Sustainable Management of Mangrove Coastal Environments in the Niger Delta Region of Nigeria: Role of Remote Sensing and GIS

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Abstract

Wetlands, which include the coastal mangroves, are amongst the Earth's most productive ecosystems. They support millions of people and provide a wide range of direct and indirect goods and services or functions. Despite the wide range of important ecosystem goods and services provided by the wetlands they are under serious threat to extinction worldwide. Due to mainly: erratic and haphazard physical developments, externalities from users (e.g. agriculture, oil and gas industry. In Nigeria, 21,342 hectares of mangrove vegetation was reported to have been lost between 1986 and 2003 due to urbanization, dredging activities, and pollution from the oil and gas industries. Recognizing the continuous degradation of the region, mangrove (or wetland) goods and services must be given a quantitative value if their conservation is to be well appreciated. GIS and RS offer opportunities in accurate monitoring and assessment of environmental changes and effects taking place in the mangrove areas. It also helps to identify the driving forces of the environmental changes. GIS mapping will assist in assessing the spatial distribution and ecological change of the environment, identifying the baseline data of the region such as vegetation types and densities, the land use types. GIS and RS will complement many existing cases of wetland (including mangrove restoration developments) and provide government and all stakeholders involved in the development of the region with strategic framework for identifying and calculating projects and programs for the restoration of degraded mangroves and development of conservation action Plans for the sustainable management of Niger Delta mangroves.

Keywords: Coastal Mangrove, Ecosystem Services, GIS and RS, Hyper spectral, Niger Delta Region, Sustainable Management

Introduction

Mangrove forests are coastal plant communities that are part of a larger coastal ecosystem that typically includes mud flats, sea grass meadows, tidal marshes, salt barrens and even coastal upland forests and freshwater wetlands (i.e. peat lands), freshwater streams and rivers. In more tropical climates coral reefs may also be part of this ecosystem (Barbier et al., 1997; Kumar, 2000). They are critical habitat for many species of fish and wildlife, serve as coastal fish and shellfish nursery habitat, and produce large quantities of leaf material that becomes the basis for a detritus food web ((James et al., 2007; James, 2008). The important mangrove vegetation such as the sea grass beds is widely recognized. Despite their importance, mangrove vegetations are threatened all over the world by direct and indirect causes. Apart from the global climate change and its effects such as rise of temperature, sea level, atmospheric CO2 etc (their decline is mainly related to anthropogenic activities (Balmford and Bond, 2005; Saunders et al., 2006). In terms of degradation, major oil spills have occurred that have devastated rivers, killed mangroves and coastal life and affected the health and livelihoods of millions of inhabitants. They have lost farming land and their incomes from oil spills and breathe air that reeks of oil, gas and other pollutants (Amnesty International Australia, 2009). The consequences of this have been enormous financial loss, extensive habitat degradation, and poverty leading to the continuous crises in the Niger Delta region, that have recently culminated into several communal conflicts, kidnapping of oil workers, and vandalization of oil installations. This continued growth has resulted in environmental problems such as coastal wetland loss, habitat degradation, water pollution, gas flaring, and destruction of forest vegetation and host of other issues.

Nigeria with the Niger Delta region hosts the largest extent of mangroves in Africa and fifth largest mangrove nation in the world (Spalding et al., 2010) and Niger Delta is the world's third largest delta, and West/Central Africa's most extensive freshwater swamp forest (Ikwegbu, 2007). The spatial boundary of the mangrove ecosystem in Nigeria is unique because it is shielded from sea water, a characteristic that differs from that of several other African countries where the mangroves are directly exposed to sea water' (NDES., 1997). Over sixty percent of the mangrove stands in Nigeria are found in the Niger Delta coastal region located in the central part of Southern Nigeria (HRW, 1999). In the Niger Delta region the mangrove ecosystem is extensive and spreads across Ondo, Edo, Delta, Bayelsa and Rivers States (WB, 1995).

On the basis of morphological, physiological, biochemical and reproductive adaptations, 84 species of plants belonging to 39 genera in 26 families are recognized throughout the world as mangroves (Saenger, 2002) of which only six indigenous and one exotic species are found within the Atlantic Coast of West Africa (Blasco, 1998). The Niger Delta is home to three endemic families represented by five plant species and the introduced family of exotic species (James et al., 2007, James, 2008). In terms of the soil, the Niger Delta coastal mangroves ecosystem is supported by saline soil with potential of Hydrogen (pH) value of between 4 for freshly deposited soft silt low tide and 7 for transitional swamps at high tide. The other intermediate soil types include the peat – clay which constitutes about 90% of the soil formation in the ecosystem (Anderson, 1967, Adegbehin and Nwaigbo., 1990).The ecosystem is considered pioneer because aluminium and organic matter caught by mangrove roots in addition to biomass created by the trees, develop their own medium and literally extend land into the lagoons, creeks, and rivers (Ashton-Jones, 1998.) Such a regional assessment is important as the region has become a flash point of conflicts and contending view points on the adverse ecological impact of oil and gas exploration activities by transnational oil corporations operating in the region (WRM., 2003.). Thus collection of spatial temporal data of such regional assessment, will particularly contribute to mapping of mangrove ecosystem that is being encouraged at both global, regional scales and even more local scales (Spalding et al., 2010).

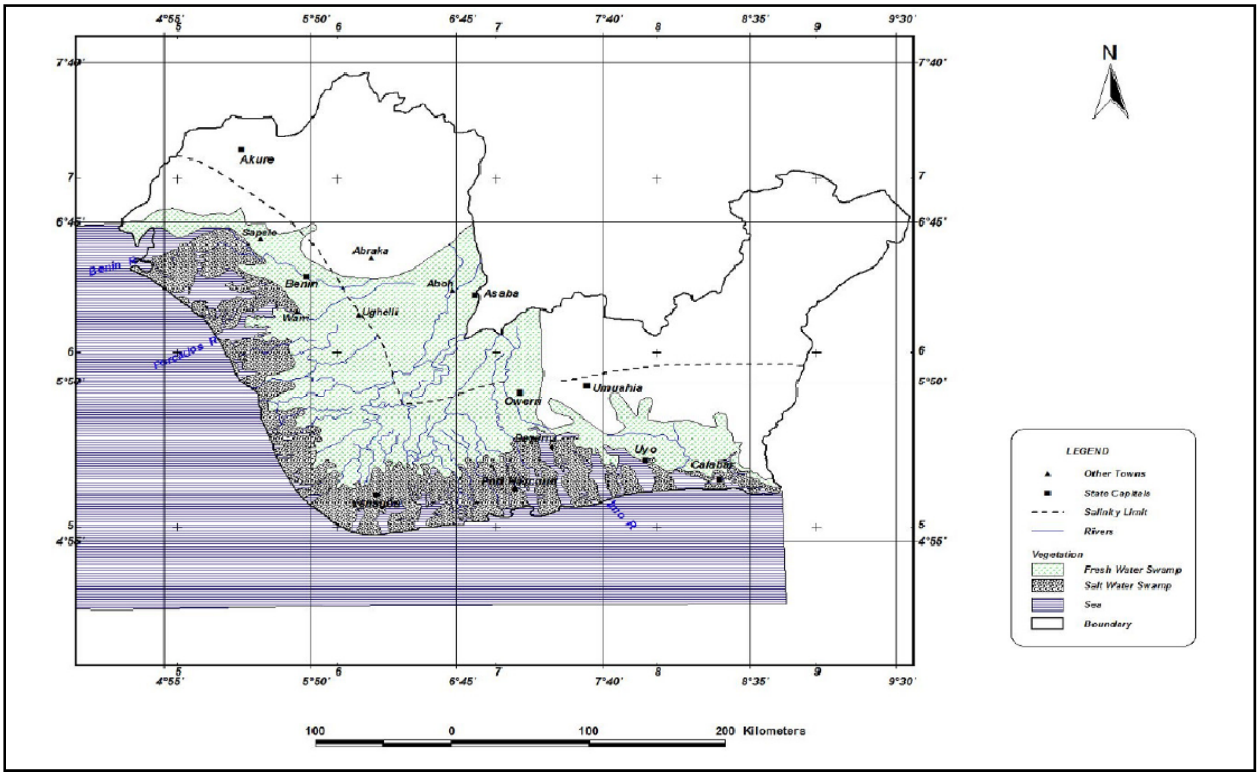

Figure 1: Niger Delta Region

Several efforts to assess the state of the environment and the environmental stewardship of economic development along the Niger Delta ecosystem of Nigeria like many other developing countries are often hindered by the lack of access to a comprehensive regional environmental information system. There is a need for concerted effort at ensuring sustainable management of Mangrove Coastal Environments in Nigeria, especially the Niger Delta Region of Nigeria. The objective of this study was therefore, to assess the utility of hyperspectral data in estimating and mapping mangrove coastal vegetation forest structural parameters.

Need for Geospatial Technology

Nigeria as a country currently suffers from the lack or inadequacy of major geospatial scientific work that would offer an impartial evaluation of the destruction caused by oil and gas activities in the Delta area of the South (Human Rights Watch, 1999). Until recently when the nation's earth observation satellites (i.e. SAT-2 and SAT-X) were launched to replace SAT-1 allegedly lost in orbit. Majority of the existing studies (e.g. Hanley and Craig, 1991; Barbier et al., 1997; Bateman et al 1995; NDES., 1997, Ashton-Jones, 1998., James, 2008) on sustainable issues on wetlands in general and coastal mangrove ecosystem in particular, have focused largely on valuation of ecosystem goods and services to underscore the economic cost (or opportunity cost) of the degradation of these ecosystem resources. The problem facing the area has been compounded by gaps in previous research. One of the major reasons attributed to this failure is the lack of adequate information addressing the *real* needs of the region. Many studies have examined the problems of environmental degradation in the region and the need for improved understanding, monitoring, and management of the area's ecosystems. To date, there are only a few in-depth studies which employ geospatial technology studies to understand land use changes of coastal ecosystems which can help estimate the environmental impact on the livelihood of communities, and eventually help governments sustainably manage the environment.

Collecting information on the current condition and trends of ecosystem services and identifying the drivers that affect human well-being results in an understanding of *current* changes to ecosystem services Ranganathan et al., 2008). Current attempts to assess the state of the environment and the environmental stewardship of economic development along the Niger Delta ecosystem are often handicapped by the lack of complete access to a comprehensive regional environmental information system (Yaw and Merem, (2006). Furthermore, Haag and Hoagland (2002) stressed that there is limited emphasis on the assessment of change through spatial information technologies such as remote sensing and (GIS)]. Numerous studies in the literature, examining environmental risk assessment, rightly point to the need for improved understanding, of monitoring on environmental issues faced by oil and gas producing communities but without concrete allusion to the use of geospatial technologies. GIS technology as a tool used by geographers, archaeologists, geologists and other scientists in the social and natural sciences provide opportunities for storage, manipulation and mapping of data with a spatial reference (Rashmin, 2004).

Since the launch of the first Earth Resources Technology Satellite in 1972 (ERTS-1, later renamed Landsat 1), there has been significant activity related to mapping and monitoring environmental change as a function of anthropogenic pressures and natural processes. Geo-information science has presented flexible, suitable and affordable technology for data collection, information extraction, data management; routine manipulation and visualization of processes that are taking place on the earth include issues surrounding the management of mangrove coastal environments. In areas such as the Niger Delta region of Nigeria, sustainable management of resources involves a movement from a data-poor environment to data-rich environment. There is more and more need for filtering, processing, and integrating various data/information in such a way that they can be supportive to management decision. Given the rapid socio-economic and environmental changes in this region, such studies are currently in demand. The goal of this study is to use remote sensing and GIS technologies to develop an effective decision-making framework for policy makers in their assessment of the economic costs of environmental remediation or restoration projects and the formulation of conservation or management action plans for coastal mangroves of Nigeria's Niger Delta region. This research elaborates on developing a framework for planning and decision support systems, and its supporting tools for sustainable management of mangrove coastal environments. It seeks to know what opportunities remote sensing and GIS offer in accurate monitoring and assessment of environmental changes and effects taking place in Nigeria's Niger Delta coastal mangrove areas. In addition, it also proposed the use and application remote sensing and GIS technologies (e.g. Hyperspectral Remote Sensing) to monitor changes in the vegetation of the coastal mangrove environments.

A significant progress has been realised in the remote sensing of forest ecosystem in recent years linked to technological advances in sensor design, growth in information extraction techniques and increasing requirement to quantitatively describe and understand our environment (Welder & Franklin, 2003). Remote sensing instruments measure the radiation that is emitted or reflected from the earth's surface. The diversity of instruments available at present and in the future provide data with broad to fine spectral resolution, with large to small spatial resolution and other characteristics (e.g. multi-directionality) suitable for the quantitative and qualitative analysis of forests (Peterson & Running, 1989). Accurate quantitative estimation of vegetation biochemical and biophysical characteristics is necessary for a large variety of agricultural, ecological and meteorological applications (Asner, 1998).

Remote sensing science has become a critical and universal tool for natural resource managers and researchers in government agencies, conservation organizations, and industry (Philipson & Lindell, 2003; Stow et al., 2004). Information derived from remote sensing data has often been used to assist in the formulation of policies and provide insight into land-cover and land-use patterns, and multi-temporal trends. Interpretation of aerial photographs continues to be a standard tool for mapping and monitoring land-cover and land-use change (Loveland et al., 2002). The range and opportunity for remote sensing of ecosystem structure, dynamics and processes is improved with change in technology (Lunetta, 1998). Detection and characterization of change in key resource attributes allows resource managers to monitor landscape dynamics over large areas, including those areas where access is difficult or hazardous, and facilitates extrapolation of expensive ground measurements or strategic deployment of more expensive resources for monitoring or management (Li et al., 2003; Schuck et al., 2003). In addition, long-term change detection results can provide insight into the stressors and drivers of change, potentially allowing for management strategies targeted toward cause rather than simply the symptoms of the cause.

The techniques based on multi-temporal, multi-spectral, satellite-sensor-acquired data serve to detect, identify, map and monitor ecosystem changes, irrespective of their causal agents. Extracting information from a digital image begins with "spectral space" (which for our purposes includes SAR intensity or comparable LIDAR measurements). Spectral space is the data space that can be visualized by plotting measured intensity of reflected radiance in different spectral bands against each other (Lillesand & Kiefer, 2000). Remote sensing change detection studies involve a series of sequential steps that are detailed extensively elsewhere (e.g. Cihlar, 2000; Coops et al., 2007; Lunetta, 1998; Schott, 1997). For the natural resource manager, our goal here is to simplify these steps into four broad stages: data acquisition, pre-processing and/or enhancement, analysis, and evaluation. The better a manager understands how decisions in each stage affect the outcome of the study or project, the better he or she can guide those decisions.

Ecosystem services are the benefits that people derive from nature. Some benefits, such as crops, fish, and freshwater (provisioning services), are tangible. Others such as pollination, erosion regulation, climate regulation (regulating services) and aesthetic and spiritual fulfilment (cultural services) are less tangible (MA, 2005b). Ecosystem services such as provided by the mangrove can be assessed using the technologies of remote sensing and GIS, which will provide decision-makers with guidelines in making decisions and formulating policies that will affect the ecosystem generally. Remote sensing and GIS can be used for assessing mangrove ecosystem based on the Millennium Assessment as shown below.

Table 1: Methods to Assess Mangrove Ecosystem

Method	Description	Sample uses	Example
Remote Sensing	Data Obtained from satellite sensors or aerial photographs (LANDSAT, MODIS,SPOT, ASTER)	Assessment of large areas, land cover, land use and biodiversity	Assessment of mangrove vegetation and deforestation
Geographic Information Systems damage	Software that spatially maps and analyzes digitized data (ArcGIS, ArcView, IDRIS)	Analyses of spatio-Temporal changes in mangrove ecosystems, Over laying social and economic information with ecosystem information; correlating trends in ecosystem services with land use change	Niger-Delta ecosystem assessment using GIS to analyze the extent of to mangrove vegetation
Participatory Approaches and Expert Opinion	Information supplied by stakeholder groups, scientific experts, workshops, traditional knowledge	Collection of knowledge available in scientific literature, fills gaps in literature, add new perspectives, knowledge (PGIS)	Niger-Delta ecosystem assessment using (PGIS) with stakeholders

Source: Adapted from MA, 2005a

Hyperspectral Remote Sensing for Wetland Vegetation

Wetland vegetation is an important component of wetland ecosystems that plays a vital role in environmental function (Kokaly et al. 2003; Lin and Liquan 2006). It can serve as an indicator for early signs of any physical or chemical degradation and general health of the wetland environments (Dennison et al. 1993). Mapping and monitoring vegetation species distribution, quality, and quantity are important technical tasks in sustainable management of wetlands. Successful monitoring programme requires up-to-date spatial information about the magnitude and the quality of vegetation cover in order to initiate vegetation protection and restoration programme (He et al. 2005). Hyperspectral remote sensing offers a practical and economical means to discriminate and estimate the biochemical and biophysical parameters of the wetland species and it can make field sampling more focused and efficient. Hyperspectral remote sensing or imaging spectrometry refers to the recording of remote sensing data using imaging spectrometers. These instruments collect radiance values in many narrow bands forming continuous spectra. As imaging spectrometer data is characterised by a high spectral resolution compared to multispectral data it is also called hyperspectral. The concept of imaging spectrometry is shown in Figure 2.

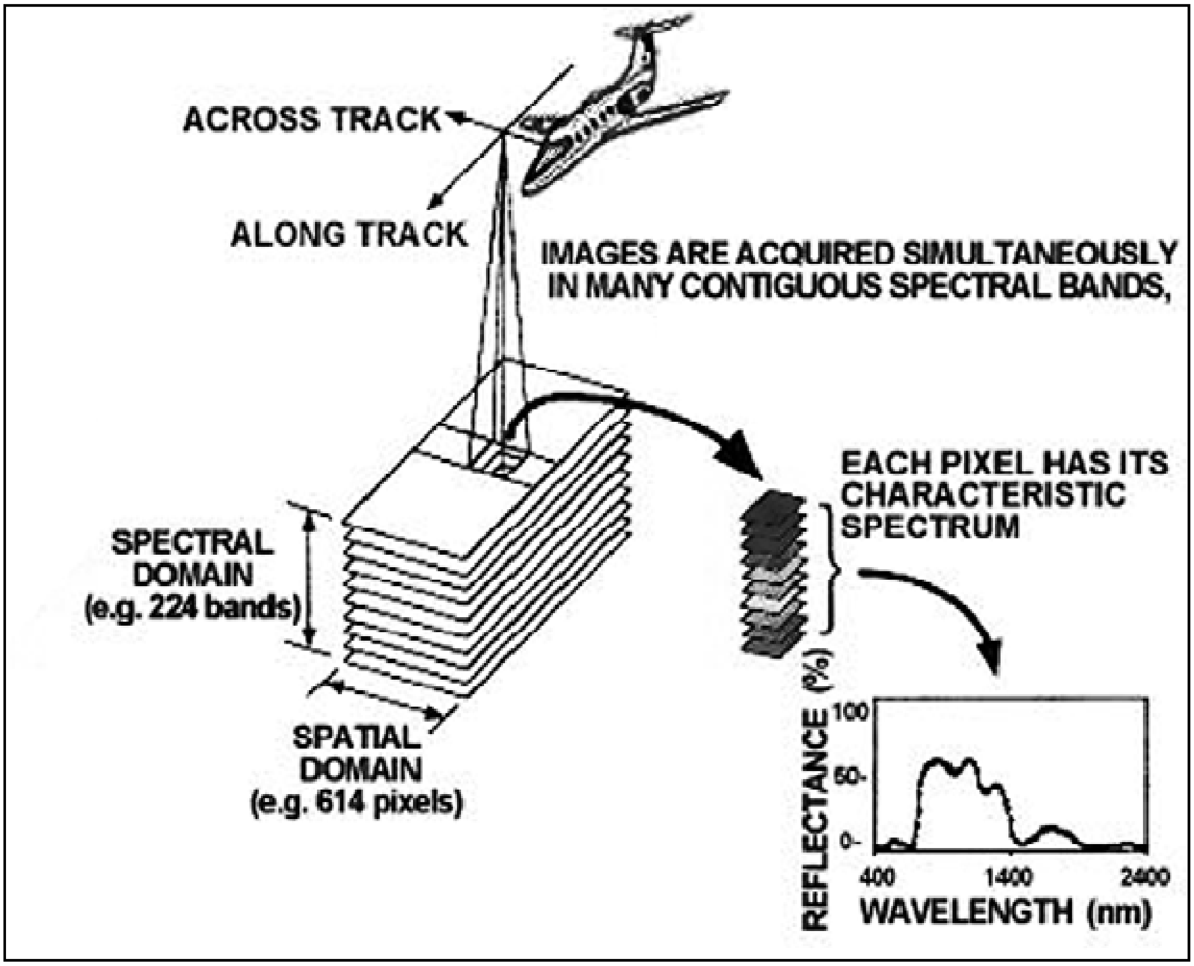

Figure 2: The concept of imaging spectrometry (after Vane & Goetz, 1988) adapted from Schlerf (2006)

The technology has been used worldwide to detect surface-water pollution discharges, map sensitive vegetation distribution, monitor agricultural plant communities, and detect vegetation health. It can easily be integrated into Geographic Information System (GIS) for more analysis because of the repeat coverage offers. Thus, changes in vegetation over time and be detected and monitored (Shaikh et al. 2001; Ozesmi and Bauer 2002). Hyperspectral sensors are the most advanced optical remote sensing systems compared to the traditionally, multispectral satellite remote sensors such as Landsat Thematic Mapper (TM), Multispectral Scanner (MSS), and Advanced Space borne Thermal Emission Radiometer (ASTER) which often lack the spatial and spectral resolution necessary to differentiate characteristics of the Earth's surface—especially when the spectral changes are very small or in a very narrow area of the electromagnetic spectrum (Jensen et al. 2004, Hardin and Jensen 2005).

Hyperspectral sensors has hundreds of narrow continuous spectral bands between 400 and 2,500 nm, throughout the visible (0.4–0.7 nm), near-infrared (0.7–1 nm), and short wave infrared (1–2.5 nm) portions of the electromagnetic spectrum (Govender et al., 2006; Vaiphasa et al. 2005). This greater spectral dimensionality of hyperspectral remote sensing allows in-depth examination and discrimination of vegetation types which would be lost with other broad band multi-spectral scanners (Cochrane 2000; Schmidt and Skidmore 2003; Mutanga et al. 2003; Govender et al. 2006). Hyperspectral remote sensing data can be acquired using a hand-held spectrometer or airborne sensors. A hand-held spectrometer is an optical instrument used for measuring the spectrum emanating from a target in one or more fixed wavelengths in the laboratory and the field (Kumar et al., 2001). Hyperspectral imagery has significant potential to aid environmental monitoring and detection efforts by providing spatially comprehensive data that can stand alone or complement existing, conventional environmental data products. Estimating wetland biomass is necessary for studying productivity, carbon cycles, and nutrient allocation (Zheng et al. 2004; Mutanga and Skidmore 2004). Many studies of field biomass have used vegetation indices based on the ratio of broadband red and near infrared (NIR) reflectance. Tan et al. (2003) used Landsat ETM bands 4, 3, and 2 false colour, and field biomass data to estimate wetland vegetation biomass in the Poyang natural wetland, China.

Studies have shown that wetland plants and their properties are not as easily detectable as terrestrial plants, which occur in large stratification (Adam and Mutanga, 2009). A major problem is that herbaceous wetland vegetation exhibits high spectral and spatial variability because of the steep environmental gradients, which produce short eco tones and sharp demarcation between the vegetation units (Zomer et al., 2008; Schmidt and Skidmore, 2003). This thus makes it difficult to identify the boundaries between vegetation community types. In addition, the reflectance spectra of wetland vegetation canopies are often very similar and are combined with reflectance spectra of the underlying soil, hydrologic regime, and atmospheric vapour (Guyot, 1990; Malthus and George, 1997; Lin and Liquan, 2006) (Figure 3). These combinations usually complicate the optical classification and results in a decrease in the spectral reflectance, especially in the near-to mid-infrared regions where water absorption is stronger (Fyfe 2003; Silva et al. 2008). However, hyperspectral narrow spectral channels offer the potential to detect and map the spatial heterogeneity of wetland vegetation (Treitz and Howarth, 1999; Jensen, 2000; Franklin, 2001; Herold et al., 2002; Hestir et al., 2008; Vaiphasa et al., 2007; Schmidt and Skidmore, 2003).

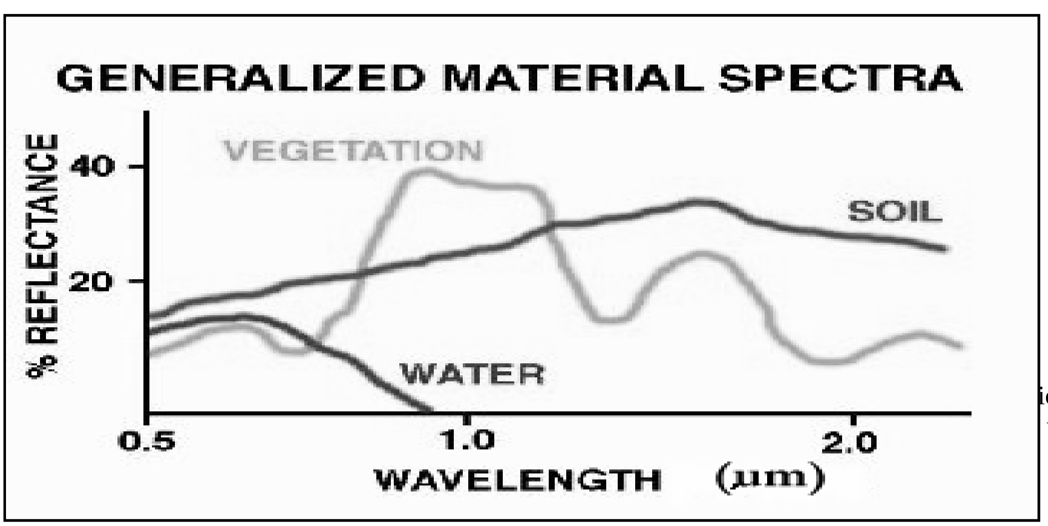

Figure 3: Spectral reflectance of soil, water and vegetation

The spectral reflectance curves of materials are used to discriminate them for identification (Figure 3). The figure shows the differences in spectral curves for vegetation, soil and water. Green plants exhibit a sharp intensity change over a short spectral distance that is formed by strong chlorophyll energy absorption near the red wavelength (0.6µm) and high reflectivity at the near-IR wavelength (0.76µm). Changes in the health status of plants are often expressed as a shift of this red-edge toward longer or shorter wavelengths. Although not detectable by the human eye, this spectral change can be indicative of senescence, water deprivation or toxic materials. Other spectral changes in vegetation detectable by hyperspectral techniques occur at wavelengths corresponding to water absorption (0.94µm) or the actual total chlorophyll absorption depth at 0.6µm. Vegetation phenology refers to the timing of different life-cycle events of the plants (such as leaf unfolding, flower first bloom, leaf fall, etc.), which are related with the change of leaf density and photosynthetic activity through the seasons (Bradley et al., 2007). These methods can be used in a quantitative assessment of change in the mangrove vegetation in the Niger Delta of Nigeria. Successful utilization of remotely sensed data for land-cover and land-use monitoring however, requires careful selection of an appropriate data set and image processing technique(s) (Lunetta, 1998).

Vegetation Indices

The most commonly used broadband remote sensing predictors of forest parameters are ratio indices (vegetation indices) computed from near infrared (NIR) and visible reflectance. The most known vegetation index is the normalised difference vegetation index (NDVI) developed by Rouse et al. (1974). NDVI is based on the contrast between the maximum absorption in the red due to chlorophyll pigments and the maximum reflectance in the NIR caused by scattering in the leaf mesophyll. For example, with increasing leaf area index (LAI) or canopy thickness, red reflectance decreases as leaf pigments absorb light, while NIR reflectance increases as more leaf layers are present to scatter the radiation (Gates et al., 1965). The use of imaging spectroscopy for forest stand structural estimation is based on the assumption that increased identification of particular spectral features associated with narrowband could improve estimation of forest attributes compared to broadband sensors (Lefsky et al., 2001; Lee et al., 2004). Narrowband two-band vegetation indices (VIs) calculated according to the principle of NDVI (see Equation below) was derived from all possible two-band combinations involving 126 bands of HyMap spectrum using the calibration data. This resulted into 15,876 (i.e. 126 x 126) VIs for each spectrum.

$$VI_{(i,j,n)} = \frac{R_{(i,n)} - R_{(j,n)}}{R_{(i,n)} + R_{(j,n)}}$$

where $R_{(i,n)}$ and $R_{(j,n)}$ are the reflectance of any two bands for each sample (n).

Linear regression analyses were performed between each VI with each forest structural parameter (mean DBH, mean height and tree density). The VIs that yielded the highest calibration coefficient of determination (R2) was subsequently selected for assessing their predictive capability on the independent data set.

One of the powerful tools to study the spatial distribution of vegetation is remote sensing (Jin, 2009). Remote sensing has traditionally been used in large-scale global assessments of vegetation distribution and land cover with the Normalized Difference Vegetation Index (NDVI) data from Advanced Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectroradiometer (MODIS) (Chen and Brutsaert 1997; Defries et al. 1995; Friedl et al. 2002; Loveland et al. 1999, 2000). The NDVI is an index derived from reflectance measurements in the red and infrared portions of the electromagnetic spectrum to describe the relative amount of green biomass from one area to the next (Deering 1978). This index is an indicator of photosynthetic activity of plants and has been widely used for assessing vegetation phenology and estimating landscape patterns of primary productivity (Sellers, 1985; Tucker and Sellers, 1986). The NDVI was designed to quantitatively evaluate vegetation growth: higher NDVI values imply more vegetation coverage, lower NDVI values imply less or non-vegetated coverage, and zero NDVI indicates rock or bare land. Furthermore, the MODIS NDVI data is also used for vegetation index mapping. It depicts spatial and temporal variations in vegetation activities, derived by monitoring the Earth’s vegetation. These vegetation index maps are corrected for molecular scattering, ozone absorption, and aerosols. The MODIS NDVI data is based on 16-day composites and its spatial resolution is 250 m. Currently, the MODIS NDVI products have been used throughout a wide range of disciplines, such as inter- and intra-annual global vegetation monitoring, climate and hydrologic modelling, and agricultural activities and drought studies (Zhan et al. 2000; Sakamoto et al. 2005; Lunetta et al. 2006; Jin, 2009).

Conclusion

Too often, development policies have unwittingly diminished nature’s capacity to provide the goods and services people depend on. Decision makers may be focused on reducing poverty, increasing food production, strengthening resilience to climate change, or producing energy. Ultimately, the developments goals are undermined as the effects of these trade-offs are felt by people who depend on nature for their livelihood and well-being. Reconciling development and nature is challenging but quite important for sustainability of the environment and its inhabitants. To fully understand changes that have already occurred in the coastal mangrove vegetation of the Niger Delta, land cover data are needed to generate scenarios of future modification of the environmental system. Land use and land cover data can be obtained using in situ field measurements or remote sensing technology. There is the need to establish integrated watershed Management. This is important considering the widespread growth and the pressure on the area’s environmental indicators such as wetlands, rivers and forests cover. The states located along the Niger Delta watershed should adopt an ecosystem based integrated watershed management approach using remote sensing and GIS to quicken the periodic monitoring of the Delta's ecosystem health and the interaction between human activities and the environment in the region.

The paper demonstrates the use of hyperspectral remote sensing and GIS a practical method and technique to map wetland vegetation. It is possible to differentiate wetland vegetation using hyperspectral remote sensing, given that from afar vegetation looks homogeneous and only closer inspection reveals differences in species composition to such an extent that one can define ecologically meaningful vegetation types. Consequently hyperspectral remote sensing of vegetated surfaces in the wetland areas can be used to map species composition in considerable detail, with accuracies greater than those of conventional aerial photograph interpretation. Furthermore, vegetation mapping up to a detailed level can be improved when adding expert knowledge about the ecology of the mangrove wetland to the classification of the hyperspectral imagery.

GIS and RS offer opportunities in accurate monitoring and assessment of environmental changes and effects taking place in the mangrove areas. It also helps to identify the driving forces of the environmental changes. GIS mapping will assist in assessing the spatial distribution and ecological change of the environment, identifying the baseline data of the region such as vegetation types and densities, the land use types. GIS and RS will complement many existing cases of wetland (including mangrove restoration developments) and provide government and all stakeholders involved in the development of the region with strategic framework for identifying and calculating projects and programmes for the restoration of degraded mangroves and development of conservation action Plans for the sustainable management of Niger Delta mangroves. Extraction of information from hyperspectral measurements can enhance our understanding of vegetation biophysical and biochemical characteristics estimation and can serve as essential input to biogeochemical and climate models. In addition, efforts should be made to design a regional geo-spatial data infrastructure (GDI) because of lack of accessible regional geo-spatial information system capable of computing the interactions between humans and the environment. Such an inventory will offer the decision makers access to the appropriate temporal-spatial data for monitoring the pressures mounted on the areas ecosystem by development activities. It could act as an effective decision support system to keep development in harmony with environmental sustainability.

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