far higher benefits in terms of disaster management, environmental monitoring and spin-offs for socio-economic development

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