FUDMA Journal of Sciences (FJS)
ISSN: 2616-1370
Vol. 2 No. 2, June, 2018, pp 262 - 272

MONITORING THE HEALTH OF DRYLAND ECOSYSTEM ACROSS NORTH-WESTERN NIGERIA USING MULTI-TEMPORAL MODIS-NDVI REMOTE SENSING DATA.

[1, 2]Abubakar, M. J., [1]Mokhtar, J. and [1]Lam, K. C.

[1]Social, Environmental and Developmental Sustainability (SEEDS) Research Centre, Faculty of Social Sciences and Humanities, Universiti Kebangsaan Malaysia.
[2]Department of Geography, Usmanu Danfodiyo University, Sokoto, Nigeria.

Corresponding Author's email: Amj72@siswa.ukm.edu.my

ABSTRACT
The study aimed at monitoring the health of the dryland ecosystem of Northwestern Nigeria using geospatial techniques. The need for constant monitoring of the ecosystem in order to keep track of its condition viz a viz its ability to produce qualitative and adequate good and service necessary for human survival and economic development cannot be over emphasized. This is particularly so with fragile dryland ecosystem of Northwestern Nigeria due to the constant disturbances it suffers from both natural and anthropogenic drivers, which could negatively affect the structure and functions of the ecosystem. In this study, MODIS – NDVI remote sensing data was used to monitor the health of the dryland ecosystem of North-western Nigeria. Findings of the study indicate a steady decline in the ecosystem health as indicated by the declining trend of mean NDVI values from 0.56 in 2000 to 0.47 in 2016, which is positively correlated (r = 0.85) with the annual rainfall distributions of the area during the same years. Similarly, the spatial extent of the vegetation cover declined from 97% in 2000 to 84% in 2015. This has a very serious implications on the livelihood of the inhabitants of the area as it negatively affects the supply of ecosystem goods and services, threatening the livelihoods in multiple ways. Collaborations amongst different stake holders, sustainable land management practices, environmental protection policies, as well as Ecosystem-based Adaptation (EbA) are recommended as means of addressing this negative development.

Keywords: *Landscape; Ecology; Livelihood; Remote sensing*

INTRODUCTION

The need for regular monitoring of the state of ecosystem is more compelling nowadays than ever before. This is because of the increasing intensity and complexity of pressures exerted on the physical environment from both natural and anthropogenic drivers that causes change in both the structure and functions of ecosystem, either directly or indirectly. In support of this assertion, in the year 2005, the Millennium Ecosystem Assessment (MEA) reported that, about 60% of the basic ecosystem services that sustained human existence on this planet have been degraded (MEA, 2005). This was earlier reported by Rapport *et al*. (1998), a situation they described as "Ecosystem Distress Syndrome (EDS)". They maintained that, this situation manifests in both aquatic and terrestrial ecosystems. According to them, many of the world's ecosystem are unhealthy, and their functions that support human existence become impaired. This fact was further acknowledged by the Rio Declaration on Environment and Development in the year 1992. Principle number seven of the declaration, specifically called for a global partnership to conserve, protect and restore the health and integrity of the global ecosystems.

An ecosystem can undergo four different types of changes all of which could be monitored using remotely sensed data. These changes include abrupt change, seasonal change, gradual change and short-term in consequential change (Vogelmann *et al*., 2012). Abrupt changes are caused by such derivers of change in ecosystems that radically transforms landscape within a short period of time such as deforestation, wild fire, agricultural expansion and urbanisation among others. There are sufficient literatures on how these types of changes are monitored using remotely sensed data (Coppin *et al.* 2004; Clark & Bobbe, 2006; Hansen *et al*., 2008). Seasonal changes refers to the intra and inter annual fluctuations in vegetation phenology in response to changes in the climatic variables such as rainfall and temperature. These types of changes are usually more pronounced in dryland ecosystems such as grasslands with distinctive dry and rainy seasons (Vogelmann *et al*, 2012). Changes in vegetation phenology is a strong indicator of the impact of climate change and variability on ecosystem (Zhang *et al*., 2003; Walker *et al*., 2014). Another type of ecosystem change which is the focus of this study, is the gradual change which relate to subtle changes taking place in some components of ecosystem such as vegetation communities that are beyond normal phenological cycles (Vogelmann *et al.,* 2012). These may include such changes as vegetation damage due to pest and disease, overgrazing, natural succession, climate-induced shifts in biomes as well as extreme climatic events such as droughts and flooding. The overall impacts of these kind of changes can to a large extent affect ecological processes including micro-climate, carbon balance, biogeochemical cycles and biodiversity (Beck *et al*., 2007; Kennedy *et al*., 2010; Vogelmann *et al*., 2012). Lastly, short-term in consequential changes could results due to a number of events capable of influencing the spectral properties of some components of ecosystem such as vegetation. Although generally considered as having no long-term ecological importance, such events may include rainfall events, wind and light frost or snow, all of which could affect spectral properties of some components of ecosystem at the time of data acquisition thus, causing a noise that can affect the spectral properties of the data as well as the results of the data analysis (Lord *et al*., 1985; Fuller & Ottke, 2002).

Of the four types of vegetation changes described above, this paper focuses on the gradual ecosystem changes and seek to monitor the subtle decrease or increase in the spatial extent of vegetation cover as well as vegetation vigor in the dryland ecosystem of North-western Nigeria from the years 2000 to 2015. This type of information can give an insight into the trend and magnitude of gradual ecosystem change that are not easily discernible, how it affects the supply of essential ecosystem goods and services, its potential causes as well as its impacts on the livelihood of the inhabitants of the area. This is particularly handy in realisation of the fact that, as part of global ecosystem, the fragile dryland ecosystem of North-western Nigeria has over the years, suffers some sort of ecosystem distress syndromes which threaten both its survival as well as the provision of basic ecosystem goods and services upon which human survival and economic development depends (MEA, 2005; Jibrillah 2012). Some of the causes of ecosystem distress in the area includes such natural factor as climate change and variability resulting notably from increased temperature, declining and changing pattern of rainfall, shortening of growing season, land degradation, as well as anthropogenic forces emanating from unsustainable resource exploitations such as deforestation, over cultivation, overgrazing, bush burning etc. all of which are fuelled by the rapid population growth leading to increased demand for ecosystem goods and services (Jibrillah, 2012). This underscores the need for frequent monitoring and assessment of the state of ecosystem in the area to support appropriate preventive and restorative measures to protect the health and integrity of the already fragile ecosystem in the area.

NDVI indicators such as annual maximum NDVI and NDVI annual Average have been used as indicators of vegetation Vigor (Cramer *et al*. 1999; Rapport, 1999; Chen & Wang 2005; Suo *et al* 2008; Chen *et al*, 2010). NDVI is derived from the ratio of red and near infrared reflectance and is based theoretically on the fact that, vegetation chlorophyll absorbs red rays of the electromagnetic spectrum (EMS), while mesophyll leaf structure scatters near infrared rays of EMS, leading to low reflectance in red and high reflectance in the near infrared regions of the EMS, the ratio of which is used to discriminate vegetation from other types of land cover. NDVI values ranges from -1 to +1, with positive values representing vegetated areas, while negative values corresponding to areas that are devoid of vegetation cover. NDVI values positively correlate with the vegetation health and productivity. That is the higher the NDVI values, the more healthy and productive the vegetation (Chen *et al*., 2010; Pettorelli, 2014).

Vegetation vigor, which can be measured by ecosystem's primary productivity, is one of the major indicators of ecosystem health (Rapport *et al*. 1998; Zhao *et al*. 2014). This is because, vegetation play vital roles in stabilising global ecosystems. It provides the base and support to all life forms and plays a significant role in the global climate system. Generally, vegetation through its important role of primary production, provides food and habitat to all other biotic components of the ecosystem. Specifically, it provides food, shelter and raw materials to man, pasture to livestock, protects soil from erosion and provides fuel woods amongst other things to the inhabitants of the semi-arid environment of Sokoto (Zhigila *et al.* 2015; Adegboyega *et al*. 2016). Periodic monitoring of vegetation vigor will therefore provide a reliable information on the health status of a given ecosystem for informed policies and actions. In this study, Normalized Difference Vegetation Index (NDVI) derived from the Moderate Resolution Imaging Spectrometer (MODIS) on board TERRA/EOS (MOD13Q1.V6) was used to monitor the health of dryland ecosystem of North-western Nigeria. The aim is to highlight and assess those subtle changes in the ecosystem that can hardly be noticed without making a conscious effort to monitor and assess them. NDVI is commonly used in assessing and monitoring different aspects of ecosystem such vegetation vigor, (health and productivity), ecosystem stresses such as diseases, droughts and wild fires as well as disturbances from other forms of drivers of change (Xu & Guo, 2015).

STUDY Area

The study area comprises the three states in the extreme North-western Nigeria, namely Sokoto, Kebbi and Zamfara states. Together, they occupied approximately a total land area of 131, 600km^2, stretching from latitudes 11° to 13° 30' North of the equator and Longitudes 3° to 7°30' East of the Greenwich Meridian (Figure 1). The area is characterized by tropical continental climate with marked alternating wet and dry seasons, high temperatures and low variable rainfall. Temperatures are generally high all year round and could reach as high as 39^{o}C between the months of April to June. Rainfall is erratic and low both in amount and duration. Average annual rainfall hardly exceeds 600 to 700mm which usually, falls between the months of May to September. Vegetation type is typical of Sudan Savannah dominated by grasses and stunted thorny shrubs that are interspaced by the drought resistant trees such as acacia, locust bean, Shea-butter and baobab. (Abdullahi et al. 2014; Davis, 1982). In many areas however, the ecosystem is largely dominated by man through such activities as crop cultivation, grazing, fishing and other resource exploitations. This couple with the unfavourable climatic conditions makes the ecosystem of the area very fragile and susceptible to both direct and indirect drivers of change that could be natural or anthropogenic. Dominant economic activities in the area includes agriculture, animal husbandry and fishing along major rivers and stream which are largely seasonal in their flow.

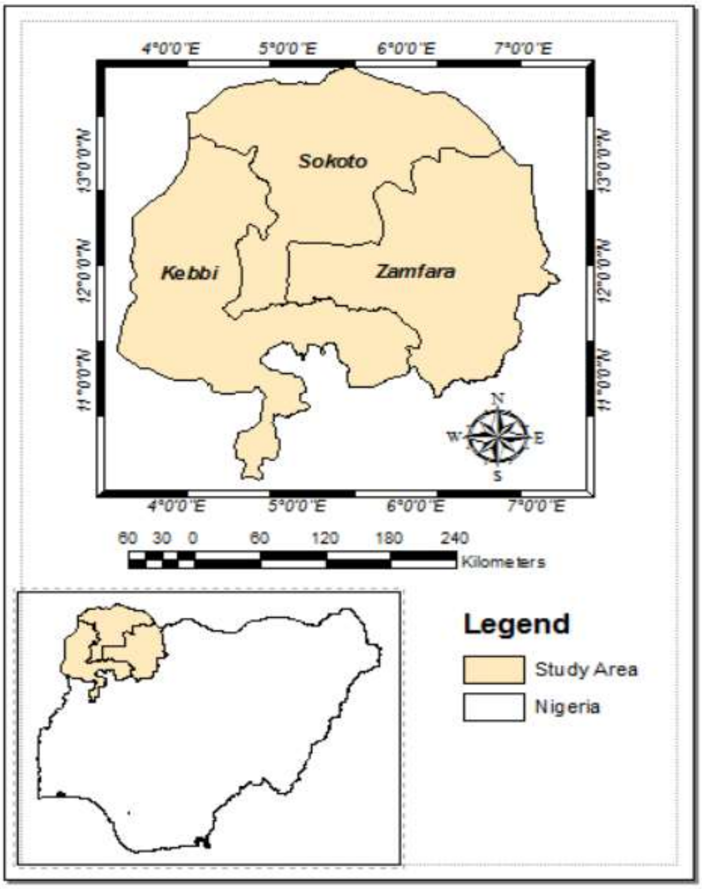

Fig. 1: The Study Area

MATERIALS AND METHODS

The satellite data used in this study is the Moderate-resolution Imaging Spectroradiometer (MODIS), on board NASA's Terra (EOS AM) and Aqua (EOS PM) satellites. MODIS Normalised Difference Vegetation Index (NDVI) is one of the products of MODIS that is designed to provide consistent spatial and temporal comparisons of vegetation condition using blue, red and near-infrared reflectance captured at 469 nanometres, 645 nanometres and 858 nanometres respectively (Didan, 2015). The data is presented using 16 days composite and 250m spatial resolution computed from the atmospherically corrected bi-directional surface reflectance that have been masked for water, clouds, heavy aerosols and cloud shadows. NDVI data for the 29th of August 2000, 2005, 2010 and 2015, downloaded from the official site of the United States Geological Survey (USGS) via the Earth Explorer was use for this study. The month of August was chosen because it has the highest amount of rainfall in the year and hence vegetation vigor is at its highest at the time.

All processing techniques were performed using ArcGIS software Version 10.3. These includes extraction of NDVI sub-dataset from a series of data-sets (Layers) contained in "MOD13Q1" vegetation indices data, raster calculation to rescale the data range to the original NDVI range of "From -1 to +1", re-projection of the original dataset from sinusoidal projection to WGS 84, for appropriate representation of the study area, clipping of the study area from the larger datasets (Figure 2), computations of ecosystem health indicators used in this studies such as maximum and mean NDVI values as well as calculation of percentage vegetation cover for each of the study year. GPS coordinates of some Ground Control Points (GCPs) were collected and plotted on the images as a means of identification and validation of the results, while local traditional knowledge of the study area aids the interpretation of the results. SPSS version 23 statistical package was used to compute the degree of relationship between NDVI values which represent ecosystem's condition (Health and productivity) and the total annual rainfall, while Microsoft excel was also used for plotting graphs and charts.

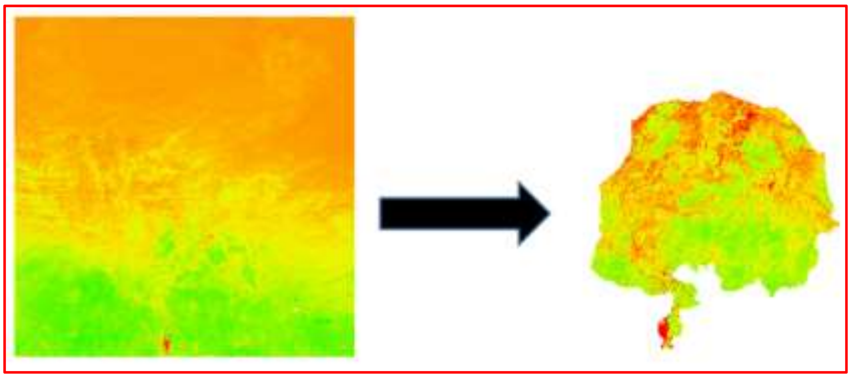

Fig. 2: Clipped Study Area.

RESULTS AND DISCUSSIONS

Mean NDVI value was used as a measure of ecosystem vigor (Health and productivity), as higher mean NDVI values represents increased photosynthetic activities and greater vegetation density which is an indication of healthy ecosystem. On the other hand, decrease in the mean NDVI values is an indication of a negative change (distress) in an ecosystem (Ahmed, 2016; Cui et al., 2013; Tarpley et al., 1988). Figure 3 show the temporal distributions of the mean NDVI values computed from the MODIS NDVI of 29th August 2000, 2005, 2010 and 2015 respectively.

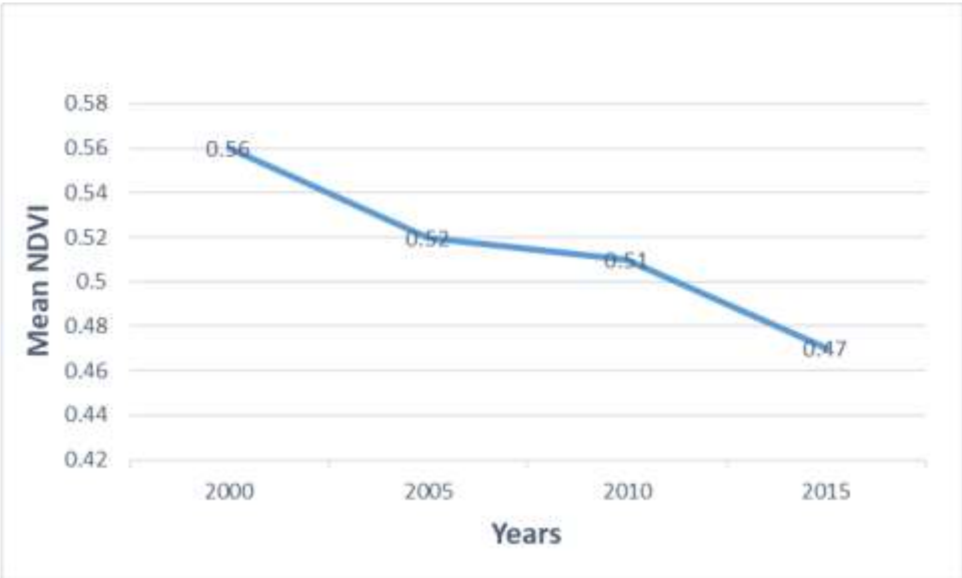

Fig. 3 Ecosystem Vigor (Health and Productivity)

The figure above clearly indicate a declining vegetation vigor (health and productivity), which is an indication of distress in the ecosystem. Mean NDVI values are steadily declining from 0.56 in 2000, to 0.52 in 2005, 0.51 in 2010 and 0.47 in 2015. Thus, as NDVI is strongly related to the photosynthetic activities of vegetation, which also determine the productivity of the vegetation, declining NDVI values is clear indication of declining health and productivity of the vegetation component of the ecosystem (Tunner, *et al*., 2003; Jackson, *et al*., 2004; Shalaby & Tateishy, 2007; Borrelli, *et al*., 2014; Olexa & Lawrence, 2014; Abdul Aziz, *et al*., 2015). Furthermore, any negative change in the function and structure of the vegetation will undoubtedly affect the structure and functions of the entire ecosystem leading to ecosystem distress syndrome (EDS) as rightly observed by Rapport *et al*. (1998). This because, all the components of ecosystem both biotic and abiotic are tightly knit together through mutual interactions and interdependence, to the extent that, a change in one component, can affect all other components. This is particularly so with the vegetation in view of its important roles in the ecosystem as a primary producer from which all other living components of the ecosystem derived their energy either directly or indirectly. In addition, vegetation also protect soil from erosion, prevent flooding and play a vital role in biogeochemical cycles and global climate system (Zhigila *et al*, 2015; Adegboyega *et al*, 2016).

A number of drivers of ecosystem change could be responsible for the above change both direct and indirect drivers. A driver is any factor, natural or anthropogenic that is capable of causing changes in an aspect of ecosystem, being it positive or negative change (MEA, 2005). Those drivers that directly affects ecosystem by influencing its processes are regarded as direct derivers. Example under this category include climate change and variability, land conversion, pest and disease and the presence of invasive species. On the other hand, those drivers that affects ecosystem indirectly only by altering one or more direct derives are called indirect derivers of change in ecosystem. Some of the indirect derivers includes population growth, cultural practices, political decisions and the likes. Climate change and variability is one of the direct drivers of ecosystem change in the study area (MEA, 2005; IPCC, 2007) and though may not be fully responsible for the above change, but a strong positive relationship (r = 0.85) is observed between mean NDVI values and annual distribution of rainfall in the area (Figure 4). Other derivers of change such as population growth, urban expansion, land use changes, pest and diseases, deforestation and other socio-cultural practice also contributed in changing the ecosystem of the area at different degrees both in spatial and temporal scales.

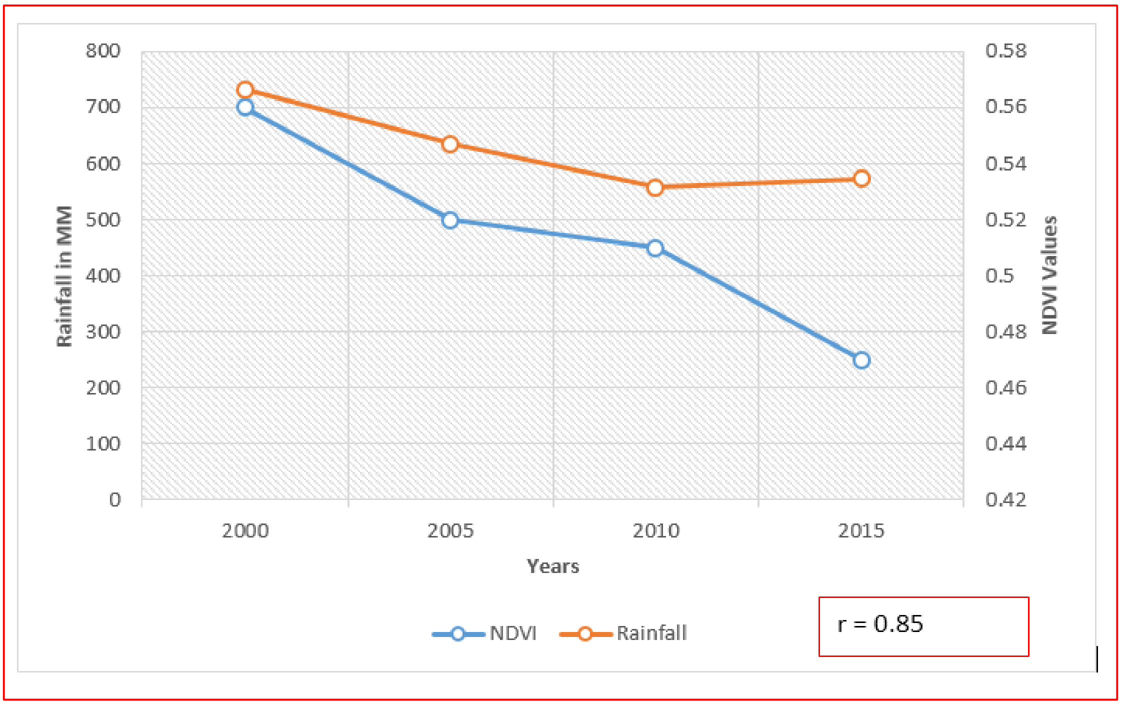

Fig. 4 Relations between NDVI and Annual Rainfall

Furthermore, in addition to the declining ecosystem vigor (health and productivity) the spatial extent of vegetation cover is also declining. Figures 5 & 6 shows the NDVI images and percentage of vegetation cover in the study years.

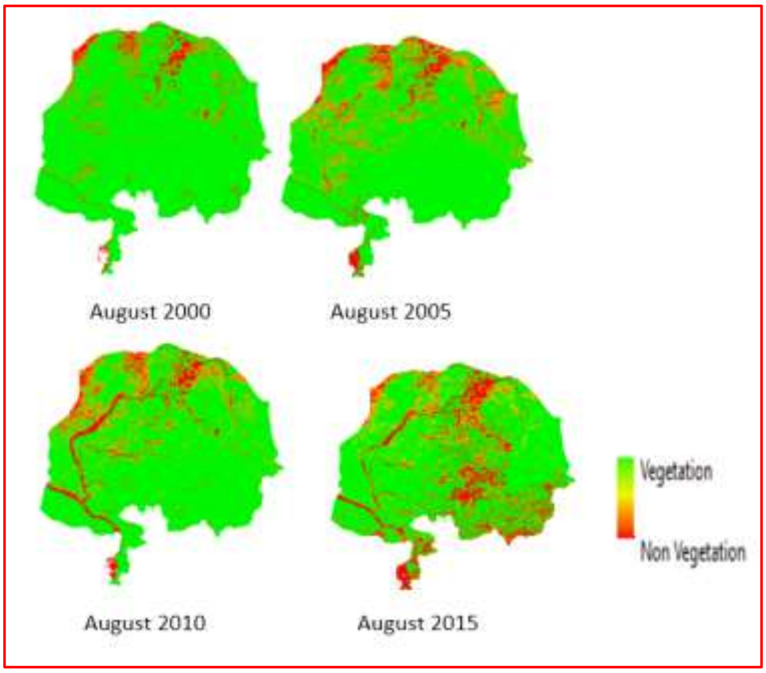

Figure 4 Trend in Land Cover

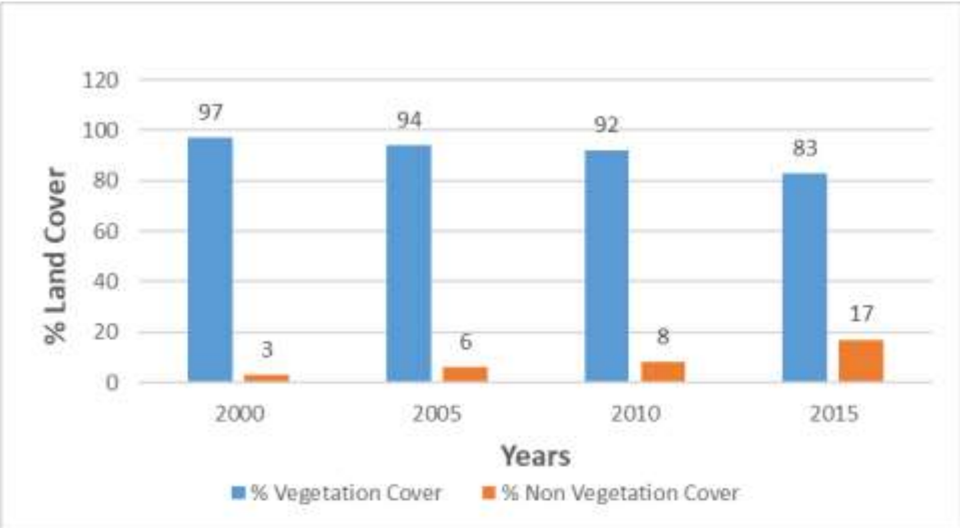

Fig. 5 Land Cover Change

From figure 5, it is evidently clear that, there is a negative change (decrease) in the spatial extent of the vegetation cover in the study area. The vegetation cover decline steadily from 97% in 2000 to 94% in 2005, 92% in 2010 and 83% in 2015. This has a very serious implication to both ecosystem and the economic development of the area considering the role of vegetation in ecosystem enumerated above. Many drivers of change could be responsible for a decline in the spatial distribution of the vegetation chief among could be population growth and climate change. The area has witnessed tremendous increase in population over the years. Sokoto state for example, which is one the three states that make up the study area has a population of 3.7 million people as reported during the 1991 National Population and Housing Census (NPC, 1993). With a growth rate of 3.0 per year, this was projected to 3.8 million and 4.7 million in 2007 and 2014 respectively (NPC, 2014). Other two states of Kebbi and Zamfara also experienced similar population growth over the same period. This expansion in the population size of the study area would no doubt increase demand and pressure on ecosystem goods and services such as housing, food, water and other residential and urban structures. This demand and pressure will in turn leads to transformations of different components of the ecosystem in the area, including the spatial extent and distribution of vegetation. Decline in the vigor and spatial distribution of vegetation could seriously affect the ability of the ecosystem to provide essential good and service upon which the inhabitant of the area depends for livelihood and overall economic development. This is particularly in view of the fact that, the vegetation of the area comprises both natural vegetation and human managed agricultural fields used for the production of different crops, mostly grains such as millet, sorghum, rice, wheat, cowpeas and the likes. It also includes grazing areas for teeming population of livestock in the area. Causes for this ecosystem distress in the area could be both natural such as climate change and variability as well as anthropogenic causes emanating from bad and unsustainable land management practices.

CONCLUSION

The result of this study revealed a clear deterioration of the ecosystem health in the North-western Nigeria. This is evident in the progressive decline in the vigor and spatial extent of the vegetation in the area as indicated by the NDVI indicators. This result is in accord with the earlier report by the Millennium Ecosystem Assessment (MEA) in 2005, which identified land degradation in the form of declining biological and economic productivity of land as the major type of ecosystem change in the dryland ecosystems. The report also states that, over 10% of the global ecosystem is degraded. Decline in the health of these vital components of ecosystem, can also negatively affect other components of the ecosystem given the fact that, an ecosystem is such a tightly knit system of living things and their natural environment that is so much interconnected to the extent that, if one component is affected, a riffle effect can be started, endangering the entire system. This will therefore no doubt affect the teeming human population in the area in many negative ways which include declining food production and forage for livestock. This will in turn, poses a serious threat to food security and livelihood in the area with other serious related consequences such as increasing poverty, malnutrition, diseases, declining household income, conflicts over scarce resources and migration.

RECOMMENDATIONS

Unless necessary preventive and restoration measures are put in place to halt this deteriorating health of the ecosystem in the area, the lives and sustainable development of the inhabitant of this are will continue to be in jeopardy. This is because, vast majority of the inhabitants of the area depends largely on the ecosystem and its goods and services for their livelihoods though such activities as crop cultivation, animal husbandry and artisanal fishing. It is recommended that both the government, individual, private and public sectors, international organisations and all stake holders should collaborate in order to embark in a holistic approach toward addressing this negative development. People should not be only taking from the ecosystem, but should to also give back to it through embarking on sustainable land and water management practices as well as formulating and enforcing appropriate environmental protection policies and laws.

Advocating, practicing and fully integrating ecosystem-based adaptation (EbA) strategy into development policies will in no small measure assist in mitigating this deteriorating condition of ecosystem health in the area. It would also equipped the people in the study area to adapt to the adverse effects of ecosystem change caused climate change and other drivers of change. EbA emphasizes the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change (CBD, 2009). It was based on the general fact that, people in all parts of the world depends on healthy and functional ecosystems and variety of services they provides such as food, clean water, soil fertility, climate regulation and other essential resources. This is particularly true with poor people in the developing nations whose livelihoods are closely related to the environment and are highly climate dependent. It is therefore, believed that, maintaining a healthy functioning ecosystems could help people and the natural world adapt to climate change effects. The practice of (EbA) involves a wide range of ecosystem management activities aimed at increasing resilience and reducing the vulnerability of people and the environment to negative effects climate change and other drivers of change in ecosystem. Some of these activities include:

- Sustainable water management, where river basins, aquifers, flood plains, and their associated vegetation are managed to provide water storage and flood regulation services.
- Sustainable management of grasslands and rangelands, to enhance pastoral livelihoods and increase resilience to drought and flooding.
- Establishment of diverse agricultural systems, where using indigenous knowledge of specific crop and livestock varieties, maintaining genetic diversity of crops and

livestock, and conserving diverse agricultural landscapes secures food provision in changing local climatic conditions.

- Strategic management of shrublands and forests to limit the frequency and size of uncontrolled forest fires
- Establishing and effectively managing protected area systems to ensure the continued delivery of ecosystem services that increase resilience to climate change and other drivers of change.
- Disaster risk reduction, where restoration of lost ecosystems such as coastal habitats (mangroves) can be a particularly effective measure against storm-surges, saline intrusion and coastal erosion.

EbA thus, represents an anthropocentric approach concerned with the way ecosystems can help people adapt to both current climate variability and future climate change. This will to very large extent help reducing vulnerability and increasing resilience to both climate and non-climate risks and provide multiple benefit to both the environment and society. Finally, regular and effective ecosystem monitoring and assessment in order keep a track of the condition of ecosystem, and to ascertain the effects of development projects on the environment, as well as the effectiveness of mitigation and adaptation policies and projects should also be put in place. The task of maintaining environmental integrity and using its diverse resources judiciously and sustainably so that it can be handed in a good , healthy and useful state to the generations yet unborn rest on all and sundry.

REFERENCES

Abdul Aziz, A., Phina, S., Dargusch, P., Omar, H. & Arjasakusuma, S. (2015). Assessing the potential of Landsat archive in the ecological monitoring and management of a production mangrove forest in Malaysia. We*tland Ecology and Management,* 23(6), 1049 – 1066.

Abdullahi, S. A., Muhammad, M. M., Adeogun, B. K. & Muhammed, I. U. (2014). Assessment of Water Availability in the Sokoto Rima River Basin. *Resource & Environment*, 4(5), 220 – 233.

Adegboyega, S. A., Olajuyigbe, A. E., Balogun, I. & Olatoye, O. (2016). Monitoring Drought and Effects on Vegetation in Sokoto State, Nigeria using Statistical and Geospatial Techniques. *Ethiopean Journal of Environmental Studies and Management,* 9(1), 56 – 69.

Ahmed, N. (2016). Application of NDVI in Vegetation Monitoring using GIS and Remote Sensing in Northern Ethiopian Highlands. *Abyssinia Journal of Science and Technology,* 1(1), 12 – 17.

Beck, P. S. A., Jonsson, P., Hogda, K. A., Karlsen, S. R., Eklundh, L. & Skidmore, A. K. (2007), A Ground-validated NDVI Dataset for Monitoring Vegetation Dynamics and Mapping Phenology in Fennoscandia and the Kola Peninsula. *International Journal of Remote Sensing,* 28, 4311 - 4330

Borrelli, P., Modugno, M., Panagos, P., Marchetti, M., Schutt, B. & Montanarella, L. (2014). Detection of harvest forest areas in Italy using Landsat imagery. *Applied Geography,* 48, 102 – 111.

Chen, Z. H. & Wang, J. (2005). Establishing Ecosystem Health Model in Arid and Semi-arid Area by using Remote Sensing Data. P*roceedings of 2005 IEEE International Geoscience and Remote Sensing Symposium*, Seoul, Korea, 25–29 July 2005, pp. 2953–2956.

Chen, Z. H., Yin, Q., Li, L. & Xu, H. (2010). Ecosystem Health Assessment by using Remote Sensing derived Data: A case study of Terrestrial Region along the Coast in Zhejiang Province. *Proceedings of the 2010 IEEE International Geoscience and Remote Sensing Symposium,* Honolulu, HI, USA, 25–30 July 2010; pp. 4526–4529.

Clark, J. & Bobbe, T. (2006). Using Remote Sensing to Map and Monitor Fire damage in Forest Ecosystems. In Wulda, M. A. & Franklin, S. E. (Eds). *Understanding Forest Disturbances and Spatial Pattern Boca Raton.* Florida: CRC Press.

Convention on Biological Diversity (CBD) 2009. Year in Review 2009. Online at: http://www.cbd.int/doc/legal/cbd-un-en.pdf. Retrieved 15/15/2017

Coppin, P., Johnckeere, I., Nackaerts, K., Muys, B. & Lambin, E. (2004). Digital Change Detection Methods in Ecosystem Monitoring: A review. *International Journal of Remote Sensing,* 25, 1565 - 1596.

Cramer, W., Kicklighter, D., Bondeau, A., I, B. M.. Churkina, G., Nemry, B., Ruimy, A. & Schloss, A.

(1999). Comparing Global Models of Terrestrial Net Primary Productivity (NPP): Overview and Key Results. *Glob. Chang. Biol.* 5, 1–15.

Cui, X., Gibbes, C., Southworth, J. & Waylen, P. (2013). Using Remote Sensing to Quantify Vegetation Change and Ecological Resilience in a Semi-Arid System. *Land,* 2, 108 – 130.

Davis, G. (1982). Rainfall and Temperature. In Abdu, P. S. 1982. *Sokoto State in Maps. An Atlas of physical and Human Resources.* Ibadan, University press.

Didan. K. (2015). MOD13Q1 MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V006. NASA EOSDIS Land Processes DAAC. Online at: https://doi.org/10.5067/MODIS/MOD13Q1.006. Retrieved 16/01/2017.

Fuller, D. O. & Ottke, C. (2002). Land cover, Rainfall and Land-surface Albedo in West Africa. *Climate Change,* 54, 181 – 204.

Hansen, M. C., Roy, D. P., Lindquist, E., Adusei, B., Justice, C. O. & Alstatt, A. (2008). A Method for Integrating MODIS and Landsat Data for ystematic Monitoring of Vegetation Cover and Change in Congo Basin. *Remote Sensing of Environment*, 112, 2495 – 2513.

Intergovernmental Panel on Climate Change (IPCC) (2007). *Summary for Policy Makers in: Climate Change 2007: The Physical Science Basis*. The contribution of the Working Group I to the Forth Association of the ICPC, Solomom, S., Quin, D., Karing, M., Chan, Z., Marquins, M., Avery, K. B., Tignnor, M. and Miller, H. L. (eds) Cambridge University Press, Cambridge, UK.

Jackson, T. J., Chen, D., Cosh, M., Li, F., Anderson, M., Walthall, C. & Doriaswamy, P. et al. (2004). Vegetation Water Content Mapping using Landsat Data derived NDWI for Corn and Soya beans. *Remote Sensing of Environment*, 92, 475 – 482

Jibrillah, M. A. (2012). The Impact of Climate Change on Education in Sokoto State in Iliya, M. A. and Fada A. G (eds) *The Impacts of Climate Change in Sokoto State, Nigeria Evidence and Challenges* UNDP/Sokoto State Government, Nigeria.

Kennedy, R. E., Yang, Z. & Cohen, W. (2010). Detecting Trend in Forest Disturbance and Recovery using Yearly Landsat Time series: 1. Landtrendr-Temporal Segmentation Algorithm. *Remote Sensing of Environment*, 114, 2897 – 2910.

Lord, D., Desjardins, R. L. & Dube, P. A. (1985). Influence of Wind on Crop Canopy Reflectance Measurement. *Remote Sensing of Environment*, 18, 113 – 123.

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

National Population Commission (NPC) (1993). The 1991 Census Result. Census News. NPC. Quarterly Publication. NPC, Nigeria

National Population Commission (NPC) (2014). Census News. NPC. Quarterly Publication. NPC, Nigeria

Olexa, E. M. & Lawrence, R. L. (2014). Performance effects of land cover type on synthetic surface reflective data and NDVI estimate for assessment and monitoring of semi-arid rangeland. *International Journal of Applied Earth Observation and Geo-information*, 30, 30 – 41

Pettorelli, N., Laurence, W. F., O'Brien, T. G., Wengmann, M., Nagendra, H. & Turner, W. (2014). Satellite Remote Sensing for Applied Ecologists: Opportunities and Challenges. *Journal of Applied Ecology*, 51, 839 – 848.

Rapport, D. J., Costanza, R. & McMichael. J. (1998). Assessing Ecosystem Health. *Three.* 13(10), 397 – 402.

Rapport, D. J. (1999) Gaining respectability: Development of quantitative methods in ecosystem health. *Ecosyst. Health.* 5, 1–2.

Rio Declaration on Environment and Development (1992). The Earth Summit: the United Nations Conference on Environment and Development (Johnson, S., ed.), Graham and Troutman/Martinus Nijhoff, London

Shalaby, A. & Tateishi R. (2007). Remote Sensing and GIS for Mapping and Monitoring Land Cover and Land Use Changes in the North-west Coastal one of Egypt. *Applied Geography*, 27, 28 – 41.

Suo, A. N., Xiong, Y. C., Wang, T. M., Yue, D. X. & Ge, J. P. (2008). Ecosystem Health Assessment of the Jinghe River Watershed on the Huangtu Plateau. *Ecosyt. Health.* 5, 127–136.

Tarpley, J. D., Schneider, S. R., & Money, R. L. (1988). Global Vegetation Indices from the NOAA-7 Meteorological Satellite. *Journal of Applied Meteorology and Climatology*, 23(3), 491- 494.

Tunner, W., Spector, S., Gardiner, N., Fladdad, M., Sterling, E. & Steininger, M. (2003). Remote Sensing for Biodiversity Science and Conservation. *Trends in Ecology and Evolution*, 18(6), 306 – 314.

Vogelmann, J. E., Xian, G., Homer, C. & Tolk, B. (2012). Monitoring Gradual Ecosystem Change using Landsat Time Series Analyses: Case Studies in Selected Forest and Rangeland Ecosystems. *Remote Sensing of Environment.* 122, 92 – 105.

Walker, J. J., Beurs, K. M. D. & Wynne, R. H. (2014). Dryland Vegetation Phenology across Elevation Gradient in Arizona, USA, investigated with Fused MODIS and Landsat Data. *Remote Sensing of Environment.* 144, 85 – 97.

Xu, D. & Guo, X. (2015). Some Insights on Grassland Health Assessment based on Remote Sensing. *Sensors,* 15, 3070 – 3089.

Zhang, X., Friedl, M. A., Schaaf, C. B., Strahler, A. H., Hodges, J. C. F., Gao, F. & Reed, B. C. (2003). Monitoring Vegetation Phenology using MODIS. *Remote Sening of Environment.* 84, 471 – 475.

Zhao, X., Hu, H., Shen, H., Zhou, D., Zhou, L., Myneni, R. B., & Fang, J. (2014). Satellite-indicated long-term vegetation changes and drives in the Mongolian Plateau. *Landscape Ecology,* 30. (9), 1599 -1611

Zhigila, D. A., Sawa, F. B. J., Abdul, S. D., Abba, H. M.and Tela,M. (2015). Diversity and phytogeographic Investigation into the Woody Plants of West Tangaza Forest Reserve, Sokoto State, Nigeria. *International Journal of Plants Research,* 5(1), 73 – 79.