OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.

INAUGURAL LECTURE SERIES 265

ENVIRONMENT, ORGANISMS, INTERACTIONS AND CONTINUED LIFE ON EARTH

By

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An Inaugural Lecture Delivered at Oduduwa Hall,
Obafemi Awolowo University, Ile-Ife, Nigeria
On 22nd July, 2014

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Inaugural Lecture Series No 265

Obafemi Awolowo University Press Limited,
Ile-Ife, Nigeria.

ISSN 0189-7848

Printed by
Obafemi Awolowo University Press Limited,
Ile-Ife, Nigeria.

INTRODUCTION.

The Vice-Chancellor sir, distinguished guests, ladies and gentlemen, I never dreamt or thought I would ever be an academic but by divine providence ("Chim" in Igbo Language); I became one and today; I stand before you to render an account of my little contribution to knowledge. I thank the Almighty God for this day.

Living organisms and their non-living environment are inseparably interrelated and interact upon each other. Any community of living organisms (plants, animals and microbes) in conjunction with the non-living components of their environment (things like air, climate, minerals, soil, and water) interacting as a system so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles within the system is an ecological system or ecosystem (Tansley, 1934; Moles, 1999; Chapin et al., 2002; Schulze et al., 2005; Smith and Smith, 2012). Thus, an ecosystem consists of two major parts, the biotic (living) and abiotic (non-living). The biotic component consists of all interacting organisms living in an area. In aquatic and terrestrial ecosystems, they consist of autotrophs (producers) and heterotrophs (consumers and decomposers). The producers, mainly green plants and algae, trap solar energy and convert it into chemical energy in form of organic matter through the process of photosynthesis. They also include chemosynthetic bacteria, all of which obtain energy by oxidizing simple inorganic compounds. The consumers are all animals that eat plants or one another while the decomposers, often microorganisms such as bacteria and fungi and detritivorous animals function in an ecosystem by breaking dead organic matter (plant and animal material) into simpler components and thus returning nutrients to autotrophs to re-use and carbon dioxide to the atmosphere (or water) where it can be used for photosynthesis. Decomposers are therefore important in recycling matter within an ecosystem. In the absence of decomposers, dead organic matter would accumulate in an ecosystem and nutrients and atmospheric carbon dioxide would be depleted (Chapin *et al.*, 2002). All heterotrophs (consumers and decomposers) directly or indirectly depend upon autotrophs for energy because it is the material produced by autotrophs that serves as food for heterotrophs. Humans are also a component of these ecosystems and in many regions are the dominant organism. Humans depend on ecosystem properties and on the network of interactions among organisms and within and among ecosystems for sustenance, just like all other species.

The living organisms form the biological or living resources. The most valuable aspect of the living resource is the diversity of organisms on Earth known as biodiversity. Human survival is utterly dependent on biodiversity. The abiotic component is the physical environment with which the organisms of the ecosystem interact. The biotic and abiotic components exchange energy and materials (Smith, 1996). The abiotic factors are usually the governing forces of environment, one organism ordinarily affecting others by the ability to modify the abiotic environment. The abiotic factors influence the well-being and distribution of organisms and the functions of the ecosystem. For instance, temperature and moisture acting together determine in large measure the climate of a region and the distribution of plant and animal life on land and in water.

Every organism that lives in an ecosystem is dependent on the other organisms and the abiotic factors of the ecosystem. The organisms depend upon the flow of energy and the circulation of materials (mainly mineral elements) through the ecosystem (Smith, 1996). Both influence the abundance of organisms, the rate of their metabolism, and the complexity and structure of the ecosystem (Smith, 1996). Energy and materials flow through the ecosystem together as organic matter, one cannot be separated from the other. The flow of energy is unidirectional and non-cyclic and materials flow is cyclic. The cyclic flow of materials paid for by the unidirectional non-cyclic flow of energy, keeps ecosystems functioning.

The ultimate source of energy for all ecosystems (thus for all organisms) is solar radiation, which is trapped by autotrophic green plants and converted into chemical energy in the form of organic compounds in the plant themselves by the process of photosynthesis and passed along an ecosystem's food chain. The solar radiation is also the source of heat energy which warms the earth, heats the atmosphere, drives the water cycle and produces the currents of air and water. Plants absorb nutrients from soil and water and in some cases, from the atmosphere (Smith, 1996). The basic source of the nutrients is the physical and chemical weathering of bedrocks and deposits. Other sources are biological fixation (nitrogen fixation), precipitation and atmospheric fall out (dust) and human inputs in the form of fertilizer applications. These nutrients are lost from the ecosystem through soil erosion, leaching of elements deep into soil profiles beyond the reach of plant roots, water flow into streams and rivers, extraction for resource use (such as guano), fire and removal of harvested plant material and animal bodies. In these cases, the output of minerals from the ecosystem exceeds the input and this often leads to ecological in balance and soil depletion. These elements move through the ecosystem in biogeochemical cycles which involve chemical exchanges of elements among atmosphere, rocks of Earth's crust, water and living organisms (Smith, 1996).

Biogeochemical cycles sustain the function of the biosphere and link ecosystems and climate by regulating chemical concentrations in soil, biota, atmosphere and ocean (Fischlin *et al.,* 2007). However, man through the ages has, to varying degrees had impact on biogeochemical cycles. Man has injected into the biosphere natural substances such as nitrogen, sulphur, carbon, mercury and lead compounds in quantities greater than the system can handle. He further upset biogeochemical cycles by throwing in such unnatural substances as chlorinated hydrocarbons, which circulate through local and global systems. These materials injected into the biosphere in great quantities have affected the functioning of ecosystems and have had adverse effect on plants, animals and man as pollutants.

1.1 ECOSYSTEM TYPES, SOCIO-ECONOMIC IMPORTANCE AND DISTURBANCE

The abundance of water divides the environment into aquatic and terrestrial ecosystems. The aquatic ecosystems include marine (saltwater, seas) and freshwater (rivers, steams). The world major terrestrial ecosystems are tropical forest, savanna, desert, temperate grassland, temperate deciduous forest, coniferous forest, polar and high-mountain ice, tundra (arctic and antarctic) and chaparral. Each ecosystem has its own climate, soil, plants and animals. Of these terrestrial ecosystems, the tropical forests cover about 2-5 per cent of the Earth's surface and house an estimated 50 per cent of all life (plant and animal species) on the planet (Aiken and Leigh, 1992; Butler, 2006). The tropical forests also store more aboveground carbon than any other ecosystem. Forests and savannas dominate the total geographic area (923,768 km^2) of Nigeria.

These ecosystems provide many goods and services that are of vital importance for the functioning of the biosphere, and provide the basis for the delivery of tangible benefits to human society (Fischlin *et al.*, 2007). Ecosystem services are indispensable to the wellbeing of all people everywhere in the world. The human economy depends upon the services performed "for free" by ecosystems. Hassan *et al.* (2005) define these ecosystem services which are the benefits people obtain from ecosystems to include supporting, provisioning, regulating and cultural services.

These goods and services provided by ecosystems are important contributors to wealth at the household, community, national, sub-regional, regional or even global level. Many efforts have been made to use standard economic techniques to estimate the economic value of ecosystem goods and services (e.g. Costanza, 2000, 2001; Reid *et al.*, 2005). The estimate from these techniques, for example, for the value of ecological goods and services for entire biosphere is US$16-54 trillion ($10^{12}$), with an average of US$33 trillion each year as against a global Gross Natural Product (GNP) of US$18 trillion (Costanza et al., 1997). Biodiversity underpins most ecosystem goods and services. Loss of biodiversity therefore has considerable negative consequences for the provision of these goods and services.

Ecosystems are increasingly being subjected to disturbance, human-induced and natural, which is altering the capacity of ecosystems to provide their goods and services for continued life on earth. Chapin *et al.* (2002) define disturbance as a relatively discrete event in time and space that alters the structure of populations, communities and ecosystems and causes changes in resource availability or the physical environment. Natural disturbance categories include wildfires, hurricanes, floods, droughts, pathogens, disease, lava flows and insect outbreak. Anthropogenic or human-induced disturbance categories include logging, deforestation, clearing for cultivation, chemical pollution, alien species introductions and other extractive use of goods and increasing fragmentation and degradation of natural habitat. Anthropogenic and natural disturbances affect a significant proportion of Earth's ecosystems and climate change is generally increasing the incidence of natural disturbances (Dale *et al.*, 2001). Climate change will increasingly exacerbate the effects of these disturbances. For instance, Fischlin *et al.* (2007) stated that during the course of this century the resilience of many ecosystems (their ability to adapt naturally) is likely to be exceeded by an unprecedented combination of change in climate, associated disturbances (e.g. flooding, drought, wildfire, insects, ocean acidification) and in other global change drivers (especially land-use change, pollution and over-exploitation of resources) if greenhouse gas emissions and other changes continue at or above current rates. Projected changes from these disturbances may increase the likelihood of ecological surprises that are detrimental for human well-being (Burkett *et al.*, 2005, Duraiappah *et al.*, 2005) such as rapid and abrupt changes in temperature and precipitation, leading to an increase in extreme events such as floods, fires and landslides, increases in eutrophication, invasion of alien species or rapid and sudden increases in disease (Carpenter *et al.*, 2005).

Disturbances, both human-induced and natural, play an important role in ecosystem composition, structure and ecological processes. Disturbances can greatly affect ecological processes such as flow of energy and nutrient cycling through organisms and the physical environment. Ecosystem disturbances also alter ecosystem productivity and resource availability (light and nutrient availability) for organisms on large spatial and temporal scales. Furthermore, ecosystem disturbances can also contribute to the current rise of carbon dioxide (CO_2) levels in the atmosphere which has global implications for climate change, which can in turn affect a vast number of species on earth and the functioning of virtually all ecosystems. For instance, fire effects on forests include acceleration of nutrient cycling, mortality of individual trees, shifts in successional direction, induced seed germination, loss of soil seed bank, increased landscape heterogeneity, changes in surface-soil organic layers and underground plant root and reproductive tissues, and volatilization of soil nutrients (Whean,1995).

Over the past 50 years, humans have converted and modified natural ecosystems more rapidly and over larger areas than in any comparable period of human history (e.g. Steffen *et al.*, 2004).

These changes have been driven by the rapidly growing demands for food, freshwater, timber and fuel (e.g. Vitousek *et al.*, 1997) and have contributed to substantial net gains in human well-being and economic development, while resulting in a substantial and largely irreversible loss of biodiversity and degradation in ecosystems and their services (Reid *et al.*, 2005). These human-induced and natural disturbances of ecosystems are followed by ecological succession, that is, a "directional change in ecosystem structure and functioning resulting from biotically driven changes in resources supply" (Chapin *et al.*, 2002). Ecosystems that experience very severe disturbance such as volcanic eruption undergo primary succession and take a long time to recover while ecosystems that experience less severe disturbance like forest fires, result in secondary succession and recover more quickly (Chapin *et al.*, 2002). Ecosystems are dynamic entities which are always subject to periodic disturbances and are in the process of recovering from some past disturbance. As ecosystems recover from disturbance they try to return to their former composition, structure and ecological processes.

Mr. Vice-Chancellor sir, it is the impact of human activities on ecosystems and the processes that go on in ecosystems recovering from disturbances that I have spent my working career in this University, studying with the aim of understanding these processes for effective management of these ecosystems for the benefit of man. These studies are summarized under the following headings.

2.0 CONTRIBUTION TO KNOWLEDGE

2.1 Savanna functioning, structure and management.

Savannas are vegetation stands with continuous grass cover and trees or shrubs varying in density, frequently with twisted stems. Most of the woody species possess some degree of fire-tolerance.

Savannas are associated with tropical areas where there is an annual dry season of sufficient duration and intensity that most of the woody plants shed their leaves, and grasses dry out. This accumulation of dry fuel permits fires every year and the fires help prevent complete domination by the woody plants (Scholes and Hall, 1996). Savannas cover 48.53% of Nigeria total geographic area of 923,768 km^2 (FEPA, 1993), support large number of herbivores, possess significant faunal diversity and constitute the main rangeland of the country, providing fodder for wild and domestic animals.

An important ecological and agriculture problem in range management and agroforestry in savannas and similar regions is whether to clear savanna vegetation of trees to improve savanna herbaceous productivity or not. In farming in savanna the usual practice is to completely clear the vegetation preserving valuable fruit trees such as *Parkia biglobosa, Vitellaria paradoxa, Prosopis africana and Vitex domiana* and well grown trees such as *Afzelia africana* and *Daniellia oliveri* which are used in making such articles as farm implements and mortars. Several researchers (Walker *et al.*, 1972; Afolayan and Fafunsho, 1978) have advocated the retention of trees and shrubs while managing savanna habitats for livestock and wildlife because of their beneficial effect. Other researchers (Edroma, 1979; Brinckman and de Leeuw, 1979) have suggested the removal of trees to improve rangeland utilization and increase fodder supplies.

In order to address the above problem we (Professor Isichei and I) carried out studies on savanna vegetation floristics and structure (Muoghalu and Isichei, 1991a) and the effect of trees on the productivity and structural constituents of forbs and grasses in Nigerian Guinea savanna under the auspices of Nigerian Man and Biosphere Committee (Muoghalu and Isichei 1991b; Isichei and Muoghalu, 1992; Muoghalu and Isichei, 1994; Muoghalu, 1996). The results from these studies showed that Guinea savanna vegetation consists of a ground layer made up of grasses and forbs and three tree layers consisting of trees above 7 m high, those 3-7 m and others less than 3 m being dominant (Muoghalu and Isichei, 1991a). The number of forb species is greater than the number of grass species (almost double the number of grass species). The yield of some forb species shows a tendency of being higher under tree canopy than in open though no statistical significance can be shown (Muoghalu and Isichei, 1991b). Trees in savanna do not have a significant effect on the overall mean yield of grass species (Muoghalu and Isichei, 1994). However, yield under a tree canopy may be higher than in the open depending on the proportionate contribution of the following grass species, *Andropogon gayanus, Hyparrhenia smithiana, Pennisetum polystachion, Rottboellia cochinchinensis* and *Setaria bartata* which occur more under tree canopies than in the open (Muoghalu and Isichei, 1994). Grass and forb yields were significantly higher under canopies provided by trees taller than 7 m than under shorter canopies. There was no significant difference between percentage crude protein, fibre and lignin in plants growing under tree canopies and those in the open (Muoghalu and Isichei, 1991b, 1994). Soils under tree canopies have significantly higher levels of organic matter, calcium, magnesium, potassium, total exchangeable bases, cation exchange capacity and pH than those in open grasslands (Isichei and Muoghalu, 1992). Trees 7 m and above had more influence on soil properties than smaller trees.

The results of the above studies indicate that trees in savanna have a beneficial effect on soil nutrient status and yield of grass and forb species with canopies provided by trees above 7 m leading to significantly higher yield than lower canopies. Therefore, the common practice of clearing all woody trees in order to establish farms and improve rangeland should be reconsidered. The practice not only removes these beneficial effects of trees such as the provision of shade for grazing animals, habitat for birds and wildlife and browse for livestock and wildlife for several months in the dry season when the grasses and forbs are not available. Thus, trees must be taken into consideration in managing savanna and similar ecosystems as rangeland.

2.2 FOREST DISTURBANCE AND TREE POPULATION DYNAMICS

Forests cover a total of 41.6 Mkm^2 (about 30 % of all land), with 42% in the tropics, 25% in the temperate, and 33% in the boreal zone (Sabine *et al., 2004)*. FAO estimates that there were 1803 million ha of tropical forest in 2000, 49% in tropical America, 34% in tropical Africa and 16% in tropical Asia (from country estimates; FAO, 2001). These forests are important for climate change mitigation (Watson *et al.*, 2000), agricultural uses (Fischlin *et al.*, 2007) and goods and services they provide to man. A large and growing proportion of these forests has been and is being affected by major disturbances, anthropogenic and natural. Globally, secondary forests recovering from anthropogenic disturbances such as agriculture and wood harvesting cover an estimated 27 million km^2 (Hurtt *et al.*, 2011), and an estimated 1.2 million km^2 are in use as forestry plantations (Kirilenko and Sedjo, 2007). In addition, natural disturbances such as fires, storms, droughts and insect outbreaks affect a significant proportion of these forests. Climate change is generally increasing the incidence of natural disturbances (Dale *et al.*, 2001), including fires (Westerling *et al.*, 2006) and biotic disturbances such as insect outbreaks (Evangelista *et al.*, 2011; Hicke *et al.*, 2012). Following major disturbances, natural or anthropogenic, such as hurricanes, fires, logging, swidden agriculture or cattle raising activities several attributes of forest structure, composition and function try to recover through forest regeneration called ecological succession. A complete understanding of the dynamics of and the factors that influence tropical forest change undergoing natural regeneration following major disturbances is necessary. This is because of the important roles of such secondary forests in the maintenance of species diversity, as different species use forests of different ages as habitat patches (Anderson-Teixeira *et al.*, 2013), in climate regulation as forests recovering from disturbance are strong C sinks and play an important role in global C cycle (Running, 2008; Pan *et al.*, 2011) and as sources of timber and non-timber products. Furthermore, understanding distribution patterns in the secondary forests such as those of species composition and diversity helps guide appropriate planning and effective decision-making for ecosystem management and conservation. Currently, there is paucity of long-term vegetation dynamics study of tropical forest recovery following anthropogenic and natural disturbances.

In early 1983, there was fire incident that burnt the secondary rain forest within the Biological Gardens of Obafemi Awolowo University, Ile-Ife. The fire occurred after species listing and girth measurements for woody species had been completed in a 50 m x 50 m area of the forest demarcated in January 1983 for a baseline study of tree girth increases and litter deposition patterns. The fire disturbance provided a site and an opportunity to study tree population dynamics and nutrient cycling of tropical forest undergoing natural forest regeneration after it has been disturbed by fire. Five surveys have been carried out in the forest in 1984 (1 year), 1997 (14 years), 2001(18 years) and 2008 (25 years) respectively after the fire to assess changes in species composition, mortality, recruitment and general structure of the forest. The analysis of data from these surveys showed there had been changes in tree species composition, mortality and recruitment rates and structural characteristics of this forest in its course of succession after the fire disturbance (Odiwe and Muoghalu, 2001; Muoghalu, 2006 and Nwosu, 2010). While the different taxons (number of species, genera and families) increased after fire, the number of species peaked in 25 years after the fire and dropped 18 years after (Table 1). The number of genera and families continued to increase and peaked 25 years after (Table 1). The species diversity which peaked (H^1=3.41) 14 years after the fire in 1997 has dropped to 2.050, 25 years after the fire (Table 1).

Table 1. Comparison of some structure and diversity parameters of the secondary lowland rain forest in Ile-Ife, Nigeria before and after ground fire.

Parameter	before fire 1983	1 year after 1984	14 years after 1997	18 years after 2001	25 years after 2008
Stem density (ha^{-1})	1516	3192	2416	10,064	4332
Basal area (m2 ha^{-1})	22.51	13.36	20.07	24.26	14.62
Species richness (0.25 ha^{-1})	37	40	71	63	74
Number of genera	37	37	56	56	62
Number of families	22	22	25	27	29
Shannon-Wiener Index of diversity (H^1)	2.98	1.07	3.41	3.07	2.50
Annual mortality (% $year^{-1}$)	-	-74.5	2.1	0	-5.16
Annual recruitment (% $year^{-1}$)	-	74.5	-2.02	35.7	5.6

The density of the plants fluctuated through the years with the highest density of 10,064 plants ha^{-1} recorded 18 years after (Table 1). There were changes in the densities of individual species which brought about changes in the dominance of species in the plot. The highest basal area of the woody plants in the plot was recorded 18 years after the fire (Table 1). The annual mortality rates in the plot showed there was no overall annual mortality of the trees in 1983-1984 and 2001-2008 (negative mortality) and 1997-2001 (Table 1). However, the annual mortality rate among the species showed that there was higher mortality of the species 1 year after fire than at other periods (1984-1997; 1997-2001). Though the highest annual recruitment rate was recorded 1 year (1983-1984) (Table 1), the recruitment rates for the species show that more species established new individuals 18 years after fire (1997-2001) than at any other period even though the species that recruited new individuals yearly in 1983-1984 had more individuals. A very remarkable observation on tree species population dynamics in the forest was that early successional tree species decreased in density, basal area and annual recruitment rate and increased in annual mortality rate as the forest recovered from the disturbance in the course of succession while the reverse trend was the case for late successional tree species. For instance, *Manihot glaziovii*, an early successional tree species, which had a density of 2,584 plants ha^{-1} (81.0% of total plant population), a basal area of 2.01 m^2 ha^{-1} (15.1% of total plot basal area), 0% $year^{-1}$ annual mortality rate and 294.4% $year^{-1}$ annual recruitment rate one year after the fire (1984) had a density of 20 plants ha^{-1} (0.56% of total plant density), basal area of 0.33 m^2 ha^{-1} (2.3% total plot basal area), annual mortality rate of 21.46% $year^{-1}$ and 0% $year^{-1}$ annual recruitment rate 25 years after the fire in 2008; a drastic decrease in the density, basal area and recruitment rate and increase in mortality rate as the forest recovers from the fire disturbance through the years.

The above findings of these studies give insight to the secondary rain forest succession after fire disturbance. They also show that fire disturbance can increase plant biodiversity by creating a wide range of habitats at different stages along the successional continuum from disturbed state to climax vegetation. Furthermore, that the species diversity of the forest has started decreasing indicates that the forest has attained the peak diversity of middle stage of succession from which it will be expected to drop gradually as tree density and reproduction increase. These studies are important in the effective management and conservation of fire damaged tropical rain forest because of recent proliferation of forest fires throughout the tropical rain forest zones of the world which are generally held to be fairly immune to fire. The effect of fire on rain forest vegetation is devastating and could transform dry forest into savanna; once established such savanna is maintained by fire (Swaine, 1992).

Vice-Chancellor sir, this burnt plot is about the only tropical rain forest permanent sample plot that has been used for long-term vegetation dynamics study to document forest recovery following fire disturbance. Studies are still on-going on vegetation dynamics on the plot because one of my graduate students is currently studying changes on the plot after 30 years of the fire disturbance.

In the course of the above studies one of my students and I studied the species composition, abundance and relationship with tree species of climbers in the forest; a group of plants along with herbs and epiphytes which are less commonly used to characterize the diversity of plant species in tropical forests. Statements about the diversity of plant species in tropical forest ecosystems are usually based on results from vegetation inventories that are restricted to woody species, usually trees and shrubs. For full understanding of tropical forest plant biodiversity, it is necessary to include these plant life-forms in forest studies. Furthermore, climbers play different roles in forest biology and ecology, are overexploited because of their economic use as non-timber forest products and the first to be eliminated during forest clearing and therefore vulnerable (Isichei, 1995). This forest is rich in climber species; 49 climber species distributed over 41 genera and 28 families, consisting of 35 liana and 14 vine species

(Muoghalu and Okeesan, 2005). Among the species are *Dioscoreophyllum cumminsii*, a sweetener, and others used as herbal medicine. The climbers (liana, vine) contribute 48% of climber, shrub and tree species in the forest. Attention should be paid to their survival in the forest through conservation.

2.3 DISTURBANCE AND NUTRIENT CYCLING IN TROPICAL LOWLAND RAIN FOREST.

Most tropical forest vegetation thrives on poor soil because the forest literally feeds on itself. Most of the nutrients the plants need are supplied by litter which covers the forest floor and is rapidly decomposed and recycled. Nutrients are also transferred from the atmosphere and from various plant parts to the forest ecosystem as rain falls and passes through the forest canopy. Litter fall, throughfall and stemflow are the fluxes through which nutrients move from the vegetation to the soil surface (Herbohn and Congdon, 1998). Nutrients are primarily transferred as litter fall which is subsequently leached by percolating water and decomposed by organisms (Eaton *et al.*, 1973). Throughfall and stemflow involve the transfer of nutrient elements from the forest directly to the available nutrient pool without the intervention of any process of decomposition on forest floor (Eaton *et al.*, 1973). The nutrients carried to the forest floor by litter fall, throughfall, stemflow and other sources are taken up in time by tree roots and translocated to the canopy. These nutrients are recycled through the same routes. This internal cycling of nutrients in forest is disrupted by disturbances, natural and anthropogenic. An understanding of nutrient cycling processes is fundamental to management of natural and disturbed vegetation growing on tropical soils of low fertility (Congdon and Herbohn 1993). Nutrient cycling and allocation patterns may also influence the successional processes (Ewel, 1976). There is marked lack of information on the effects of disturbance on and dynamics of nutrient cycling in forest recovering from fire disturbance.

After the 1983 fire disturbance of the forest in Ile-Ife, changes in nutrient cycling as the forest recovered from the disturbance were studied. A study that examined seasonal litter fall and mineral element concentration of different components of litter in the regrowth 7 years after the fire showed that litter fall (t ha^{-1} yr^{-1}) was 4.6 (total), 4.2 (leaf), and 0.3 (small wood) and 0.1 (reproductive parts: fruits and flowers) (Muoghalu *et al.*, 1993a). Leaf litter contributed 91.7%, wood litter 7.0% and reproductive litter 1.3% to the annual litter fall. Through leaf litter ≥ 88.5% of nitrogen, phosphorous, calcium, magnesium and potassium was returned into the forest, through wood litter ≥ 4.0 % and through reproductive organs ≥ 0.3 % (Muoghalu *et al.*, 1993a). Studies on litter production dynamics in the forest 14 years after the fire show that annual litter fall (t ha^{-1} yr^{-1}) increased to 12.5 (total), 8.2 (leaf), 2.8 (wood) and 0.9 (reproductive parts) (Odiwe and Muoghalu, 2003).The percentage leaf litter contribution to annual litter fall decreased from 91.3 % in 1990 to 65.6% in 1997-1998 while those of wood and reproductive litter increased.

Litter decomposition, a natural process, recognized as being a very important part of the nutrient cycle whereby essential mineral elements, tied up in the plant biomass, are made available for further plant growth (Maclean and Wein, 1978) was studied in the forest. The results of the study on the rate of decomposition and mineral element dynamics of decomposing leaf litter of four forest tree species in the forest show that decomposition rate varied among leaf litter of the tree species and it took a minimum of six months for the litter to completely decompose (Muoghalu *et al.*, 1994). Temperature was observed to have negative effect on the decomposition of litter in the forest. In contrast, moisture availability was found to be a more important factor than temperature in affecting decomposition of litter in the forest and tropics (Muoghalu *et al.*, 1994). Furthermore, the general trend of the concentrations of elements in the decomposing litter of the species show that Mn, Fe, Cu, and Zn increased in concentration, Ca, Mg, K, and Na first increased before decreasing in concentration and N and P first decreased before increasing in concentration with decomposition (Muoghalu *et al.*,1994). A further study of woody branch decomposition of some tree species in the forest show that decomposing wood branch litter lost 38 to 82% of their original weight after 11 months of decomposition (Muoghalu *et al.*, 1993b). The woody branch litter show different trends in the concentration of elements as decomposition proceeded. Some elements had concentrations lower than their initial concentration while some had concentrations higher than their initial values (Muoghalu *et al.*, 1993b). This implies losses and accumulation of these elements in the environment.

Studies of nutrient inputs through precipitation in the forest 12 years (1995) after the fire show that throughfall and stemflow comprised 78.8 % and 5.2 % respectively; 16 % of the incident rainfall was intercepted by the forest canopy (Muoghalu and Oakhumen, 2000). The highest quantities of each element (Ca, Mg, K, Na, Mn, Zn, Cu, P, N) was deposited in the forest via throughfall followed by incident precipitation and the lowest via stemflow. The tree species affected the quantities of these elements by the volume of their stemflow and throughfall and the concentrations of the various elements herein (Muoghalu and Oakhumen, 2000). Furthermore, a comparison of the relative contributions of litter fall and net precipitation (stemflow and throughfall) components to nutrient cycling in the forest show that throughfall accounted for the highest proportion of nutrients reaching the forest floor from tree canopy except for Ca, N and micronutrients (Mn, Fe, Cu) which were greater in leaf litter(Muoghalu, 2003). Stemflow, wood litter and reproductive litter contributed only small amounts to the cycling of the elements (Muoghalu, 2003). There was net retention of hydrogen ions by the forest canopy as precipitation passes through it (Muoghalu, 1999) which is of significance because of the importance of hydrogen ion exchange as a mechanism in leaching cations from above-ground vegetation (Wood and Bormann, 1975) and the potential effects of increased hydrogen ion deposition to the biota in the canopy and tropical forest ecosystem as whole.

Vice-Chancellor sir, as mentioned above, all natural forest ecosystems depend on cycling of nutrients to meet the nutritional demands of the growing plants. However, in agricultural systems, nutrient supply rate and nutrient limitation are closely linked via management. For instance, management practice of wide-use of pesticides to control pests and diseases poses potential threat to the decomposing processes (Gottschalk and Shure, 1979) and could disrupt nutrient cycling by adversely affecting the microorganisms, especially bacteria and fungi, involved in decomposition processes in agro-ecosystems. Cacao (*Cacao theobroma* L.) and Kola nut (*Cola nitida* (Vent.) Scott & Endl.) plantations abound in Nigeria, especially in the southwest. Farmers faced with the problems of pest and disease in these plantations use pesticides to control them such as copper based fungicides to control *Phytophthora* pod rot in cacao plantations. Appreciable accumulation of litter is a common sight in these plantation floor especially cacao plantation in the dry season. Studies to address litter production, decomposition and nutrient cycling in two economic tree species plantations, cacao and kola nut show that there was a significantly higher total litter fall in kola nut plantation (7.34±0.64 t ha^{-1} yr^{-1}) than in cacao plantation (4.73±0.30 t ha^{-1} yr^{-1}) ($p < 0.001$) (Muoghalu and Odiwe,2011). However, kola nut leaf litter had a higher decomposition rate quotient (2.00) than that of cacao (1.03) after 15 months of decomposition. After 15 months of decomposition, kola nut leaf litter lost 86.5% of its initial weight while cacao had lost 64.1%

and 87.9% after 20 months of decomposition (Muoghalu and Odiwe, 2011) while it took six months for complete decomposition of leaf litter of four tree species in a secondary rain forest in the area (Muoghalu *et al.*, 1994). The low decomposition rates of cacao and kola nut litter reflects the high accumulation of litter on these plantation floors, which is a common sight especially in cacao plantations during the dry season. Furthermore, it suggests that management practices, such as widespread use of pesticides to control pests and diseases, have adversely affected the decomposition activities in these plantations. The litter accumulation has profound implications in nutrient cycling in the plantations. The fertility of soils under the plantations can only be maintained or sustained for fairly long periods due to the ability of the plantations to recycle nutrients back into the soil through litter fall and decomposition.

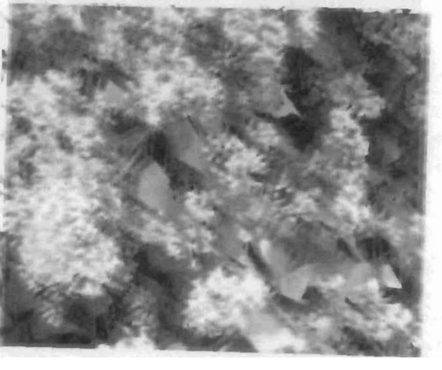
Nutrient inputs through precipitation in the plantations show that kola nut intercepted a higher amount of incident rainfall (31.4-40.3 %) than cacao (1.9-28.3%) (Muoghalu *et al.*, 2010). Higher percentages of annual incident precipitation reached the plantation floor as throughfall (57.8-60.9%) and stemflow (13.9-37.2%) under crown of cacao and lowest under the crown of kola nut (throughfall 52.5-61.2%; stemflow 7.2-7.4%). High amounts of nutrient elements (Ca, Mg, K, Mn, Fe, Zn, Cu, P, S) were deposited on the floor of or recycled in the plantations via net precipitation (stemflow and throughfall). Throughfall accounted for the highest deposition (Muoghalu *et al.*, 2010).

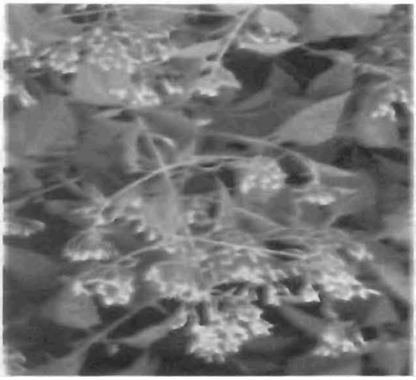
These studies show that natural nutrient element inputs through litter fall and net precipitation contribute to maintain soil fertility thereby sustaining productivity in these tree crop plantations in the tropics where soils are relatively infertile and rapidly lose their fertility and are incapable of supporting agricultural production for long. The finding is in agreement with the belief of peasant tree crop farmers that when fully established, tree crops fertilize themselves. Thus, from soil biology viewpoint, ecologically sustainable low-input tree crop production in the tropics benefits from natural nutrient inputs.

2.2 INVASIVE ALIEN PLANT SPECIES

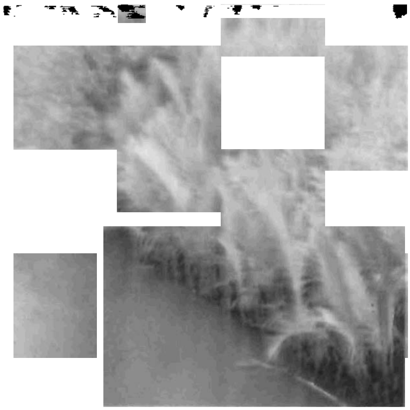
Invasive alien species are species introduced deliberately or unintentionally outside their natural habitat, where they have the ability to establish themselves, invade, out-compete natives and take over the new environments (CBD News, 2001). They include all categories of living organisms (animals, plants and microorganisms) and can affect all types of ecosystems, nevertheless, plants, mammals and insects comprise the most common types of invasive alien species in terrestrial environments (Raghubanshi *et al.*, 2005). They are now considered a major element of global environment change because they are already a serious threat to the conservation of biodiversity in many parts of the world (Cronk and Fuller, 1995). Invasive species are ecologically and often economically harmful (IUCN, 1998). The adverse changes that they cause include damage to crops, disruption of natural processes, domination of natural ecosystems and extinction of native species through competition or predation (IUCN, 1998). Total annual costs including losses to crops, pastures and forests, as well as environmental damages and control costs, have been conservatively estimated to be in the hundreds of billions of dollars and possibly more than one trillion (Pimentel *et al.*, 2001). Disturbance of natural ecosystems by a wide range of human actions is the primary cause of the successful spread and proliferation of these species. The threat of these invasions is growing as more and more species of plants are moved around the world, planted in gardens or used in agriculture or forestry (Cronk and Fuller, 1995). The problem will likely worsen with time because of climatic change that promotes species migration worldwide.

Some invasive plant species such as *Chromolaena odorata* (Plate 1(a)) in the rain forest regions, *Nypa fruticans* (Nipah palm) (Plate 1(b)) which is displacing the native mangrove flora in the Niger Delta, *Eichhornia crassipis* (water hyacinth) (Plate 1(c)) in open water bodies and recently *Tithonia diversifolia* (Plate 1(d)) and *Tithonia rotundifolia* (Plate 1(e)) have been introduced into Nigeria. Since their introduction, these species have established and are invading natural and semi-natural habitats, constituting a threat to biodiversity. They have also affected agricultural productivity or impeded certain economic activities in Nigeria. For instance, in aquatic systems, water hyacinth (*Eichhornia crassipes)* and water lettuce (*Pistia stratiotes*) (Plate 1(f)) have invaded many lakes and rivers and disrupted boat transport and fishing activities. In smaller water bodies, these invasive plant species have also caused eutrophication and losses of aquacultural productivity. Their lasting and pervasive threat is currently ignored in the country.





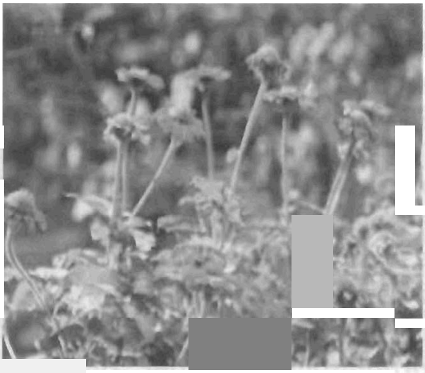
1(a). Chromolaena odorata



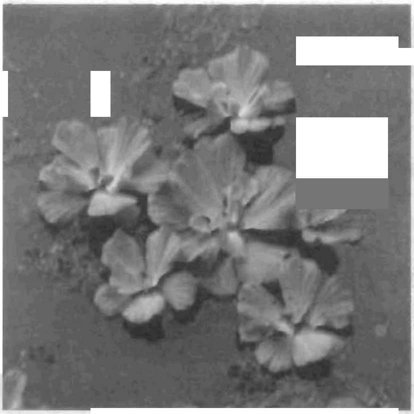
1(b). *Nypa fruticans*

1(c) Eichhornia crassipes

1(d). Tithonia diversifolia



1(e). *Tithonia rotundifolia*



1(f). *Pistia stratiotes*

Plate 1. Some aquatic and terrestrial alien invasive plant species in Nigeria.

In 2003 just before I went on sabbatical leave to the University of Zambia, Lusaka, Zambia I examined a Ph.D. Thesis on *Tithonia* *diversifolia* at the University of Ibadan, Ibadan. On getting to Zambia, I found *T. diversifolia* and *T. rotundifolia* widely spread or invasive. What intrigued me was that these species were allopatric, never found growing in mixed population so I decided to investigate the characteristics responsible for their invasive habits. *Tithonia diversifolia* is a perennial and polycarpic plant which reproduces from seeds and vegetative regrowth of basal stem when the plant is slashed while *T. rotundifolia* is an annual monocarpic plant that completes its life cycle-flowering, setting seeds and dying by the end of a growing season and reproduces from only seeds (Muoghalu and Chuba, 2005). *Tithonia diversifolia* also produces larger number per plant (134,451.75±49,792.14 seeds) of and smaller sized light weight (0.00105 g) seeds than *T. rotundifolia* (number of seeds 17629.33±3843.23; seed weight 0.0124 g). *Tithonia diversifolia* allocated 10.5% and *T. rotundifolia* 41.6% of the available resources to reproduction (Muoghalu and Chuba, 2005).The smaller sized light weight seeds of *T. diversifolia* implies that the seeds are generally likely to be more widely dispersed and have a potential of rapid colonization of sites. So that in an environment that is open and colonisable , the seeds will be at an advantage. This probably accounts for the rapid spread of *T. diversifolia*, as is evident in Nigeria. Also, *T. diversifolia* perennial habit and the ability to reproduce sexually and vegetatively may account for the species colonizing new habitats and stabilizing fast in colonized sites (Muoghalu and Chuba, 2005). Vegetative reproduction allows it to occupy a temporary site quickly while seeds produced by sexual reproduction allow long-distance dispersal to new sites. The large heavier seeds of *T. rotundifolia* imply that its embryo is large and that it carries large food reserves. The large embryo and food reserves of the seed make it possible for the seedlings to emerge as more completely developed plantlets, survive for longer and grow to a more aggressive size in an environment that is starved of resources. This initial boost gives *T. rotundifolia* competitive advantage over other plant species in the same environment (Muoghalu, 2008). The larger seeds may restrict its dispersal and probably accounts for the species not being widely spread as *T. diversifolia*. The seeds of the two species also exhibit innate dormancy (Muoghalu and Chuba, 2005) which ensures that they survive adverse conditions in their environment as dormant seeds only to germinate when environmental conditions favour the survival of their seedlings. Thus the characteristics contributing to invasive habits of the two species are seed dormancy in both species, small sized light numerous seeds production and sexual and vegetative reproduction of *T. diversifolia* and large sized seeds and high reproductive allocation of *T. rotundifolia*. For both species, control of recruitment would be a means of limiting their invasiveness (Muoghalu, 2008).

On return to Nigeria in 2006 after my leave, I observed that recently introduced *T. diversifolia* was fast spreading throughout the country especially in humid areas and displacing *Chromolaena odorata* from its habitat. My two graduate students and I investigated the invasiveness and impacts of the two species on invaded terrestrial communities. The studies show that *Tithonia diversifolia* has higher vegetative growth and earlier maturity than *C. odorata*. It negatively impacted on the vegetative growth of *C. odorata* in mixed populations of both species; and hence ability to displace *C. odorata* from its habitat (Adesiyan, 2012). The invasion of *Tithonia diversifolia* and *C. odorata* drastically reduced the species composition, Shannon-Weiner diversity index and index of evenness of invaded communities by 25.4%, 27.0%, 24.9%, and 31.6%, 13.0%, 10.5% respectively (Agboola, 2012). However, the two species improved the soil fertility of invaded plant communities by significantly increasing organic matter content, and concentrations of N, Ca, Mg, K, Na and P of soils of invaded communities (Agboola, 2012).

Vice-Chancellor sir, Nigeria is currently undergoing a rapid economic development and increasing international trade, translating into ecological side effects that are of direct significance for the spread of invasive plant species such as construction of new roads, increased disturbance and increased species introduction. All these may promote the spread of invasive plant species and increasingly be a threat to integrity and diversity of Nigeria's ecosystems and species as shown in the above studies. The problem of plant invasions and alien floras of Nigeria and the magnitude of damages, both ecological and economic, caused by these alien species are understudied and need to be adequately addressed.

2.2 ENVIRONMENTAL DEGRADATION AND CLIMATE CHANGE IMPACT ON ECOSYSTEMS.

Human activities are adversely impacting on most environmental factors essential for survival of man and other organisms on Earth. Humans have injected materials into the biosphere in large quantities that have affected the functioning of ecosystems and have an adverse effect on plants, animals, and humans. These substances have affected the process by which Earth dissipates absorbed solar radiation, leading to global warming, have led to depletion of the ozone layer, resulting in greater penetration of ultraviolet radiation in the atmosphere; and have polluted water bodies and soil, thereby reducing the suitability of the environment for the survival of humans and other organisms. Because some of the environmental factors are essential for the survival of organisms on Earth and because human activities are adversely affecting these factors thereby threatening continued life on Earth, these factors can be considered as priority abiotic and biotic environmental factors (Muoghalu, 2002a). Some of these human activities and their consequences on the environment that are making the environment less suitable for continued life on Earth have also engaged my attention through these years.

Mineral exploitation directly affects organisms through both physical and chemical modification of their environment, and indirectly in a variety of ways (Ratcliffe, 1974). The most obvious consequence of mineral exploitation is that of physical change to the land surface, with its cover of soil and vegetation. Limestone quarrying for cement production and gold mining has impacted on landscape and vegetation of sites of these industries in Nigeria. Commercial cement production in Nigeria started in 1958 after The Nigerian Cement Company Limited, Nkalagu (NIGERCEM) was incorporated in 1954 and started production in 1958. Other cement factories which are commercially producing cement came on stream after this date and are scattered throughout the country. Studies my colleagues and I carried out on the impact of limestone excavation and cement production in two of these factories, NIGERCEM, Nkalagu, Ebonyi State and West African Portland Cement Company (WAPCCO), Ewekoro, Ogun State on the landscape and vegetation of the sites of these factories show that limestone quarrying has altered the landscape of NIGERCEM factory site by creating new and varied habitats, namely, large man-made ponds whose sizes vary with the extent of quarrying (i.e. depth and area covered) and hills of spoil heap which were not originally in the area (Muoghalu, 1996). These habitats now support faunal and floral species not found in any other sites in the area. The spoil heaps have provided a haven for *Acacia sieberiana,* an uncommon species of the vegetation of the area while *Sacciolepis cymbiandra* and *Anielema dispermum* are herbaceous species peculiar to the pond banks (Muoghalu, 1996). Workers in the factory (*personal communication*) reported there are crocodiles-one of the endangered animal species worldwide and different fish species in these ponds which are now perennial water bodies. The predominance of *A. sieberiana* in younger heaps which are skeletal and lack most of physical and biological characteristics of normal soils, suggests that the species is the first tree species to colonize these heaps and may be a possible candidate species for the revegetation and stabilization of quarry sites in cement producing towns of this country (Muoghalu, 1996). Cement dust emissions from the factory of WAPCCO, Ewekoro adversely affected the vegetation around the factory by decreasing plant species diversity, chlorophyll content, leaf abundance and area, and woody density and basal area up to a distance of 5 km from the factory site (Salami *et al.*, 2002). Furthermore, our study of the impacts of gold mining on the vegetation and soil in southwestern Nigeria show that mining activities drastically reduced the vegetal cover and plant species diversity of the area (Salami *et al.*, 2003). There was also appreciable level of contamination of soil and plant species of mined sites compared with unmined areas, with the levels of some toxic heavy metals such as Pb in cassava and oil palm on mined sites much higher than the FAO/WHO guideline (Salami *et al.*, 2003). Thus, gold mining in the area is exacerbating the problems of vegetation degradation and contaminating the soil and vegetation with toxic trace metals (Fe, Hg, Pb). The results of these studies underscore the need for close monitoring of mining operations in Nigeria.

Vice-Chancellor sir, in 2000 I was one of the scholars from over 100 countries of the world commissioned to contribute articles to Encyclopedia of Life Support Systems (EOLSS) sponsored by UNESCO. I was commissioned to contribute two articles which were published in EOLSS. The EOLSS publication which is available at www.eolss.net has been reported as the world's largest on-line encyclopedia-a virtual dynamic library equivalent of 200 volumes and the world's most sought after reference site. According to information from the UNESCO, a count in 2005 showed that the average number of hourly visitors was approximately 78,000 and these figures were steadily increasing. One of my articles in EOLSS on Priority Parameters: Abiotic and Biotic Components identified the priority abiotic and biotic environmental factors that affect the global distribution of organisms and human impact and effect on them. Human impact on these factors, namely, temperature, moisture, light, soil, and living organisms and their biotic interactions, has resulted in environmental problems such as global climate change, sea-level rise, intrusion of saltwater into aquifers near the coast, disruption of hydrologic (water) cycle, ozone layer depletion, biodiversity loss through species extinction, soil degradation and desertification of arid and semi-arid lands thereby threatening the continued existence of life on Earth (Muoghalu, 2002a). The second contribution to EOLSS, Desertification and Vegetation Monitoring, described the causes of desertification which globally irretrievably claims 6 million ha of land every year, and vegetation degradation and destruction and identified indicators to be used in monitoring these processes (Muoghalu, 2002b). The human activities that impact on vegetation arise as a result of population growth and the expansion of economic activities. The human impact will continue to intensify as human population increases (Muoghalu, 2002b). Desertification and the destruction of vegetation cover have a lot of socioeconomic and ecological consequences. For instance, the destruction of vegetation is robbing human population of sources of fruit, staples, medicinal plants, construction material, industrial raw material and genetic material from the wild needed to improve domesticated crop species so as to withstand the constant challenges from disease, climate, pests and genetic drift away from vigor and disrupting ecological services. Also, desertification has reduced large areas of land to zero economic productivity and more useful land is going out of production every year in the world because of desertification. The increasing area of arid lands coming under desertification and its consequent adverse effect on the ecosystem and the socioeconomic and ecological consequences of desertification and vegetation degradation and destruction call for regular monitoring of the indicators of desertification and vegetation destruction in order to determine when there are drastic changes in them so as to employ appropriate measures to mitigate them and halt desertification processes and vegetation degradation and destruction (Muoghalu, 2002b).

Also, in 2012 the African Forest Forum commissioned me to write two chapters on Climate Vulnerability of Biophysical and Socioeconomic Systems and Permanent Sample Plots: one in moist tropical forests of West and Central Africa and the other in Savannas and Woodlands of West and Central Africa. The two contributions were presented at the Workshop on Capacity Building and Skills Development in Forest-Based Climate Change Adaptation and Mitigation, held in Nairobi, Kenya, 12-16 November, 2012 and are in press. My review of climate vulnerability of biophysical and socioeconomic systems and permanent sample plots in moist tropical forests, savannas and woodlands of West and Central Africa revealed that though there is lack of accurate climate forecasting to accurately predict future climates in the sub-regions the following are the likely impacts of climate change on forests, savannas, woodlands and people who depend on their products and services in the sub-regions:

- Changes in temperature and rainfall will alter the environmental conditions to which moist tropical forest trees in Central and West Africa are adapted and expose them to new pests and diseases. The rich biodiversity, some of which is concentrated in several centres of endemism of these moist tropical forest is at risk through extinction;

- Increased flooding as a result of storm surges and intense rainstorms and sea-level rise will expose large numbers of people to immediate deaths and injuries from drowning, infectious diseases and exposure to toxic substances. It will also affect agriculture and cause damage to property and infrastructure, e.g. roads, dams, power generation and communication;

- Predicted higher temperatures and altered precipitation would adversely affect agriculture by reducing the production potential of many crops grown in the sub-regions and cause disease infection. Furthermore, higher temperatures will accelerate the decay of soil organic matter. Increasing atmospheric carbon dioxide agricultural impact in the sub-regions will be complicated by the effects carbon dioxide has on crop plants besides its alteration of their climate regime;

- The temporal and spatial changes in temperature, precipitation and humidity that are expected to occur under the different climate scenarios will affect the biology and ecology of vectors and intermediate hosts and consequently increase the risk of transmission of diseases such as malaria, cholera, Rift Valley Fever, plague and other vector-borne diseases;

- Anticipated future impact on water resources are likely to result in increase in water runoff in Central Africa but a decrease in West Africa and increase potential evapotranspiration which would lead to reduction in soil water and change in precipitation. The enhanced evaporation could have profound effects on some lakes and reservoirs such as on water storage leading to complete drying out in many cases. Rising sea level will result in the pollution of most of the water resources along the coast by intrusion of salt water;

- Reduction in water quantity will lead to a reduction in water available for tree and forest, savanna and woodland growth, leading to reduced productivity and yields of these ecosystems that would bring a gradual decrease in the forest, savanna and woodland cover. This will have far reaching consequences on these ecosystems-dependent households in these sub-regions.

Thus, current knowledge indicates that tropical moist forests, savannas and woodlands in the sub-regions are being or will be negatively affected by climate change (shifts in species composition and functional groups, reduction in productivity and resilience, impacts on biodiversity, human health, agriculture, water, socioeconomic development and livelihoods) (Muoghalu, 2012a, b).

These reviews also show that there is a dearth of data and information on existing permanent sample plots in forests, savannas and woodlands of West and Central Africa to monitor climate change impacts in these ecosystems and generate data and information to be used for vegetation-based climate change mitigation and adaptation through periodic resampling and monitoring of the plots (Muoghalu, 2012a, b). As a result there are no local data and information to predict impacts and vulnerabilities of climate change so that most of the impacts and vulnerabilities to climate change is derived from global models which do not resolve local- and sub-regional-level changes and impacts.

Furthermore, at the Workshop in Nairobi, Kenya in 2012 I was one of the experts who developed Training Modules on Forest Based Climate Change Adaptation, Mitigation, Carbon Trading, and Payment for Other Environmental Services for Professional, Technical and Informal Groups Training for sub-Saharan Anglophone African Countries. The modules, available at www.afforum.org/node/5335 or www.afforum.org/publications/advanced, are now in use in national training in several African countries such as Ethiopia, Niger, Tanzania and Zambia, will be extended to 9-10 countries this year and even more countries in 2015 (African Forest Forum *personal communication*)

3.0 CONCLUSION.

Vice-Chancellor sir, I started my research career in 1984 in Nigerian savanna with logistic support from the Nigerian Man and Biosphere (MAB) Committee (MAB- 3 Project) which established ten one-hectare monitor permanent sample plots in different parts of Nigerian savanna to study the effect of man and his activities on the Nigerian savanna. I was able to travel as far as to Yelwa in Kebbi State on fieldwork. However, before I could complete my studies on Nigerian savanna, the support was no longer there. I was on my own to fund the studies in the savanna. At the end of those studies, I was forced to abandon my savanna studies to forest studies due to lack of funding and logistic support. The publications from my savanna studies in the 1990s were about the last major publications on Nigerian savanna structure, productivity, functioning and management. I am making this statement to highlight the importance of funding in carrying out research and to appeal to the Federal Government of Nigeria and other relevant bodies to fund research in Nigeria.

Human activities as a result of population growth and the expansion of economic activities are impacting on aquatic and terrestrial ecosystems making them less suitable for survival of humans and other organisms and continued life on Earth. These impacts will continue to intensify as human population on Earth increases with a lot of socioeconomic and ecological consequences. The environmental problems created by these human activities include climate change, ozone layer depletion, rapid spread of invasive species, biodiversity loss, deforestation and degradation of forests, desertification of arid and semi-arid lands and pollution of water bodies and soil. To avert the adverse effects of these problems on the different world ecosystems and on humans, serious effort should be made to stem the rate of human assault on ecosystems. These problems are with us in Nigeria.

Invasive alien species which are now considered to be the second cause of global biodiversity loss after direct habitat destruction and have adverse environmental, economic and social impacts are present in Nigeria. A recent study of invasive alien plant species in Nigeria and their effects on biodiversity conservation has reported 25 invasive plants in a field gene bank at National Centre for Genetic Resources and Biotechnology (NASGRAB) in Ibadan (Borokini, 2011). The lasting and pervasive threat of and the ecological and socioeconomic damages caused by these invasive alien species are currently ignored. There is paucity of studies on invasive alien species in Nigeria given the rich biodiversity status of Nigeria. There is need to compile alien invasive floras and faunas, analyze patterns of their floristic and faunal status, biological attributes, geographical distribution, and economic losses in terms of agricultural, fishery and forestry production losses and control costs or eradication programmes. These data are needed before strategies for eradicating and managing biological invaders in Nigeria can be developed. To achieve these, there is need to build research capacity of scientists and financial supports from government and non-governmental organizations to work on invasive species.

Another, problem with invasive alien species in Nigeria is the correct identification of invasive *Tithonia* species in Nigeria. Some scientists identify it as *Tithonia diversifolia* including myself, others identify it as *Tithonia rotundifolia*. I strongly doubt the identification of the species. The flowers look much like those *T. diversifolia* which is a perennial and relatively woody plant but the other morphology and habit of the species are much like those of *T. rotundifolia* which is an annual plant as the species in Nigeria. There is need to resolve this confusion by correctly identifying the species.

Climate change is impacting on forests and savannas of Nigeria and socioeconomic activities that depend on them. The climate change impacts will diminish the capacity of the forests and savannas to provide goods and services, will have far-reaching, mostly adverse consequences for livelihoods of these vegetation-dependent communities and the economic contribution to Gross Domestic Product (GDP) from the production, export and sale of forest products. These impacts are likely to worsen over time. There is a need to investigate the impacts of climate change on forests and savannas and socioeconomic activities that depend on them to generate data and information that would be used for vegetation-based mitigation and adaptation to climate change. This requires the use of permanent sample plots. There are no permanent sample plots in Nigerian forests and savannas to collect such data and information and monitor such changes in the forests and savannas. One-hectare permanent sample plots should be established across soil types in each forest and savanna zones to collect the data and information on and monitor changes due to climate change through periodic resampling of the plots.

4.0 ACKNOWLEDGEMENT

This inaugural lecture is dedicated to my late mother, Madam Rosaline Mgbudo Muoghalu who, as a widow, started this race by single handedly paying my school fees and those of my siblings, Professor A. O. Lawanson who recruited me into the system in spite of cat and mouse game I played with him because I did not want to be a lecturer at graduation but he persisted and succeeded in recruiting me and Professor A. O. Isichei who supervised my B.Sc., M.Sc. and Ph.D. studies and has mentored me through these years. I am ever grateful to all of you.

I am very grateful to the Almighty God or in Igbo traditional belief my personal god, "chim". It is believed among Ndigbo that no person runs faster than "chie". If he does, there is nothing he does in life that will be a success. I am happy I did not run faster

than "chim" by choosing the correct career it destined for me and for which I am very happy. My thanks go to Obafemi Awolowo University, Ile-Ife for providing me the opportunity and an enabling environment to pursue my research career, and to Nigerian Man and Biosphere Committee, my graduate students, past and present, my colleagues in the Department of Botany and others too numerous to mention, who have one way or the other immensely contributed to my research works. Lastly, to the lovely members of my family, my wife and children, who have always been there for me and made the home a peaceful environment for me to operate from, I say thank you.

VICE-CHANCELLOR, SIR, PRINCIPAL OFFICERS, DISTINGUISHED GUESTS, LADIES AND GENTLEMEN THANK YOU FOR YOUR ATTENTION.

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