Geospatial Technologies For Sustainable Development

Adeniyi Gbadegesin* and O.I. Orimoogunje**
Department of Geography, University of Ibadan, Ibadan. Nigeria*
Department of Geography, Obafemi Awolowo University, Ile-Ife. Nigeria**

Abstract

Previous studies have established that the purpose of sustainable natural resource management and development is to ensure that resources are utilised in a way that does not adversely affect their on-going quality for current and future populations. But it is noted that factors such as climate change, population growth, environmental pollution, agricultural intensification, and urban expansion can seriously affect the use and availability of resources for future generations. Therefore, the appraisals of critical developmental issues call for methodologies and technologies that will enable assessment of current natural resource systems, risks and needs, and provide a means for ensuring sustainability in the future. To this end, Geospatial Science such as spatial analytical techniques, earth observation satellites (active and passive), Volunteered Geographic Information and crowd sourcing are new and existing technologies to map, monitor and sense our scarce natural resources for environmental sustainability.

Keywords: Sustainable Development, Geospatial, Earth Observation Satellites, Volunteered Geographic Information, Crowd Sourcin

Introduction

Man has always sought for ways to manage and conquer his environment. Understanding human evolution is key to understanding how man has shaped his environment, especially in the cultural and biological aspects (Ehrlich, 2000). The history of man s relationship with his environment can be narrowed to determinism; where the environment determined man s cultural and biological interactions, and possibilism; where man makes his choices and bends the environment to suit his needs (Lewthwaite, 1966).

Human evolution has brought about the ability to utilize resources provided by the environment. Due to industrial revolution, human activities started to produce new impacts on natural resources whereby factories were built, producing new sources of pollution on air, water and soil; many towns and cities started to grow, generating social, human and health problems. For most of the last couple of hundred years the environment has been largely seen as external to humanity, mostly to be used and exploited, with a few special areas preserved as wilderness or parks. Environmental problems were viewed mainly as local. On the whole the relationship between people and the environment was conceived as humanity s triumph over nature (Hopwood *et al.*, 2005). However, this has posed another problem; how to utilize the environmental resources without depleting or permanently damaging it. Thus, scientists have determined that man needs to sustainably utilise available resources. Hopwood *et al.* (2005) opines that the concept of sustainable development represents a shift in understanding of humanity s place on the planet.

With recent global environmental problems, there is an increasing number of research organizations, companies, industry groups, communities, government planners, non-governmental organizations (NGOs), building and facility owners around the world are presently exploring sustainable development. They are seeking creative approaches to integrate their pursuit of economic prosperity with the assurance of environmental protection and quality of life for current and future generations. With the recent adoption of the Sustainable Development Goals (SDGs) and the call by UN Secretary General for a "revolution" in the use of data for sustainable development, geospatial technologies have tremendous potential to effectively and efficiently monitor SDG progress (Sachs, 2015).

Sustainable development, a widely used phrase and idea, has different meanings and therefore provokes different responses. For instance, the United Nations Report of the World Commission on Environment and Development defines sustainable development as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This definition was based on two concepts; the concept of need and the idea of limitations imposed by technology and the environment (Brundtland, 1987). Daly (1990) argues that „sustainable development meant qualitative, rather than quantitative, improvements of an environment or economy. Placet *et al.* (2005) considers that sustainable development has three broad goals: environmental stewardship, social responsibility and economic prosperity. Haughton (1999) summarized the ideas of sustainable development in five principles based on equity: futurity – inter-generational equity; social justice – intra-generational equity; trans-frontier responsibility – geographical equity; procedural equity – people treated openly and fairly; interspecies equity – importance of biodiversity.

The concept of sustainable development has developed as a result of the growing awareness of the global links between mounting environmental problems, socio-economic issues of poverty and inequality and concerns about a healthy future for humanity (Hopwood *et al.*, 2005). It links environmental and socio-economic issues. Brundtland (1987) definition and the ideas expressed in the report recognized the dependency of humans on the environment to meet needs and well-being in a much wider sense than merely exploiting resources. In essence, ecology and economy are becoming even more interwoven – locally, regionally, nationally and globally. The report highlighted the fact that humanity is dependent on the environment for its basic existence, security and longevity. It also points to the planet-wide interconnections: environmental problems are not local but global, so that actions and impacts have to be considered internationally to avoid displacing problems from o ne area to another by actions such as releasing pollution that crosses boundaries, moving polluting industries to another location or using up more than an equitable share of the earth s resources. Environmental problems threaten people s health, livelihoods and lives and can cause wars and threaten future generations.

The Brundtland Report (1987) has led to worldwide concern over sustainable development. Building on the United Nations Millennium Development Goals (MDGs) which had its target for 2015, the United Nation at the Sustainable Development Summit in 2015 adopted the 2030 Agenda, a set of 17 Sustainable Development Goals. The goals are; no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities, responsible consumption and production, climate action, life below water, life on land, peace and justice, and partnerships for the goals (Barclay *et al.*, 2015). The idea of the SDG is particularly important because of the growing urgency in the entire world. Sustainable development is particularly important to regions that are undergoing rapid economic development.

Policy and decision making in the context of sustainable development requires rapid, effective and efficient access to and integration of appropriate current information from a wide range of sources and disciplines (Li and Yeh, 2000; Xiuwan, 2002). Developing a strategy to ensure sustainable development requires careful study and analysis to fully understand sustainability-related opportunities and threats. Technology and innovation are key elements of sustainability-focused strategies. Governments need to integrate their pursuit of economic prosperity with the assurance of environmental protection and quality of life for current and future generation.

Thus, appraisals of pertinent developmental issues call for methodologies and technologies which will enable an assessment of current systems, risks and needs, and provide a means for ensuring sustainability in the future. Geospatial technology has been recognised as useful tools in ensuring sustainable development (Xiuwan, 2002)

Geospatial Technology

Geospatial Technologies are the methods used for the measurement, analysis and visualisation of features and phenomena that occur on Earth. The three commonly used technologies are: Global Positioning Systems (GPS); Geographical Information Systems (GIS); and Remote Sensing (RS). According to van Manen, et.al (2009) geospatial technology is built on the premise that all occurrences have spatial dimensions of location, time and duration; while economic, social and environmental processes are inherently spatial. They can hardly be fully understood without taking into account their spatial dimensions. The relationship between man and the environment cannot be represented without a reference to a location. The environment is described by the topological relationships among physical objects (soil or precipitation in a given place, land surface temperature in an area etc.), and human activities that produce impacts on the environment spatially.

Geospatial technology has evolved over time from physical description of geographic space (where is what), to combining layers of mapped data for interpretation (what and why), to spatially characterizing and communicating spatial relationships (why and what if). Over the last few years, geospatial technology has evolved and converged with a variety of information technology disciplines. Geospatial technology includes remote sensing/earth imaging, geographic information systems, GPS, location based

services and navigation systems. This technology has been made even more wide spread through the availability of broadband internet, portable devices and computers, and the ever-evolving environment of the World Wide Web. In fact, geodata is rapidly becoming a conventional and familiar data type which is re-characterising the digital world (Jackson *et al.*, 2009). Since the 1960s, spatial decision-making process has become increasingly quantitative and qualitative, incorporating mathematical models, spatial and statistical analysis, multimedia, and multiple layers and data sources. In the last four decades it has evolved from an emerging science to a fabric of society that depends on its products from getting directions to major political and environmental decision making.

The growth in spatial data availability and the development in geospatial science and technology allow us to carry on informational planning processes (analysis, design, evaluation, decision, management and communication) (Campagna, 2005). The technology provides useful tools to deal with complex spatial problems, taking into account methodological and technical, as well as organizational and societal issues related to the use of GIS to solve complex problems faced by practitioners in planning and implementing sustainable development objectives. It is an essential tool which, when properly used, may offer effective support to spatial planning and decision making, because the geographical component of the problem at hand is a determinant when dealing with sustainable development.

Campagna (2005) opines that whatever the planning paradigm adopted, a knowledge based approach is required to carry on sustainable development processes. Thus geospatial technologies are important drivers in the technical and socio-organisational implementation of knowledge-based open and integrated platforms for informed analysis, collaborative problem solving, planning and decision-making. Sustainable development is a multi-actor process that involves all levels of society, globally and locally. Sustainable development planning, decision-making and management are comprehensive processes which deal with multiple dimension problems aiming at achieving balanced economic development, environmental protection, and social equity and welfare. The process is inherently collaborative and participatory in its own nature. Senior government decision makers at the international to the local level, organizations, entrepreneurs, interest groups and citizens are involved and should have access to information and tools for decision making.

For geospatial technologies to support sustainable development, it requires availability of data and tools to analyse data to be integrated in complex information systems (Rajabifard and Williamson, 2001). Methods and techniques for data production, data modelling, system integration, and advance spatial analysis need to be developed to support spatial planning and processes. Thus, through this technology, environment can be monitored constantly and changes detected promptly. Satellite sensors have improved over time, and now offer a range of quality Satellite data in terms of spatial and spectral resolutions (Turner *et al.*, 2003). Data can now be collected more frequently and analysis made quicker. Improved availability of spatial data allows recording geographies in close time intervals. To analyze changes in physical environment, data models and analysis tools are able to take into account the time dimension of data required. Besides geometry and thematic attributes of objects, environment can be effectively described and analyzed with the support of multimedia data. Multimedia data such as text, images, videos and sound, have the advantage of been easier to interpret. The possibility for the actors involved in the sustainability planning process to supply their own information to enrich the dialogue with local knowledge and advocate their interests is an important aspect of geospatial technology for sustainable development.

Geospatial Technologies and Management of Natural Resources

Geospatial technology changes how information is viewed and decisions are made. Wright *et al.* (2009) opines that the technology blurs the boundaries between science and non-science, leading to a form of „social power in the form of providing improved access to data and maps. Geospatial World (2015) reported that in this age of social media, world has become a global village. It reported further that geospatial technology provides effective decision-making tools for modelling and policy framework, both in scientific research and day-to-day planning. The report emphasized the agricultural issues of depleting ground water, land degradation, climate change and other similar problems that could be solved through remote sensing and other geospatial techniques. Geospatial world (2015) reported that geospatial technologies offer greater impetus to understand the matrix of natural, social, cultural variations and prepare a roadmap for future challenges. It should be established that the application of Geospatial technology is the key to overcome the two-fold challenge of ensuring sustained and increased agricultural production as well as to mitigate the environmental degradation (Geospatial world, 2015). In his inaugural address, the chief guest Dr. B S Dhillon, Vice Chancellor, Punjab Agricultural University, Ludhiana congratulated Ludhiana Chapter of ISRS and PRSC, mentioned that application of Geospatial technology in India is the key to overcome the two-fold challenge of ensuring sustained and increased agricultural production as well as to mitigate the environmental degradation (Geospatial world, 2015). Lee and Kang (2015) revealed that the proven applications of GIS and remote sensing are used in agriculture sector for crop forecasting, drought assessment, cropping system analysis, site-suitability, irrigation management, precision farming, horticultural development, environmental assessment soil resource mapping, climate change studies, etc.

According to Scholars, (such as Russi, et al 2013; Muili, et.al. 2014; Lee and Kang, 2015) geospatial technology offers a wide range of innovative and cost-effective solutions for environmental sustainability; hence, many countries now appreciate the relevance of geospatial technology in the sustenance of our environment. The relevance of environmental information is based on the degree of its availability to the end users and to what extent such information can be shared effectively with external organizations largely over the internet and other available global information infrastructure (SDI) platform (Masser, 1998; Bernhaedsen, 2002). In this regard, the emphasis should be on accessibility and distribution of available information over wide range of networks and environmental information market-place (Matambanadzo, 1999).

Application of Geospatial Technology in Sustainable Development

According to Adesina (2005) the information required on natural resources to make their exploitation sustainable with tolerable damage to the environment is one that should do the following:

a) Facilitate accurate location and definition of the geographic distribution of resources;

b) Provide data about the richness of the resources;

c) Allow a determination through interpretation on how best to explore the resources;

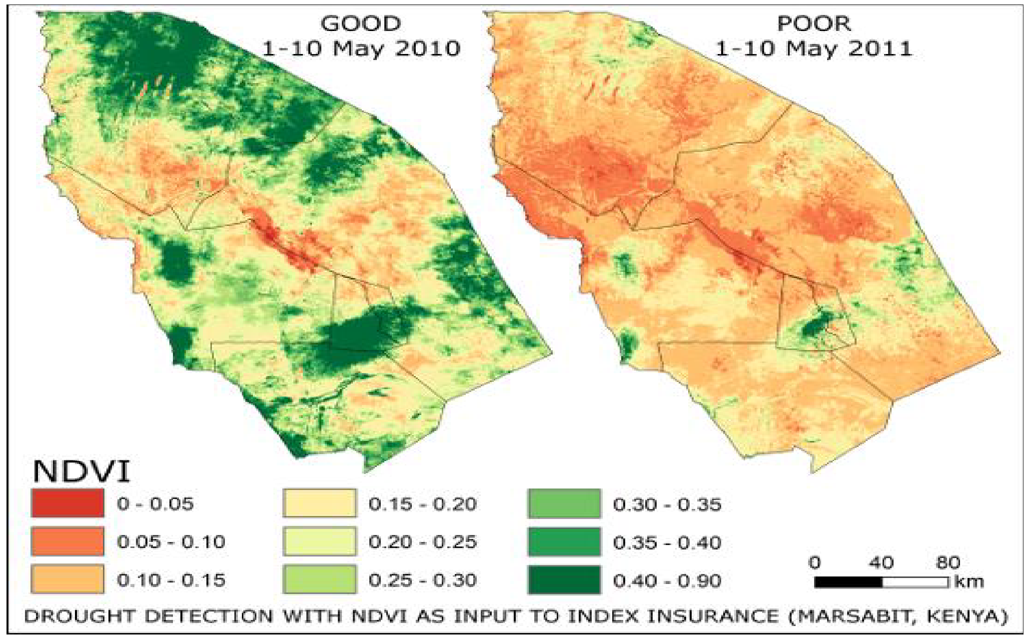
d) Permitthe identification of the actual and potential impacts of exploiting the resources for the communities located near the resource;

e) Assist in determining regional and global impacts on environment and society.

Adesina (2005) goes further to revealed that the information referred to here, is not simply the data sets generated on the environment. It is in actual fact, a product of some processing of such data sets. T his subtle distinction must be well understood to forestall the possibility of emphasizing either the data sets at the expense of the end products i.e. the information or vise-versa. The earth observing satellites generate environmental data but specialists including scientists and spatial analysts transform those data into forms that are intelligible to other people particularly the stakeholders. Therefore, the following are the some of the specific application of geospatial technologies in sustainable developments.

Agriculture and Food Security

Keeping societies stable and managing Earth's resources sustainably depend on doing a good, steady job producing and distributing food. Achieving sustainable global food security is one of humanity's contemporary challenges (West *et al.*, 2014)

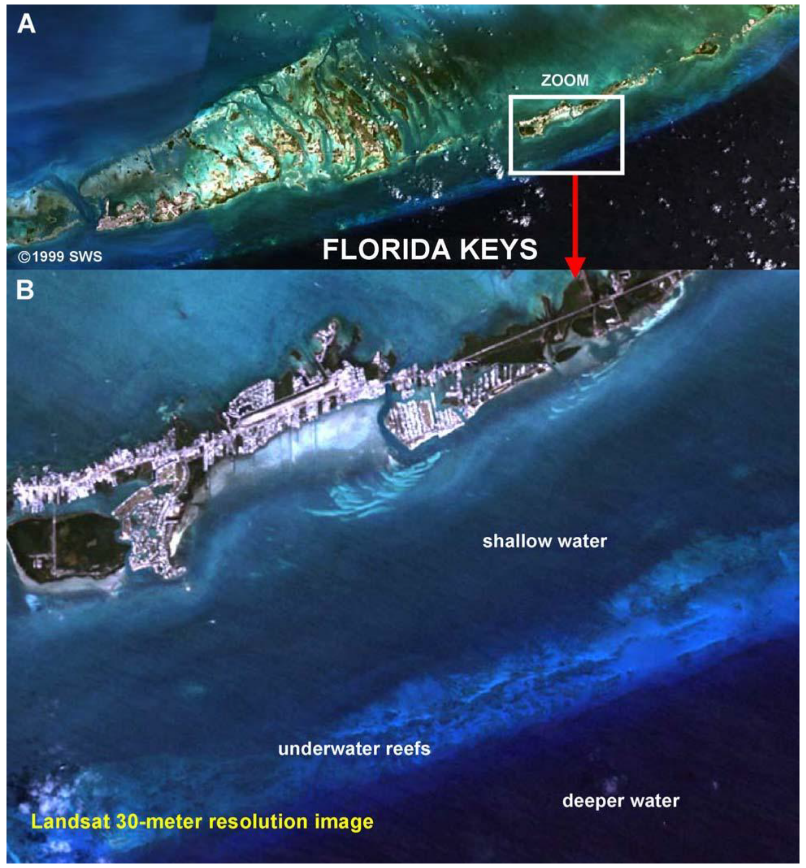


Source: www.mdpi.com/journal/remotesensing/special_issues/rs_food_production_security

Source: https://www.geospatialworld.net/article/agriculture-gets-a-makeover/

Water and Sanitation

Effective water quality monitoring is critical to water resource management programme. Without accurate, intensive and long-term data acquisition, the state of the world s water resources cannot be adequately assessed, effective preservation and remediation programs cannot be run, and program success cannot be properly evaluated. Geospatial technology advances have resulted in progress in remote monitoring capabilities for water quality. As a result, the ability to characterize dynamic hydrologic properties at adequate temporal and spatial scales has greatly improved. These advances have led to improved statistical and mechanistic modelling in monitoring of water quality trends at local, watershed and regional scales for freshwater, estuarine and marine ecosystems. In addition, they have greatly enhanced rapid (e.g., real-time) detection of hydrologic variability, recognized as a critical need for early warning systems and rapid response water related issues (Glasgow *et al.*, 2004).



(A) Remote Sensing Advanced Technology (RSAT) Lansat satellite imagery developed to assess the biological, chemical and physical properties of coastal waters and coral reefs along the Florida Keys. (B) A 30-m resolution zoom from Landsat satellite imagery showing the shallow waters and underwater reefs along the northeast coast of Florida. Source: Glasgow *et al.* (2004)

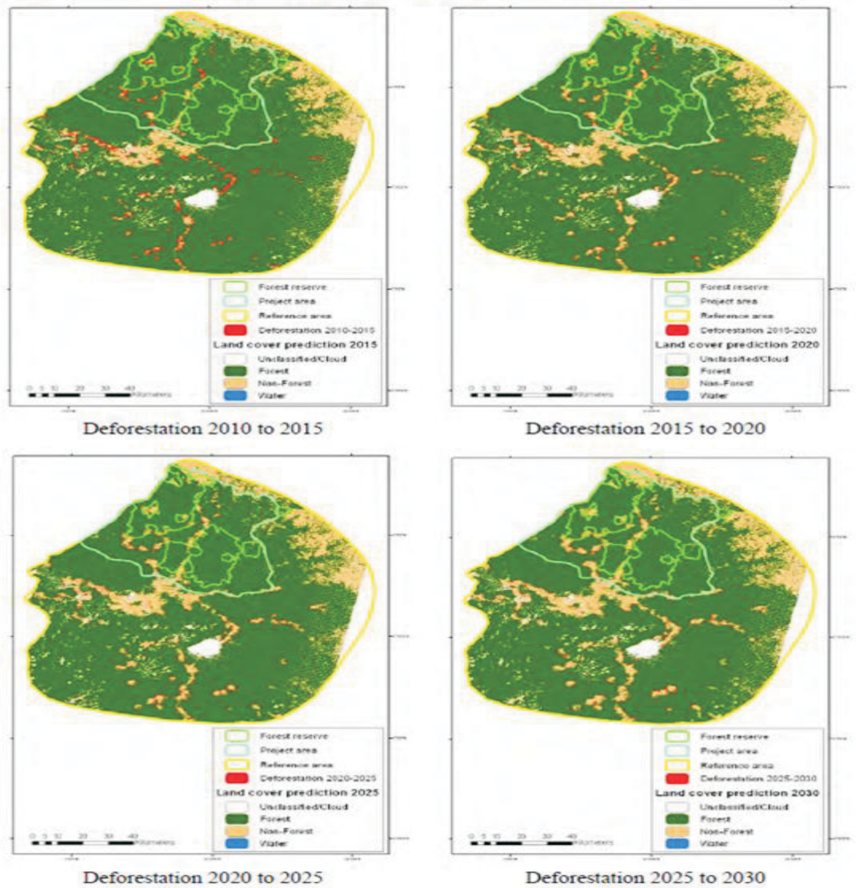
Biodiversity

Since the days of Darwin and Wallace, ecologists and evolutionary biologists have sought to explain the distribution of species or groups of species, and to discover why certain places ajre especially rich in species. Today, conservation biologists rely on estimates of species richness as they race to determine areas in which to spend limited resources in an age of rapid biodiversity decline. Scientifically sound environmental management requires frequent and spatially detailed assessments of species numbers and distributions. Geospatial technology provides imageries and data at varying scales. This allows was biodiversity assessments at local to global scales. Advances in the spatial and spectral resolutions of sensors now available to ecologists and conservationists are making it remote sensing of various aspects of biodiversity possible (Turner *et al.*, 2003). Through this technology, various direct and indirect detection and analysis of diversity, patterns and relationships can be studied. Various environmental parameters can also be incorporated in studies of diversity.

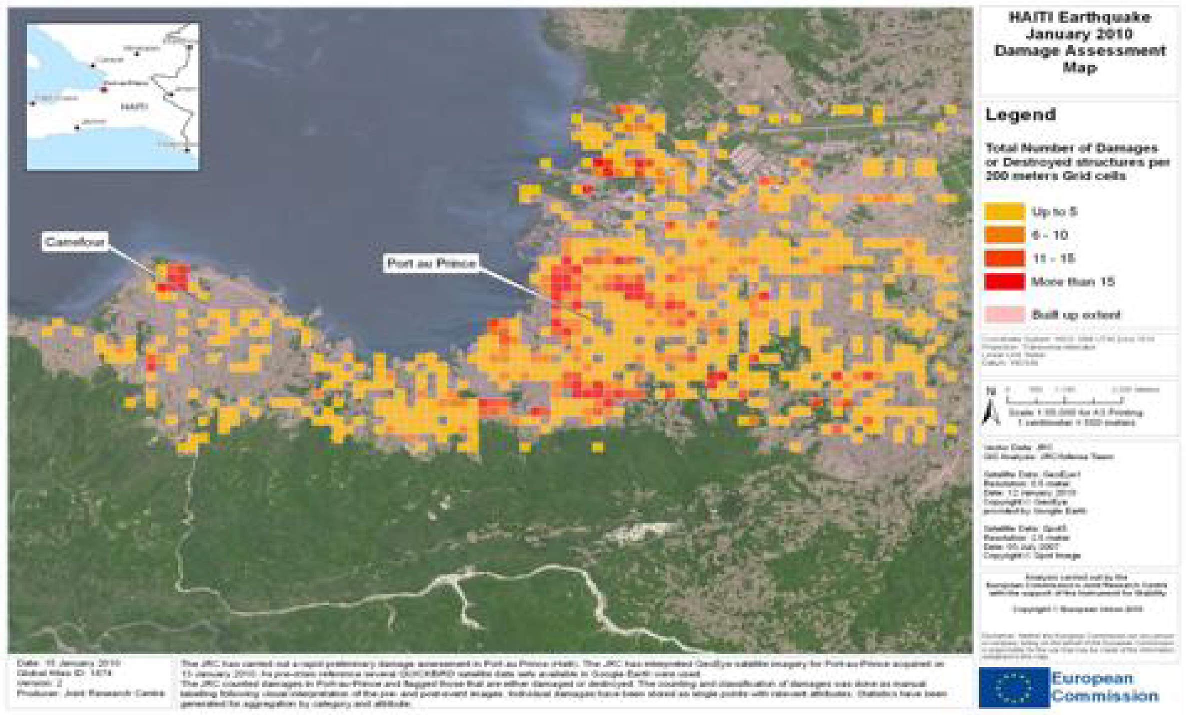
Disaster Management

conventional GIS (geographic information systems) disaster responses by governmental agencies and relief response organisations and the means for geospatial data-sharing have been transformed into a more dynamic, more transparent, and decentralised form with a wide participation (Kawasaki *et al.*, 2013). In this and in other crises, the ability to synthesise information from multiple sources and to make available up-to-date maps and location information is of critical importance in ensuring a timely and effective response. Broader use of geospatial technologies, including Geographic Information System (GIS), Remote Sensing, and Global Positioning System (GPS), provide the key for doing so in the future.

Figure 13: Deforestation predictions for 2015, 2020, 2025 and 2025



Source: http://www.conservationgis.org/scgis/2015/ScgIntl2015E.html



Source: https://www.ushahidi.com/blog/2012/03/20/predicting-locations-of-emergency-damage-during-disaster-using-vgi-data

Challenges

Data production is often the costliest part of information system development. Within GIS, beside traditional field surveying techniques, remote sensing data have proven to supply at a relatively lower cost for the end users, the possibility to collect and maintain large datasets in terms of spatial foot prints and time series. However, there is still need for improved techniques for semi-automatic data processing and thematic information production. More sophisticated data models and analysis tools are required to integrate the time dimension with geographic geometry and attributes

Many at times independent researchers in Nigeria want to carry out scientific investigations but as a result of data unavailability it becomes almost impossible to achieve this feat. This brings us to question and serious concern on the achievements of Nigeria National Geo-Spatial Data Infrastructure and the Geo-spatial data policy of the country. Information Technology (IT) also gives serious room for concern over the core activities of National Space Research and Development Agency (NASRDA) who are appointed as the data clearing house of the country and also the conflicting roles of the National Mapping Organization of Nigeria (OSGOF) in roles and responsibilities definition and specifications.

Previous researchers that have employed geospatial technology techniques fail to either properly document their data and methodologies based on a number of reasons e.g. acquisition of their respective geospatial data (geo-data) which can be very uneconomical and this could have led to them not wanting to make it readily available for other end-users who are also interested in carrying out similar investigations (lack of interoperability resulting from lack of standards and uniformity or scale problem). Adesina (2005) gave credence to the challenges of geospatial technologies in sustainable development by revealing that the main problem facing Africa in these regards is the access to and production of relevant geoinformation which requires suitable policy reorientation to recognize the needs. Africa no doubt, will continue to enjoy the benefits of advances already made elsewhere in the world in the production of geoinformation. And concluded that Africa need to develop appropriate capability that will enable Africa make meaningful contribution to the development process in the information revolution.

Conclusion

The benefit of Geospatial Technology cannot be under-estimated if researchers and stakeholders can only get it right. Studies have shown that Geospatial Technology serves as a good decision support system in environmental issues and sustainability, which has proved as an appropriate tool for managing decisions relating to environmental concerns and challenges. With the help of these modern geospatial technology, researchers and stakeholders get prepared for an increasingly global challenge as a result of increasing population with its attendant environment problems. It enhances a better means or techniques of data capture and distribution that could be done in „real time and thus will reduce the time and energy needed in data acquisition for solving environmental problems. Furthermore, it promotes participatory visualisations using the powerful tools embedded in its user interface, which help in the overall assessment of environmental impacts and also play important roles in physical planning of the environment in Nigeria. However, with the emerging trend in 3D and 4D geospatial information, visualization techniques will be better operated.

References

Adesina, F. A. (2005, April). Geoinformation and natural resources exploitation in Africa. In *UN Economic & Social Council Paper Delivered at the 4th Meeting of the Committee on Development and Information, Addis Ababa*

Barclay, H., Dattler, R., Lau, K., Abdelrhim, S., Marshall, A., & Feeney, L. (2015). Sustainable Development Goals: a SRHR CSO guide for national implementation.

Bernhardsen, T. (2002). Geographic information systems: an introduction. John Wiley & Sons.

Brundtland, G. H. (1987). Report of the world commission on environment and development:" Our common future.": United Nations.

Campagna, M. (2005). GIS for sustainable development: CRC Press.

Daly, H. E. (1990). Toward some operational principles of sustainable development. Ecological economics, 2(1), 1-6.

Ehrlich, P. R. (2000). Human natures: Genes, cultures, and the human prospect: Island Press.

Glasgow, H. B., Burkholder, J. M., Reed, R. E., Lewitus, A. J. and Kleinman, J. E. (2004). Real-time remote monitoring of water quality: A review of current applications, and advancements in sensor, telemetry, and computing technologies. Journal of Experimental Marine Biology and Ecology, 300(1), 409-448.

Geospatial World (2015). Role of geospatial technologies in managing natural resources https://www.geospatialworld.net/news/role-of-geospatial-technologies-in-managing-natural-resources/ accessed September 4, 2017

Hopwood, B., Mellor, M. and O'Brien, G. (2005). Sustainable development: Mapping different approaches. Sustainable Development, 13(1), 38-52.

Jackson, M., Schell, D. and Taylor, F. (2009). The evolution of geospatial technology calls for changes in geospatial research, education and government management. Directions Magazine, 13.

Kawasaki, A., Berman, M. L. and Guan, W. (2013). The growing role of web-based geospatial technology in disaster response and support. Disasters, 37(2), 201-221. doi: 10.1111/j.1467-7717.2012.01302.x

Lee, J. G., & Kang, M. (2015). Geospatial big data: challenges and opportunities. Big Data Research, 2(2), 74-81.

Lewthwaite, G. R. (1966). Environmentalism and determinism: A search for clarification. Annals of the Association of American Geographers, 56(1), 1-23.

Li, X. and Yeh, A. G.-O. (2000). Modelling sustainable urban development by the integration of constrained cellular automata and gis. International Journal of Geographical Information Science, 14(2), 131-152.

Masser, I. (1998). Governments and geographic information. CRC Press.

Matambanadzo, P (199). Strategic Space and Geo-information Management: The National Spatial Data Infrastructure (NSDI) concept. In: Adeniyi, P.O. (Ed.): In Geo-Information Technology Applications for Resource and Environmental Management, pp. 227-252.

Muili, A. B., Toyobo, E. A., Ige, J. O., & Ibrahim, R. B. (2014). Geospatial Analysis of Road Transport System in Peri-Urban Areas of Ibadan, Nigeria. Asian Journal of Science and Technology, 5(9), 508-515

Placet, M., Anderson, R. and Fowler, K. M. (2005). Strategies for sustainability. Research-Technology Management, 48(5), 32-41.

Rajabifard, A. and Williamson, I. P. (2001). Spatial data infrastructures: Concept, sdi hierarchy and future directions. Paper presented at the Proceedings of GEOMATICS'80 Conference.

Russi, D., ten Brink, P., Farmer, A., Badura, T., Coates, D., Förster, J., ... & Davidson, N. (2013). The economics of ecosystems and biodiversity for water and wetlands. IEEP, London and Brussels.

Sachs, J. D. (2015). The age of sustainable development. Columbia University Press.

Turner, W., Spector, S., Gardiner, N., Fladeland, M., Sterling, E. and Steininger, M. (2003). Remote sensing for biodiversity science and conservation. Trends in Ecology & Evolution, 18(6), 306-314.

Van Manen, N., Scholten, H. J. and van de Velde, R. (2009). Geospatial technology and the role of location in science Geospatial technology and the role of location in science (pp. 1-13): Springer.

West, P. C., Gerber, J. S., Engstrom, P. M., Mueller, N. D., Brauman, K. A., Carlson, K. M., Cassidy, E. S., Johnston, M., MacDonald, G. K. and Ray, D. K. (2014). Leverage points for improving global food security and the environment. Science, 345(6194), 325-328.

Wright, D., Duncan, S. and Lach, D. (2009). Social power and gis technology: A review and assessment of approaches for natural resource management. Annals of the Association of American Geographers, 99(2), 18.

Xiuwan, C. (2002). Using remote sensing and gis to analyse land cover change and its impacts on regional sustainable development. International Journal of Remote Sensing, 23(1), 107-124.