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Review

Drought, desertification and the Nigerian environment: A review

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Drought and desertification are twin global environmental problems. Nigeria is faced with rapid desert encroachment affecting fifteen northernmost states from moderate to severe rate. Out of the 909,890 km^2 of the country's land area, about 580,841 km^2 accounting for 63.83% of total land is impinge on by desertification. Climatic variability and anthropogenic activities such as deforestation, extensive cultivation, overgrazing, cultivation of marginal land, bush burning, fuel wood extraction, faulty irrigation system and urbanization are major causes of desertification. Drought and desertification impact directly or indirectly on all aspects of human life and the environment including the ecological, health, geo-chemical, hydrological and socio-economic facets. Despite several efforts by the government to end desertification, the problem still persist due to the gap between the formation of policy and strategies of combating drought and desertification. Drought and desertification can be remedied through integrated approaches such as awareness programmes, protection of marginal lands, tree planting, sustainable agricultural practices and use of alternative energy source.

Key words: Drought, desertification, Northern Nigeria, dryland, environment.

INTRODUCTION

The intimacy between drought and desertification phenomena in the environment has been a long known phenomenon. They were described by Oladipo (1993) as a twin environmental hazard. Drought and desertification are global environmental problems affecting developed and developing countries in many regions of the world, where the required causal synergistic climatic variations and anthropogenic inputs thrive. They are accompanied by the reduction in the natural potential of the land, the depletion of surface and groundwater have negative repercussions on the living conditions and the economic development of the people are affected by it (Abahussain et al., 2002). Drought and desertification processes integrate climatic elements with human activities in transforming productive land, into an ecological impoverished area generally refers to as desert. Drought and desertification cause degradation of once a fertile land through long term changes in the soil, climate and biota, which results in desert-like conditions.

Nigeria is one of the countries south of the Sahara faced with a rapid desert encroachment, with notable effects on the northern part of the country. Desertification phenomenon has been reported in the northern Nigeria since 1920s, but the impact has been more glaring since the famine of 1971 to 1973 in this part of the country. Desertification affects fifteen northernmost states of the

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country (Jaiyeoba, 2002) and almost one-fifth of the total Nigeria land area is becoming desertified. These states of the country are agricultural area supply most of the country's agricultural products such as beans, soya beans, tomato, melon, pepper, onion, cow, ram and many more. Though the contribution of climatic variability to drought and desertification phenomena, but these are aggravated by the unsustainable activities of human in the environment. Such activities include deforestation for industrial purpose and fuel wood, urbanization, bush burning, agro-activities on marginal lands and other sustainable agricultural activities. Desert encroachment is moving southwards. The impact is intense because agro-economy of Nigeria is dependent on rainfall and hence affected by fluctuating weather. Nigeria signed the convention of the United Nation to Combat Desertification on 30 October 1994 but the desert encroachment assumed increasing proportion and it a threat to the nation's economy (Okoli and Ifeakor, 2014). Tercula (2015) reported that Nigeria loses about 350,000 ha of land every year to desertification and the impacts are manifested on the environment and general livelihood of Nigerians. Desertification causes loss of biological diversity, contribute to disease burden, alter geo-chemical composition of the soil, contribute to water scarcity, reduced agricultural yield hence, contribute to food insecurity, reduced economic growth among other unfavourable impacts.

As emphasized by Medugu (2009), a lot of policies and programmes have been implemented by Nigerian government to combat desertification, yet the problem is rather aggravating because of the problem that has been treated as a sectoral issue instead of an integrated approach that will bridge the gap between the formation of policy and strategies of combating drought and desertification. Among such policies and programmes are Arid Zone Aforestation Project (AZAP) in 1977, the River Basin Development Authorities (RBDA) in 1987, Federal and State Environmental Protection Agency (FEPA / SEPA) and the Great Green Wall Project among others.

This paper examines the causes and impacts of desertification in the Nigeria environment, with a view to proffer solutions that will bridge the gaps in the existing national efforts to combat the environmental problems of drought and desertification

Drought

Drought is one of the main causes of desertification. The lack of general acceptance of a precise and objective definition of drought has been one of the principal obstacles to the investigation of drought. It is therefore important to be aware that different definitions might lead to different conclusions regarding the drought phenomenon. For instance, if the definition is based on the level of rainfall, it is possible that rainfall statistics summarized over a calendar year indicate no drought, whereas the moisture supply in the growing season does. With regards to food security, drought could be defined as naturally occurring phenomenon (usually aggravated by human activities) that exist over a particular period in a particular area such that precipitation is significantly below normal recorded levels, causing deterioration of land productive systems and invariably low agricultural outputs.

It is important, however, to stress that because drought affects so many sectors in society, there is a need for different definitions (Wilhite and Glantz, 1985). The particular problem under study, the data availability and the climatic and regional characteristics are among the factors influencing the choice of event definition. The following criteria can be used to define drought; meteorological, agricultural, hydrological, and socio-economic criteria.

Meteorological

It occurs when precipitation level fall below the normal long-term recorded level.

Agricultural

It occurs when soil moisture is insufficient to meet the needs of agricultural crops at a particular time.

Hydrological

It occurs when there is a deficiency of water supply due to reduction or absence of surface and subsurface water.

Socio-economic

This form of drought is associated with human activates. It occurs when various human activities are impaired due to reduced precipitation or water availability.

Generally, the phenomenon can be attributed to inadequate seasonal precipitation, a prolonged dry season or a series of sub-average rainy season (Sheikh and Soomro, 2006). The chief characteristic of a drought is a decrease of water availability in a particular period over a particular area. Drought is a condition of severe reduction in water availability and the deficiency could extend over a significantly long period. United Nation Convention to Combat Desertification (UNCCD) (1994) defined drought as the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resources productive systems. Continued land abuse during drought, however, increases land degradation. Rainfall deficit and the resulting periods of low flow can have severe effects on water management and utilization issues. This includes river pollution and ecological aspects, reservoir design and management, irrigation, small power plants, drinking water supply etc. Future increase in the demand for water will be most critical in periods of severe and extensive drought.

Desertification

Desertification as a concept was first discussed by European and American scientists prior to Aubrevile in 1949, in terms of increased sand movements, desiccation, desert and Sahara encroachment and man-made desert. According to the United Nation Convection to Combat Desertification (UNCCD), desertification is land degradation in arid, semi-arid and humid areas resulting from various factors, including climatic variations and human activities (UNCCD, 1997). The following aspects are important in the definition of desertification.

(a) Climate and human activities as the causal factors
(b) Vulnerability of arid and semi-arid lands and
(c) Land degradation and loss of biodiversity consequences.

On this basis, Campbell (1986), Mortimore (1989) and Oladipo (1993) have similar definitions of desertification: a process that causes land degradation due to some prevailing climatic conditions and human activities such that it resulted into the inability of the environment to sustain the demands being made upon it by socio-economic systems at existing levels of technology and economic development. Desertification entails the formation and expansion of degraded areas of soil and vegetation cover in arid and semi-arid and seasonally dry areas, caused by climatic variations and human activities (Wright and Nebel, 2002). It involves denuding and degrading a once fertile land, initiating a desert producing cycle that feed on itself and causing long term changes in soil, climate and biota of an area (Cunningham and Cunningham, 2005).

Desertification could be seen as a process whereby the productivity of arid or semi-arid land falls by 10% or more (Miller, 1999). Miller (1999) classified desertification as mild, serious and severe based on soil productivity. Mild desertification is a 10 to 25% drop in productivity, serious desertification is a 25 to 50% drop and severe desertification is a drop of more than 50% in productivity. Desertification is an advanced stage of land degradation where soil has lost part of its capability to support human communities and ecosystem. In areas undergoing desertification, people in their quest for food and desired livelihood to support the population, pursue land management and cultivation practices that deplete soils of their nutrient and organic matter content and promote erosion; overgrazing of rangelands, and cut trees and bushes for fuel wood and other purposes (Acosta-Michlik et al., 2005).

The direct effect of desertification on land degradation is either decrease of land productivity or the complete abandonment of agricultural land, which ultimately lead to the food crisis experienced in many arid and semi-arid regions especially Africa. There is direct relationship between drought, desertification and food security. These environmental menaces lead to decreased soil quality which ultimately reduced agricultural productivity-a key determinant of food security.

Features of a desertification process include

i. Impoverishment of vegetative cover
ii. Reduced quantity, available and accessible of soil moisture
iii. Deterioration of the texture, structure, nutrient status of soil
iv. Reduced biodiversity and presence of more xeric biota
v. Increase soil erosion

The Nigerian environment and extent of desertification

Nigeria is located approximately between latitudes 4^o and 14^o north of the equator and between longitudes 2^o 2' and 14^o 30' east of the Greenwich Meridian. To the north, it is bordered by the Republics of Niger and Chad, to the east by the Republic of Cameroon, to the south by the Atlantic Ocean and to the West by the Republic of Benin. Nigeria is a large country with an estimated population of over 160 million, with a substantial part of its area extending into the Sudano-sahelian belt, which, together with the neighbouring northern Guinea savannah, constitutes the drylands of the country. National Bureau of Statistics in Nigeria (2010) estimated that the country has an approximate total surface area of 909,890 km^2. About 40% of this land is believed not to have been utilized for settlement, agriculture and other human purposes. Nigeria enjoys a warm tropical climate with relatively high temperature that is typical of the tropics and two seasons; the dry and wet season. In general, where there is hardly any dry season in the extreme southern tip of the country, the wet season hardly lasts for more than three months in the north eastern part of the country. Similarly, annual rainfall totals range from over 2,500 mm in the south to less than 400 mm in parts of the extreme north (Federal Ministry of Environment of Nigeria, 1994). Northern Nigeria is situated in the semi-arid areas bordering Sahara desert with average annual rainfall or less than 600 mm (Folaji, 2007). This rainfall pattern has contributed to the desertification encroachment in 15 northern-

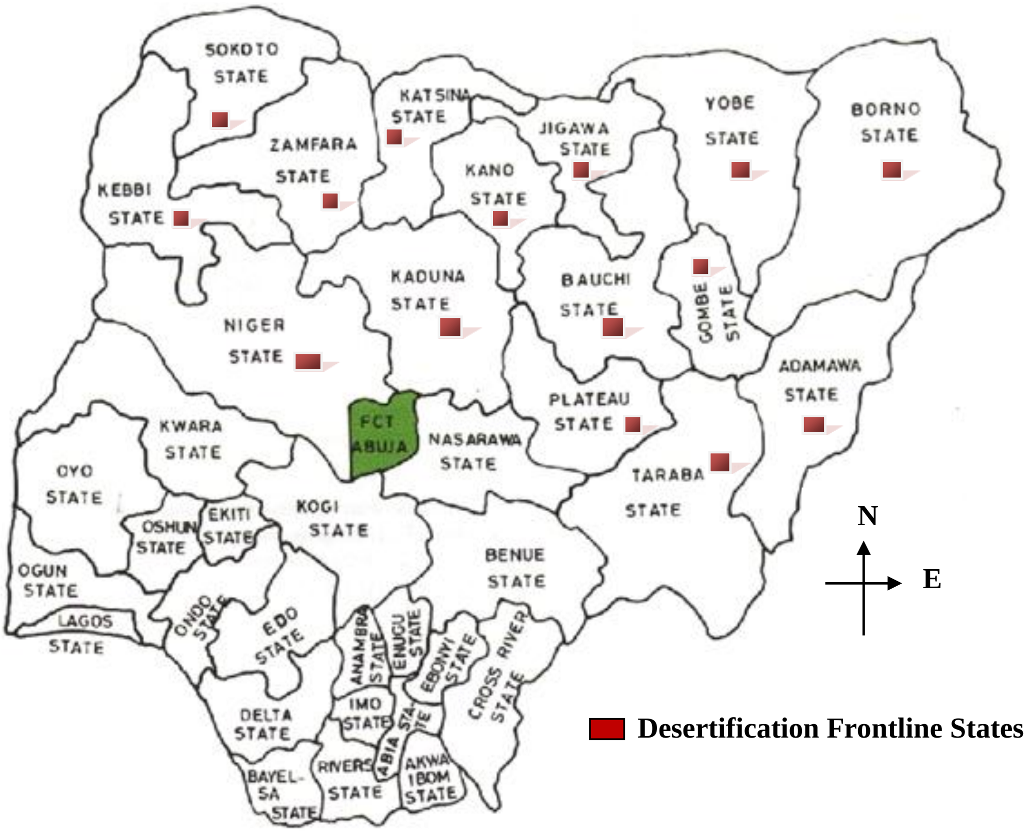

Figure 1. Map of Nigeria showing the desertification frontline states.

most states of Nigeria.

The extent and severity of desertification in northern Nigeria has not been fully established neither the rate of progression has been properly documented. Nevertheless, some reports suggested that progression rate of desertification in northern Nigeria is about 0.6 km per year and Nwafor (2006) reported that recent estimates put the area already lost to desertification at about 351,000 km^2. According to the desertification map of the world produced by Food and Agriculture Organization (FAO), the World Meteorological Organization (WMO), and U.N.E.S.C.O, about 15% of Nigeria land is prone to desertification (Emodi, 2013).

The visible sign of this phenomenon is the gradual shift in vegetation from grasses, bushes and occasional trees, to grass and bushes; and in the final stage, expansive areas of desert-like sand. It has been estimated that between 50 and 75% of states of Bauchi, Borno, Gombe, jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe and Zamfara in Nigeria are being affected by varying degrees of desertification. As illustrated in Figure 1 and Table 1, there are 15 desertification frontline states in Nigeria out of the total 36 states and the Federal Capital Territory. These states accounts for about 63.83% of the total land area of Nigeria with moderate to severe rate of desertification and about 62 million of Nigerians are either directly or indirectly affected by desertification problems.

CAUSES OF DROUGHT AND DESERTIFICATION

The causes of drought and desertification are numerous and complex, but like many other issues of environmental degradation, they are basically the resultant interactions of climatic influence and human activities in the environment. The causes include

Climatic variability

Climatic variability is a major driver of many environmental degradation phenomena. Alteration of climatic conditions leads to naturally occurring phenomena of drought and desertification. There has been increasing level of greenhouse gases causing global warming which in turn increase the variability of climate conditions. This alteration in the climatic conditions has manifested as follows;

i. A decrease in the amount of rainfall in drylands making arid and semi-arid lands more vulnerable to

Table 1. Desertification frontline states of Nigeria.

State	Geographical Region	Land Area (km^2)	Land Area % of Nigeria	Population (2006) Number	Population (2006) Density (/km^2)	Rate of Desertification
Sokoto	North West	27,825	3.06	3,702,676	133	Severe
Zamfara	North West	37,931	4.17	3,278,873	86	Severe
Katsina	North West	23,561	2.59	5,801,584	246	Severe
Jigawa	North West	23,287	2.56	4,361,002	187	Severe
Kano	North West	20,280	2.23	9,401,286	464	Moderate
Kebbi	North West	36,985	4.06	3,256,541	88	Severe
Kaduna	North West	42,481	4.67	6,113,503	144	Moderate
Borno	North East	72,609	7.98	4,171,104	57	Severe
Yobe	North East	46,609	5.12	2,321,339	50	Severe
Bauchi	North East	41,119	4.52	4,653,066	113	Moderate
Gombe	North East	17,100	1.88	2,365,040	138	Moderate
Adamawa	North East	38,700	4.25	3,178,950	82	Moderate
Taraba	North East	56,282	6.19	2,294,800	41	Moderate
Niger	North Central	68,925	7.58	3,954,772	57	Moderate
Plateau	North Central	27,147	2.98	3,206,531	118	Moderate
Total		**580,841**	**63.83**	**62,061,067**	**107**	

Source: National Bureau of Statistics, 2010; National Population Commission, 2006. *Moderate: 26 to 50% of plant community consists of climax species, or 25 to 75% of original topsoil lost, or soil salinity has reduced crop yields 10 to 50%. *Severe: 10 to 25% of plan community consists of climax species, or erosion has removed all or practically all of the topsoil, or salinity controllable by drainage and leaching has reduced crop yield by more than 50%.

desertification.

ii. High temperatures, combined with low rainfall which would lead to the drying up of water resources - drought.

iii. Poor growth of vegetation leading to the formation of a desert-like condition.

A study conducted from 1901 to 2005 showed that Nigeria is not excluded from the impacts of climatic variability and global warming with prominent localized effects in the highly industrialized cities and Northern Nigeria which has resulted into the observed environmental degradations. Increased temperature of average 1.1°C and decrease rainfall of average 81 mm were reported (Onyeanusi and Otegbeye, 2012).

Anthropogenic activities

The anthropogenic factors have been the major cause of desertification just like many ecological degradation problems. Human contribute to desertification through poor land use and the ever increasing pressure put upon the limited available resources by the expanding population. Basically, human causes of desertification can be viewed to result from; exploitation of resources from “non-ideal lands”, over exploitation of land resources, unsustainable acts when exploiting, and none replacement of exploited resources or not allowing sufficient time for natural regeneration of exploited resources. The following human activities can cause desertification:

Deforestation

Deforestation is the conversion of forested areas to non-forested land (Olagunju, 2015a). It is the large scale removal of forests resulting to non-forest to meet various human needs. Logging, expansion of agricultural croplands, urbanization, fuel wood collection, mining and resources extraction, fire-hunting and slash and burn practices have been identified as the key drivers of deforestation. Nigeria is considered the world’s highest deforested country and has lost about 55.7% of its primary forest. From 1990 to 2010, Nigeria nearly halved its amount of primary forest cover with an annual deforestation rate of 3.67% between 2000 and 2010 (FAO, 2010). The situation appears alarming that the FAO states that the forest in Nigeria will disappear by 2020 if the current rate of forest depletion continues unabated (Onyeanusi and Otegbeye, 2012). Deforestation of drylands destroys the trees and vegetation that bind the soil, and because of the prevailing climatic conditions in drylands, the possibility of regeneration of denuded vegetation is low and hence, the land becomes desertified.

Extensive cultivation

Expansion of agricultural land to meet up with the food requirements of the increasing population has led to the degradation of land in Northern Nigeria. New lands are cleared of trees and other vegetations to establish agricultural croplands in the dryland, many of such lands are unable of recuperation, and hence desertification sets in. In Nigeria, overgrazing and over-cultivation have been reported to be responsible for the conversion of 351,000 hectares of land into desert each year (www.earth-policy.org).

Overgrazing

Overgrazing is most common in the areas whose socio-economic viability depend mostly on extrinsic system of animal husbandry. The dry lands of Nigeria is said to support much of the country's livestock economy, hosting about 90% of the cattle population, about two-thirds of the goats and sheep and almost all donkeys, camels and horses. In the Sudan and the Sahel zones, which carry most of the livestock population, nomadic herdsmen graze their livestock throughout the area and are constantly in search of suitable pastures. Additional pressure is also on these natural rangelands by livestock from neighbouring countries, notably Cameroon, Chad and Niger. Overgrazing removes the vegetation cover that protects soil from erosion (UNCCD, 2011) and degrades natural vegetation that leads to desertification and decrease in the quality of rangelands (Sheikh and Soomro, 2006). Between 1950 and 2006, the Nigerian livestock population grew from 6 to 66 million, an eleven fold increase. The forage needs of livestock exceed the carrying capacity of its grasslands (Lester, 2006).

Cultivation of marginal land

Cultivation of marginal areas is one of the causes of desertification. Marginal lands are areas that are unable to support permanent or intensive agriculture which could be easily degraded following cultivation. During the periods of high rainfall, people tend to extend farming activities into the marginal areas. When these periods of high precipitation is succeeded by abrupt dry periods, the exposed land with very little vegetal cover is prone to wind erosion. And desertification may set in which could be irreversible except through carefully planned rehabilitation programme.

Bush burning

Slash and burn practice in agriculture and fire-hunting is a major cause of desertification in northern Nigeria. Owing to the low relative humidity in the area coupled with very dry harmattan wind, there is always a high incidence of bush fires every dry season. When this occurs too frequently, the vegetation may not regenerate; the soil is exposed to erosion and become degraded.

Fuel wood extraction

Due to socio-economic status of the people inhabiting Nigeria dryland, felling of tree for fuel wood will continue increasing if alternative sources of energy in the sudano-sahelian zone are not provided. The demand for fuel wood causes the removal of trees, shrubs, herbaceous plants and grass cover from the fragile land, accelerating the degradation of the soil to desert-like conditions (FAO, 2006). In Nigeria, more than 70% of the nation's population depends on fuel wood. Katsina alone, a northern state, has its over 90% energy from fuel wood (Mohammed et al., 2013). In Kano City, 75,000 tonnes of fuel wood are brought in by lorry and donkey within a radius of 20 km, which leads to denuding of the woodland.

Faulty irrigation management

Irrigation system is a common practice in northern Nigeria. Many farmers lack adequate skills in proper designing and management of irrigation system which has resulted into desert-like condition of many irrigated farmlands as a result of water logging and salinization. This scenario is already a reality on a number of irrigation projects in Nigeria today, such as the Bakolori Irrigation, South Chad Irrigation and the Hadejia – Jamaare Irrigation Projects. For instance, the drying up of Lake Chad that started during the Sahelian drought of 1972 to 1973 is aggravated due to poorly managed irrigation system in the Chad Basin. This has caused the reduction of the lake from 25,000 m^2 in 1963 to about 3,000 m^2 in 1986. This prompted the government to stop all irrigation projects in the basin in 1989 because the level of the lake fell 3 m below the critical level.

Urbanization

Nneji (2013) has attributed rapid economic growth and urbanization as causal factors of desertification. The problem is more severe and complicated in developing world. Clearing of lands to accommodate the increasing population and accommodate the necessary infrastructure in northern is commonly done without adequate environmental consideration; this has led to the removal of vegetation cover in the area and as such, making the area desertified. Urbanization in Kano City for instance has been estimated to be increasing rapidly at the rate of between 5 to 10% per annum (Federal Ministry of Environment of Nigeria, 1994). At least, 20,000 ha of land are cleared annually for construction.

IMPACTS OF DESERTIFICATION

The consequences of desertification are far-reaching and diverse. All aspects of human lives are either directly or indirectly impacted wherever the phenomenon exists. It ranges from food insecurity, water scarcity, and socio-economic hardship to political unrest. Other scholars reported that desertification also causes alteration of ecosystem services locally and globally, loss of biodiversity, habitat loss and species endangerment (FAO, 2000); changes in hydrological and climatic cycle (Shonekan, 2004); reduced agricultural yield (Ramankutty and Foley,1999) and socio-economic welfare (Singh et al., 2000).

Ecological impacts

An environment is said to be ecologically sustainable when it conserves biological diversity and the life supporting systems for the use of present generation without compromising its use by the future generations. Desertification has resulted to alteration of the ecosystems in the arid and semi-arid zones, which affect the habitat, habitat composition, abundance, distribution and relationships in the communities of living organisms. Ecological impacts include:

Habitat destruction and loss of biodiversity

Diversity is a measure of the amount of variability in the species composition of a community (Don-Pedro, 2009). Bullock and Le Houérou (1994) assert that many species are prone to be endangered due to desertification. Nigeria drylands contain a large number of species of plants and animals that are important to humankind as a whole, but which are threatened as a result of desertification process occurring in the area. NAP (2000) revealed that some important animal species such as the sitodunga antelope, cheetah, giraffe, lion and elephants in the northern states of Nigeria have become endangered and indigenous plant species especially those with medicinal values e.g. *Mitrogina spp* (known as Giyaya in the area) are now difficult to locate.

Changes in phenology

Phenology deals with the period or timing of biological events (such as mating, laying of eggs etc) of living organisms in response to climatic and other environmental circumstances. Alteration of the periodic biologic events of animals is one of the first and most easily detectable ecological responses to desertification. There are many ways animal's behaviours are altered in response to desertification. For instance, there could be alteration in their reproduction timing, mating, feeding and migration etc.

Health impacts

Health is the complete state of physical, mental and social well-being of an individual without necessarily the mere absence of disease (WHO, 2003). Desertification can impact on the public health through increased heat waves, potential to initiate skin cancer and enhancement of favourable environmental conditions for diseased conditions and vectors.

Heat waves

Dense vegetation's provide some level of heat sequestration but which are denuded due to desertification This situation caused an increase in heat waves in northern Nigeria, posing a deal of threats to the health of the people. Human populations have over time acclimatized and adapted to local climates and also able to cope with a range of weather changes. However, within populations, there are individuals whose sensitivity to extreme weather condition is high and are such prone to the risk of health implications of such unfavourable weather conditions. Extreme heat can cause heat exhaustion, cardiovascular diseases (e.g. heart attacks and strokes) (Bell et al., 2007). Higher UVR exposure could suppress the immune responses to infection of the human host. In animals, high UVR exposure has been shown to decrease host resistance to viruses such as influenza and cytomegalovirus, parasites such as malaria and other infections such as *Listeria monocytogenes* and *Trichinella spiralis* (Patz, 1996). There has been very little or probably no research in Nigeria and other developing countries on how and how much can desertification impact on thermal stress-related mortality and morbidity in human but some works on animals have been reported. In the Northern Guinea Savannah of Nigeria, Ayo et al. (2010) reported a 20% reduction in feed intake in layers chicken due to thermal stress which resulted into a significantly decreased hen-day production. They also reported 3.7% increase mortality due to stress by heat in the region. Likewise, Oladele et al. (2003) find out significantly low level of packed cell volume and haemoglobin in thermally stressed domestic chicken in northern Nigeria.

Cancer

One of the influences of desertification is deterioration of vegetation cover, such that people especially outdoor workers are exposed to direct influence of the solar radiation. It has been proved that excessive exposure to sunlight can cause skin disease and cancer (Cunningham and Cunningham, 2006). McMichael and Githeko (2001) made an observation in outdoor workers such as agricultural labourers and farmers, that skin cancer developed on areas most frequently exposed (e.g. hands, neck, and face) to sun. There are regional differences in the type of malignancies that are prevalent in Nigeria. The severity of desertification could be a contributory factor. Skin malignancies have been reported to account for higher percentage of all malignancy cases in the Northern Nigeria compared to the southern Nigeria. For instance, skin malignancies accounted for 6.81% of all malignant cases in Jos (Mandong et al., 2001); a city in the north central with moderate rate of desertification. In Kano (a farther northern city also with moderate rate of desertification), it is 12.7% (Ochicha et al., 2004). While in Maiduguri, in the extreme northern part with severe rate of desertification; it accounts for 20.9% (Nggada et al., 2003). These percentages are high compare to the report of cases in 2007 in Lagos State (Southern Nigeria) as documented by Morbid Anatomy Department of the Lagos University Teaching Hospital (LUTH). Skin cancer, accounted for just 5% of all reported malignancies (Ikawo, 2013).

Vector-borne diseases

Desertification results into increase in ambient temperature, altered precipitation and climatic variability which would alter geographical range and seasonality of transmission of many vector borne diseases. Also, insufficient water supply is typical of desertifying area; this forced the people living in such area to utilize any available water source especially in the developing countries where portable water is lacking. More so, desertification process leads to increased contamination of available sources of water and enhances the transmission of waterborne diseases such as typhoid, infectious hepatitis and cholera (Betterton and Gadzama, 1987). Currently, the World Health Organization (WHO) estimates more than one billion people to be without access to safe drinking water, and that every year approximately 1.7 million die prematurely because they do not have access to safe drinking water and sanitation.

Loss of plants of medicinal importance

Desertification has contributed to the loss of plants of potential medicinal properties. Most woody species serve as source of medicine (Kafaru, 1994; Otegbeye and Otegbeye, 2002) especially to local people. These medicinal plants are neither cultivated nor protected against desertification, so they disappear at a rapid rate with good number of them under threat of extinction especially in the arid and semi-arid lands. Madaci (*A. senegalistis*) an indigenous medicinal plant species use to cure various ailments in Maiduguri and some other place in the northern Nigeria is now endangered due to desertification.

Geo-chemical Impacts

Not only is biological environment is negatively impacted by desertification; the geological and chemical environments are as well impinged. The geo-chemical effects include:

Global warming

Bruce et al. (1996) defined global warming as an increase in earth's mean global temperature. A part of earth's outgoing infrared radiation is retained by several trace gases in the atmosphere whose concentrations have been increased because of human activities. Vegetation and soil play a great role in sequestrating carbon; an important greenhouse gas (Olagunju, 2015b). When desertification occurs, the carbon sequestration ability of vegetation and soil is greatly lost making carbon to be increased in the atmosphere thereby aggravating global warming. An increase of at least an average of 1°C has accompanied the temperature in the northern states of Nigeria bordering the Sahara when comparing the data of 1901 to 2010.

Increased erosion

Soil erosion is the movement and transport of soil by various agents particularly water and wind leading to soil loss. Impoverishment of soil's natural vegetation cover has been a primary cause of soil erosion. When land is deforested, the soil anchorage provided by trees and other plants is lost and the soil is rapidly eroded. Because of the nature of desertification prone area, soil erosion by wind is occurs but erosion by water is more disastrous during the unusual heavy rainfall. Gully erosion, that hitherto was not a major threat in Nigeria has increased, threatening about 18, 400 km^2 compared to only about 122 km^2 in 1976 and 1978. A survey conducted in Katsina State revealed that 30% of agricultural land has been severely damaged and lost from further productive use due to erosion which has resulted to crop yield out by 30 to 60%.

Soil salinization

Soil salinity is an important chemical degradation problem facing agriculture (IPCC, 1990). Agricultural sustainability in northern Nigeria is majorly by irrigation system which again predisposes such inland areas to saline soils and reduced crop productivity if not properly managed (Sehgal and Abrol, 1994). Jibrin et al. (2008) assessed the soil sodicity and salinity in Kano River Irrigation Project (KRIP). Analyses of the soil samples from the irrigated land area showed a very high exchangeable sodium percentage (ESP), with a mean value of 14.8 and 17.5% for top soil and subsoil respectively. They reported that ESP increases with depth and that the salinity is low. But compared to reports from non-irrigated area, the salinity is relatively high.

Hydrological impacts

Desertification has also impacted on the hydrology of arid zones. The water resource becomes a limiting factor, making the effects of desertification amplified, such that the ecosystem becomes fragile and at or near its limits of resilience (Batanouny, 1998). Reduction in water supply and over exploitation of groundwater are major hydrological impacts of desertification.

Reduced water supply

Water availability is usually measured in terms of renewable water per capita, population density, as well as total water volumes (Cunningham and Cunningham, 2006). The world Health Organization considers an average of 1,000 m^3 (264, 000 gal) per person per year to be a necessary amount of water for modern domestic, industrial, and agricultural uses. Nigeria (especially its northern part) and some other 45 countries, most of them in Africa or the Middle East, cannot meet the minimum essential needs of all their citizens (Cunningham and Cunningham, 2006) and desertification has been implicated as a major contributory factor (Ajayi, 1996). In Yobe state of Nigeria, sand dunes have been reported to be threatening life supporting oasis and burying water point (Toye, 2002). Musa (2008) attributed the drying up of Chad basin in Nigeria to the effect of drought and desertification. Ajayi (1996) provided a striking example of drastic impact of drought and desertification on the Hadejia/Nguru/Kirri-Kissama wetland project for the conservation of water flows. The wetland had a flood plain of about 84,143.8 km^2. The steady decline in the extent of inundation of the plain due to the phenomena led to the drastic reduction of the flood plain by at least 20%.

Over-exploitation of groundwater

Northern Nigeria depends majorly in most months of the year on groundwater for domestic and agricultural use. Due to desertification, northern Nigeria is faced with increased use of groundwater to meet their growing population. More wells are dug and water is withdrawn faster than natural recharge can replace it. On local scale, this causes a cone of depression in the water table or the depletion of the whole aquifer on a broader scale. Excessive groundwater withdrawals also allow aquifers to collapse, followed by subsidence, or sinking of the ground surface.

Socio-economic Impacts

Desertification is not only unanimously acknowledged to have significant adverse effects on flora and fauna population, the topographic and edaphic components of the ecosystems or the micro-climate variability, but also, the socio-economic impacts has also be documented (Penny, 2009; Adewuyi and Baduku, 2012). Desertification has severe impacts on food security, livelihood, economic and socio-cultural life of the affected people.

Reduced agricultural productivity and food insecurity

Agriculture is the economic mainstay of the majority of households in Nigeria and is a significant sector of Nigeria's economy. Food security in its most basic form is the access of all people to the food needed for healthy life at all times. Factors that affect soil quality affect agricultural productivity also and indirectly on food supply. Loss of soil structure and cohesion, soil crusting, soil compaction and soil erosion especially in arable lands has been enumerated as consequences of desertification which also reduce agricultural output, hence food insecurity. Toye (2002) reported that at least 50,000 farmers in about 100 villages in Yobe State were at risk of abandoning farming due reduced agricultural output caused by dunes covering a large expanse of their farmlands.

Economic loss and reduced economic growth

Desertification has economic consequences. It weakens populations and institutions rendering them more vulnerable to global economic factors (Koohafkan, 1996). Short fall in earned tax receipts occurs due to low productivity, and has consequences on the capacity of government to reimburse their foreign debt and develop national socio-economic programmes. The persistence of desertification reduces national food production and furthers the need to rely on foreign imported products. Also, government expends so much on ameliorating the effects of desertification, revenues which could have been used for other developmental projects. For example, more than 65 and 55% of Sokoto and Borno States are said to be afflicted (Emodi, 2013). In Gidan Kaura, a village 90 km northwest of Sokoto, sand dunes have been reported to have invaded vast areas of farmland and destroying nearly 300 houses. Villages such as Bulatura, Kaska, Bukarty Toshu, Tubtulova, Yunusari, among others in the extreme northern part of Borno State, have been either completely surrounded by sand dunes or are about to be buried by them. It is estimated that Nigeria loses about $5.1 billion every year owing to rapid encroachment of drought and desert in most parts of the north (Vanguard News Paper, 2010).

Migration

A major consequence of desertification is migration causing separation of families as men usually abandon the women and children to seek for employment in the urban centres due to unproductive agricultural practice at the rural areas. For example in Nigeria, people living in drylands usually the herdsmen of the north migrate into towns and villages down south and neighbouring countries that are wetter (NEST, 1991). More so, migration could enhance disease transmission from an epidemic area to another area. Emodi (2013) reported the migration of significant population from Borno State down south due to desertification that has affected their agricultural output.

Resource use conflict

Conflict is perceived divergence of interest, or a belief that the parties' current aspiration cannot be achieved simultaneously (Pruit and Robin, 1983) and conflict arises when there are incompatible or mutually exclusive goals or aims or values espoused by human beings (Deutsch, 1973). While Ross (1983) sees conflict to occur when parties disagree about the distribution of material or symbolic resources and act because of the incompatible of goals or a perceived divergence of interests. In Nigeria, conflicts over land resources are focused on areas of high productivity, especially those that provide seasonally critical resource. These critically limited resources have competitive uses amongst the various rural land users; notably farmers, herders, fishermen and hunters. According to the Institute for Peace and Conflict Resolution, Northern part of the country has witnessed a dense occurrence of conflicts resulting from the effects of desertification especially in the seasons when rainfall in very low and the graze lands are unable to sustain the population of livestock in the zone, and herdsmen (especially the popularly known Fulani herdsmen) geared their livestock to farmland area in the zone or down south in the country, situation which has caused brutal fight between the herdsmen and farmers. A conflict in Barkin ladi Shendam in North Central (Plateau State) in June to July 2002 between indigenous tribes and the nomad fulani, between Ngamo Maitatsine and Boko-Haram over farm lands and grazing areas in Yobe State, Agatu people and Fulani's in Benue State are good examples.

Unemployment

Unemployment occurs when a qualified person is actively searching for employment and is unable to find work. Unemployment is an economic indicator that refers to the number or proportion of people in an economy who are willing and able to work, but are unable to get a job (Cornet, 2002). At least 90% of the inhabitants of drylands live in developing nations, where they also suffer from poor economic and social condition (Whitford, 2002). The effect of desertification is seen on the precariousness of living conditions and the difficulty of access to resources and opportunities largely due to lack of suitable condition for farming or fishing (main occupations in the rural area). Desertification in rural lands makes the land incapable of supporting population that previously lived there. This results in mass migration out of rural areas and into urban areas, particularly in Africa. These migrations into the cities often cause large numbers of unemployed people, who end up living in slums (Pasternak and Schlissel, 2001; Briassoulis, 2005).

EFFORTS BY THE NIGERIAN GOVERNMENT TO COMBAT DESERTIFICATION

The Nigeria Government has been making efforts aimed to combating environmental problems of drought and desertification. These efforts include national policies, legislative framework, sectoral programmes and partnership with local and international organizations that is saddled with fighting desertification. Nigeria has developed many policies and programmes, received partnership in form of finance, technical assistance, loans and capacity building from partners such as World Bank, IAEA, IFAD, CIDA, UNDP, UNIDO, China Government, Japan international Agency (JICA), Agricultural Development Company Limited, Israel and the UNEP/GEF. The directive of the emirate of the Northern Nigeria by the Anglo-French Commission in 1937 to embark on tree planting to stop desert encroach in the region was probably the foremost desertification combating effort in the country. In 1977, in other to examine the problem of desertification and check desert encroachment in the arid zone of Nigeria, Federal Government set up the Arid Zone Aforestation Project. This project launched tree planting campaigns and forestry projects to check deforestation. Tree seedlings were produced and distributed which led to the establishment of Shelter Belts along the Northern borders of the country. During the administration of Major General Muhammadu Buhari in 1984, Tree Planting Campaigns was used as an instrument to enlighten and motivate people on the negative effects of desertification and the need to combat it (Jibunor, 2014). Federal Environmental Protection Agency (FEPA) was established in 1988 under Decree 58 after the Nigerian government had signed the United Nations Conference on Environment and Development (UNCED), an important step towards addressing desert encroachment in the country. States Environmental Protection Agencies (SEPA) were thereafter established in the 36 states including the Federal Capital with mandate to address environmental problems which include desertification (Medugu, 2009).

Nigeria signed the Desertification Convention on the 31st October, 1994, and ratified same on the 8th July, 1997 thereby qualifying the country as a party to the convention with effect from October, 1997. The creation of the Department of Drought and Desertification Amelioration in 1999 in the Federal Ministry of Environment was to strengthen the existing institutional arrangement for more effective coordination of activities of Nigeria Government towards the implementation of the CCD. National Action Plan (NAP) of Nigeria which is part of the National Economic and Social Development and Environmental Protection Plan was developed. NAP compiled strategies and submitted it to the Secretariat of the UNCCD Bonn, Germany, which are to help in environmental education and management, public awareness, poverty alleviation and provision of alternative sources of energy among others. These strategic policies include, National Policy on Environment, National Agricultural Policy, National Energy Policy, National Environmental Action Plan (NEAP) and State Environmental Action Plans (SEAPs), National Tropical Forestry Action Plan, National Conservation Strategy, Natural Resources Conservation Action Plan, National Water Resources Master Plan (1995 to 2020), National Biodiversity Strategy and Action Plan, The Green Agenda of the VISION 2010 Report, National AGENDA 21, National Action Programme to Combat Desertification, National Economic Empowerment and Development Strategy (NEEDS) and National Policy on Women.

In 2005, former president, Chief Olusegun Obasanjo initiated a Global Tree Planting Project to halt desert encroachment in 46 local government areas in the country's desertification frontline states. The programme was expected to generate economic activities for the citizens of the states involved and urge them to desist from felling but rather plant trees. Several of such projects was also initiated in some of these states such as the ₦5.2 million project of Gidauniyar Jihar Kastina in Katsina State, Sure-P Programme in Sokoto State for 5 km tree planting in each local government of the state and collaborative programme of Jigawa State and the United State to harness the potential of Gum Arabic to fight desert encroachment and reduce poverty in the state (Haruna and Bukar, 2010). Legislative framework was also enforced to encourage the execution of these projects in Nigeria. Despite these efforts by the Nigeria Government, significant success in remedy desertification in the country is yet to be achieved due to the following factors:

Poverty

The fragile semi-arid land of Northern Nigeria is unyielding to the efforts to reclaim it from desertification, due to the threat pose by the growing poor population in the area. The local people meet their needs from the natural environment by burning the scanty bush area for game, deforest for firewood, and their livestock overgraze the available vegetation. The 2010 poverty survey by the National Population Commission showed that the North-west and Northeast geo-political zones, which are desertification frontline states, had the highest poverty rates in the country with 77.7 and 76.3%, respectively, relative to the national rate of 69.1%. The poverty condition will continue to impede the government reclamation efforts if holistic approach is not put in place to alleviate poverty in the country.

Communal resource use

Unregulated access to land resources that are communally owned may lead many individuals to maximize their own gain by over exploiting the land resources. Since no one is accountable to such land, its open access caused common rearing of animals and farming, such that the carrying capacity of land is exceeded and desertification results.

Lack of political will, institutional weakness and corruption

This is a major impediment to combat desertification in Nigeria. Institution role in establishment and enforcement of policies and law is significant in environmental management. Laws in Nigeria is more against poor people or people of no political influence, hence, people of influence engaged in unsustainable environmental practices majorly deforestation, without any consequence. Even with the contribution of donor agencies in combating desertification in Nigeria, political office holders sees investing money in fighting desertification as waste of resource and divert it partly or wholly to another sector of the economy. Corruption from the side of the desertification policy implementation partners and institutions also militate against effective policy implementation.

REMEDIES TO DROUGHT AND DESERTIFICATION

Solution to the problem of desertification must target all aspects that relate to the problem. Though some desert conditions are irreversible even if all anthropogenic causes are stopped now, but some are reversible. Some of the remedies to desertification include:

Awareness

Raising awareness of desertification at local, national and global level is key to remedying drought and desertification. It is probably the cheapest means in combating desertification because it serves as a preventive measure. Awareness will provide people with the understanding of the causes and consequences of the phenomena so as to stop all possible causes and encourage actions that would remedy some of the consequences and prevent further degradation of soil.

Protection of marginal lands

Due to the incapability of marginal lands to support permanent or intensive agriculture, there is need for proper evaluation of such lands with government policy and enforcement aimed at protecting them from any activities that is capable of denuding its vegetation cover.

Planting and protection of indigenous tree and shrub species

Increasing the area of conspicuous vegetation into desertifying lands is vital in managing desertification. This could be done through intensive and technologically supportive reclamation, by planting and establishing indigenous trees and vegetation known to the area. Planting of trees coupled with avoided felling should be embraced in arid and semi-arid zones until if possible a forest zone is attained (Mumoki, 2006). Planting of tress helps in:

i. Soil stability
ii. Protection of soil from erosion
iii. Retention of soil moisture and nutrients
iv. Carbon sequestration

Sustainable agricultural practices

Agroforestry is a form of farming system that plays an extremely important role in the land management of semi-arid and arid zones. Agroforestry is a land use management system in which trees or shrubs are grown around or among crops or pastureland. It combines agricultural and forestry techniques to create more diverse, productive, profitable, healthy, and sustainable land-use system. Grazing systems should be improved from denuding the natural rangelands whose consumption will lead to aridity condition hence establishment of new pastures for grazing by livestock should be ensured. All water to be used for irrigation should be examined to be devoid of level of salt that could result in salt accumulation, as well as ensuring a good drainage system (Sultana, 2008).

Use of alternative source of energy

Feeling of the few trees and shrubs in desert-prone areas for fuel wood can be reduced through the development of sustainable alternative energy sources such as biofuel. This will not only conserve forest resources but will reduce environmental pollution.

CONCLUSION

Drought and desertification is a twin global environmental problem of arid and semi-arid regions. The phenomena integrate climatic elements with human activities in transforming productive land, into an impoverished area generally refers to as desert. Nigeria is a country faced with desertification problem with 15 states accounting for about 68.38% of the country's total land area, challenged with varying degrees of desertification. Impacts of drought and desertification are felt in all aspects of the environment and human livelihood. Remedies to these problems involves awareness, protection of marginal lands, planting of indigenous tree and shrub species, sustainable agricultural practices and use of alternative energy source. There is need to bridge the gap between the formation of policy and strategies of combating drought and desertification so that government efforts to combating desertification can be productive.

Conflict of interests

The authors did not declare any conflict of interest.

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Salinity effects on growth of four *Artemia franciscana* (Kellogg, 1906) populations, cultured in laboratory conditions from Yucatan Peninsula

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The aim of is study was to determine the growth performance of Mexican *A. franciscana* Yucatan Peninsula strains in different salinity tests. Four populations from different habitats were studied: Real de las Salinas (RSAL), Cancun (CAN), San Crisanto (CRIS) and Celestun (CEL). Nauplii from each population were inoculated in 200 L plastic tanks with 160 L of dissolved rock salt water at 40, 60, 80, 100 and 120 g L^{-1}. The organisms were fed with *Tetraselmis* sp. and *Pinnularia* sp. microalgae (500 x 10^3 cells mL^{-1} water concentration) during the experiment period. Biometry length was measured to obtain absolute growth rate (AGR), instantaneous growth rate (IGR), and length gain (LG) values. Variance test (ANOVA) analysis was applied to determine the significant differences (P <0.05) between final length and growth rates of four populations. The total length range was 6.675-9.589 mm; AGR values ranged between 0.395 and 0.571 mm per day. IGR percentage range was 17.623-18.91% increase per day, and length range gain values were 6.277 to 9.130 mm. No significant difference was shown between 100 g L^{-1} salinity test and 120 gL^{-1} test, and then between CEL and RSAL strains. The salinity variable showed high percentage (62 to 93%) in the salinity tests or significant strains (p<0.05). Yucatan Peninsula has several salt ponds with natural *Artemia franciscana* sources that can be used for aquaculture or aquarium industry. It is important to know growth performance of species in specific salinity concentration. This will help one to understand the adaptation of *Artemia* populations cultured in laboratory and also ensure better culture system management for producing biomass for use in aquaculture or aquarium industry or academic laboratory centers.

Key words: *Artemia franciscana,* survival, growth rates, length gain, salinity.

INTRODUCTION

Many aquatic organisms and crustacean, in particular, have wide salinity tolerance range in their environment. As a result, it is necessary to have an ion balance between the flow of ions from external environment to their internal hemolymph through osmoregulatory mechanisms. This ensures optimal ion regulation and therefore better growth rates (Abatzopoulous et al., 2002a). One of these organisms that can survive different salinity concentrations is crustacean branchiopod *Artemia*. It has two main structures responsible for carrying out the process of osmoregulation in adults: the gut epithelium (Croghan, 1958b); Plattner, 1955) and meta-epipodites in branchial segments (Copeland, 1966; Croghan, 1958a). Croghan (1958a) suggested that the inlet continuous liquid medium toward intestine gut can also take in sodium chloride (NaCl) and water, both necessary for organisms' survival.

Artemia is among the few organisms adapted to survive in very diverse living conditions. It can survive in salinities as low as 10 gL^{-1} (Abatzopoulous et al., 2006 a,b) and as high as 340 gL^{-1} (Post and Youssef, 1977). This is a wide range of salinity concentrations in natural habitat that can be used under laboratory conditions. That is why it is necessary to know the narrow salinity range in order to obtain better growth and survival results. It will also help in biomass or cysts productions from different *Artemia* populations that respond adequately to the stress of ions dissolved in medium, and osmotic pressure of internal fluids (Copeland, 1967).

Castro et al. (2013) mentioned that in Mexico, coastline and inland waters have many natural salt water bodies, both in Gulf of Mexico and Pacific Zone. Unfortunately, many of them do not produce salt anymore and *A. franciscana* populations have disappeared from these habitats. Another problem is the low budget on field investigations for knowing the presence or absence of *Artemia* populations in all these salt bodies in Mexico. In few natural habitats, the local salt producers collect *Artemia* biomass by hand and sell to aquarist industry or local aquaculture farmers (Castro et al., 2013).

In the year 2000, in Mexico, three *Artemia* inland populations were described: they originated from Coahuila, San Luis Potosí States, and Texcoco township; nine populations localized in Pacific, Gulf of Mexico and Yucatan Peninsula coastal waters. Torrentera and Dodson (1995) presented the biometry values of four populations of *Artemia* localized in Yucatan Peninsula manmade saltworks. The cysts were collected during 1990-1992. Torrentera and Abreu-Grobois (2002) studied these same populations from cytogenetic variability and differentiation angle. Torrentera and Dodson (2004) highlighted weather conditions of the habitat, phyto-plankton, bacteria and birds (flamingos), populations' dominance, also cyst and biomass productions from these *Artemia* Yucatan sites.

Maldonado-Montiel and Rodriguez-Canche (2004) studied the biomass production of *A. franciscana* population located in "Real de las Salinas", Campeche State, but they did not mention the geographical location of this habitat. Rodriguez-Canche et al. (2006) mentioned the geographical localization of "Real de las Salinas", Campeche. The cysts were collected from 1997-2000. The authors described some biological characteristics and biochemical composition of cysts and nauplii.

Castro et al*.* (2010) studied five Pacific Coast Mexican populations and mentioned the geographical localization of these *Artemia* strains. Castro et al. (2010) described recently the last habitat of *Artemia* population found in Mexico; their geographical localization is a little saltwork near Cancun, Quintana Roo. The authors studied the reproductive potential of two populations from Pacific coast: two populations from Yucatan Peninsula and two populations from Inland waters in a culture medium of 100 and 120 g L^{-1} salinity.

Therefore, it is important to determine salinity response of each Mexican *Artemia* strain to ascertain optimum conditions for their growth and understand their adaptation pattern to varying salinity.

The aim of this study was to know how length rates and length gain variables correspond with specific salinity concentrations cultured under laboratory condition. The results obtained from the study will be useful for the potential use of these strains in manmade saltworks operations as well as aquaculture and aquarium industry.

MATERIALS AND METHODS

Strains used in the experiment

This study was performed in Live Food Production Laboratory at Autonomous Metropolitan-Xochimilco University, Mexico. The dehydrated and cold (5°C) storage cysts (0.5 g) of four *Artemia franciscana* strains (Table 1, Figure 1) from Yucatan Peninsula Coastal Zone were hatched under 40 g L^{-1} of salinity, pH of 8-10 and 25±2°C temperature, with constant illumination and air supply (Castro et al., 2003).

Culture experiments

The nauplii hatched were siphoned into separated beakers and then transferred to 200 L plastic tanks with 160 L of different salt concentrations (40, 60, 80, 100 and 120 g L^{-1}). They were measured with a Vee Gee STX-3 refractometer; pH of 8-10 was tested with a HANNA pH meter. They were kept under constant illumination (white light tube, 40 watts), air supply (>2 mg O_2 L^{-1}) and temperature (25±2°C). *Artemia* nauplii density was adjusted to one individual per 1 mL to avoid growth problems for space. The animals were fed *ad libitum* with microalgae *Tetraselmis* sp*.* and *Pinnularia* sp. at 500 x 10^3 cells mL^{-1} culture density (1 L each) during their pre-adult stage (between 14-21 days).

Total length biometry

In the salinity culture where the organisms reached adulthood (when first mating was observed), fifty females and fifty males from each population were obtained and maintained separately for two weeks in 4 L beakers. The beakers have the same salinity, 250 mL

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Table 1. List of Yucatan peninsula Mexican *Artemia* strains studied, abbreviation used and geographical location.

Site	State	Abbreviation	Co-ordinates
Cancun	Quinatana Roo	CAN	21°10' N; 86°47' W
San Crisanto	Yucatan	CRIS	21º 21' N; 89º 07'W
Celestun	Yucatan	CEL	20º 52' N; 90º 23'W
Real de las Salinas	Campeche	RSAL	20°02' N; 90°14' W

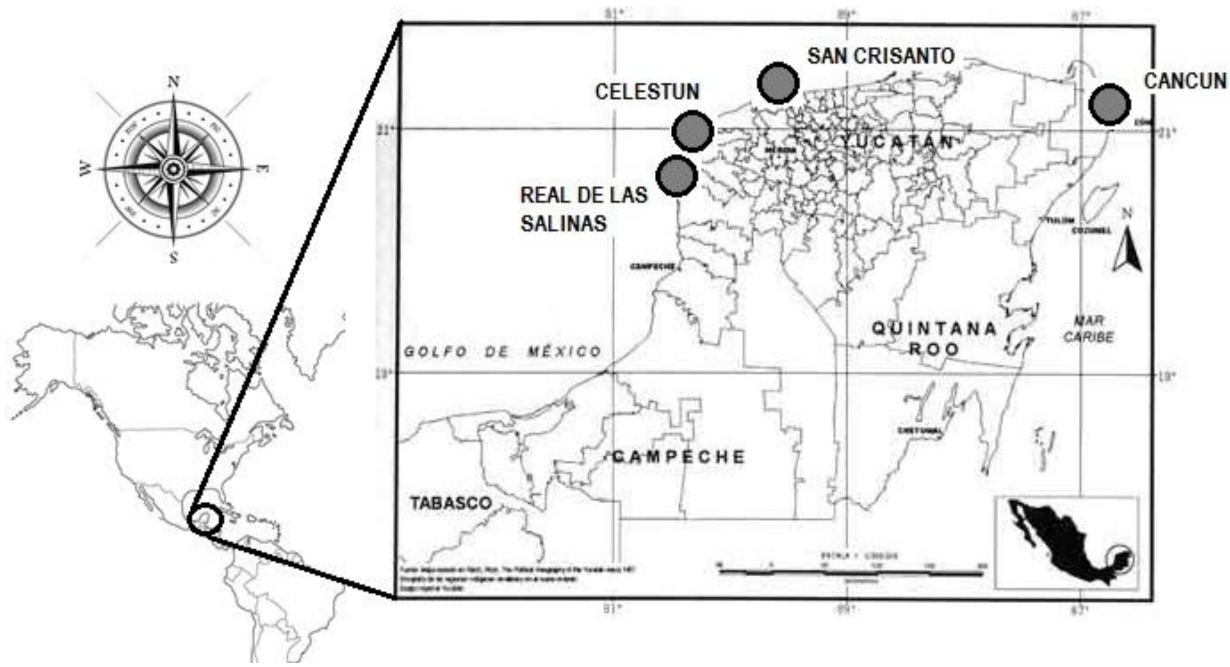

Figure 1. Geographical location of Yucatan peninsula coast, Mexico strains habitat.

of microalgae´s culture medium (125 mL from each microalga), pH of 8-10 and constant illumination and air supply. This is to allow individual growth without expending energy on reproduction. After two weeks, the adults were fixed with few drops of acetic acid. The total length biometry was measured with an optical microscope DM 750 Koheler Leica equipped with a color camera ICC50 HD Leica having Interactive Measure Module.

Growth rate analysis

The Absolute Growth Rate (AGR) formula used was:

$$\text{AGR} = \frac{\text{Final length - Initial length}}{\text{Total experimental days}}$$

Wooton (1991)

The Instantaneous Growth Rate (IGR) formula used was:

$$\text{IGR} = \frac{\text{NL Final length - NL initial length}}{\text{Total experimental days}} \times 100$$

Soriano and Hernandez (2002)

NL = natural logarithm.

For length gain (LG), the formula used was:

$$\text{LG} = \text{Final length - Initial length}$$

Moreno et al. (2000).

Statistical analysis

A Microsoft and Box Plot techniques were performed to ensure that the assumption of normality was held for each parameter using Excel 2010 (Microsoft Corp., Washington, USA). Mean values and standard deviation for total length biometry were made with descriptive statistical analysis. One way ANOVA was used to determine if there was a significant difference (Kachigan, 1991) between the strains. The pairwise comparison Tukey method (p=0.05) was used to compare pairs of sample means. Type classification was based on population grouped according to their specific salinity cultured medium (Sokal and Rohlf, 1981; Kachigan, 1991). The SYSTAT 13 (Systat Software Inc., California, USA) software package was used for statistical analysis.

Table 2. Mean values and ± SD of total length (in mm) of Mexican Yucatan peninsula *Artemia* strains studied.

Strain	Culture salinity test			
	60 g L^{-1}	80 g L^{-1}	100 g L^{-1}	120 g L^{-1}
Cancun	7.344 ± 0.249	6.675 ± 0.048	8.093 ± 0.088[1]	8.205 ± 0.206[1]
San Crisanto	8.161 ± 0.324	7.496 ± 0.132	9.042 ± 0.098[1]	9.139 ± 0.225[1]
Celestun	8.577 ± 0.187[a]	7.756 ± 0.145[a]	9.368 ± 0.081	9.531 ± 0.136[a]
Real de las Salinas	8.646 ± 0.342[a]	7.816 ± 0.147[a]	9.432 ± 0.063	9.595 ± 0.138[a]

Same letter in column did not show significant differences (p>0.05). Same number in a row did not show significant differences (p>0.05).

Table 3. Mean AGR values and ± SD of millimeters per day of Mexican Yucatan peninsula *Artemia* strains studied.

Strain	Culture salinity test			
	60 g L^{-1}	80 g L^{-1}	100 g L^{-1}	120 g L^{-1}
Cancun	0.434 ± 0.016	0.395 ± 0.018	0.480 ± 0.006[1]	0.489 ± 0.013[1]
San Crisanto	0.482 ± 0.020	0.444 ± 0.020	0.537 ± 0.006[1]	0.543 ± 0.014[1]
Celestun	0.507 ± 0.012[a]	0.460 ± 0.021[a]	0.557 ± 0.006	0.567 ± 0.009[a]
Real de las Salinas	0.511 ± 0.021[a]	0.463 ± 0.020[a]	0.561 ± 0.005	0.571 ± 0.009[a]

Same letter in column did not show significant differences (p>0.05). Same number in a row did not show significant differences (p>0.05).

RESULTS

At 40 g L^{-1} salinity test, the final length biometry values cannot be taken because all individuals from each population died at juvenile stage.

Total length biometry

The total length means ±SD (in mm) of Yucatan Peninsula *Artemia* strains are shown in Table 2.

In all the populations, the highest values were observed at 120 g L^{-1} salinity test and the lowest length values at 80 g L^{-1} salinity test. The ANOVA test showed no significant differences between CEL/RSAL populations at 120 g L^{-1} (p=0.521), 80 gL^{-1} (p=0.251) and 60 g L^{-1} salinity experiment tests (p=0.779). In 100 gL^{-1} salinity test, all populations showed significant differences between them (p<0.001). With respect to significant differences between salinity tests at same population, only CAN (p=0.056) and CRIS (p=0.296) populations did not show significant differences at 100/120 g L^{-1} salinity test. The variation percentage was 35% for the population; 60% for the salinity and only 0.23% for the interaction between these two variables.

Absolute growth rate (AGR)

The AGR values are shown in Table 3. The highest values were at 120 g L^{-1} salinity and the lowest values at 80 g L^{-1} salinity culture test. The highest values were in RSAL strain with 0.571 mm per day and the lowest one was shown in CAN strain with 0.395 mm per day. The ANOVA test showed significant differences between salinity tests at same strain; only CAN and CRIS strains did not show significant differences at 100/120 gL^{-1} salinity tests (p=0.056 and p= 0.296 respectively), also between CEL/RSAL strains at 60, 80 and 120 g L^{-1} salinity tests. The variation in significance was 62.58% for salinity, 32.71% for the strain and only 0.24% for the interaction between salinity and strain variables.

Instantaneous growth rate (IGR)

The final percentage rates are shown in Table 4. The highest values were at 120 g L^{-1} salinity and the lowest values at 80 g L^{-1} salinity. The highest values were recorded for RSAL strain with a length increase of 18.918% per day and the lowest value was for CAN strain with 17.623%. ANOVA test did not show significant differences between salinity tests and strains variables (p>0.05). The variation of significance is given by the salinity with 93.19%.

Length gain

The final length gain values are reported in Table 5. The

Table 4. Mean IGR values and + SD in percentage of Mexican Yucatan peninsula *Artemia* strains studied.

Strain	Culture salinity test			
	60 g L^{-1}	80 g L^{-1}	100 g L^{-1}	120 g L^{-1}
Cancun	18.217 ± 0.213	17.623 ± 0.045	18.827 ± 0.068[1]	18.911 ± 0.158[1]
San Crisanto	18.163 ± 0.248	17.635 ± 0.110	18.808 ± 0.068[1]	18.873 ± 0.153[1]
Celestun	18.270 ± 0.137	17.642 ± 0.116	18.822 ± 0.054	18.930 ± 0.089
Real de las Salinas	18.263 ± 0.248	17.636 ± 0.117	18.811 ± 0.042	18.918 ± 0.090

Same number in a row did not show significant differences (p>0.05).

Table 5. Mean length gain values and + SD (in mm) of Mexican Yucatan peninsula *Artemia* strains studied.

Strain	Culture salinity test			
	60 g L^{-1}	80 g L^{-1}	100 g L^{-1}	120 g L^{-1}
Cancun	6.946 ± 0.249	6.277 ± 0.048	7.695 ± 0.088[1]	7.807 ± 0.206[1]
San Crisanto	7.715 ± 0.324	7.050 ± 0.132	8.596 ± 0.098[1]	8.693 ± 0.225[1]
Celestun	8.116 ± 0.187[a]	7.295 ± 0.145[a]	8.907 ± 0.081	9.070 ± 0.136[a]
Real de las Salinas	8.181 ± 0.342[a]	7.351 ± 0.147[a]	8.967 ± 0.063	9.130 ± 0.138[a]

Same letter in column did not show significant differences (p>0.05). Same number in a row did not show significant differences (p>0.05).

highest values were at 120 g L^{-1} salinity culture test with a range of 7.807 to 9.130 mm and the lowest values at 80 g L^{-1} salinity culture test, with 6.277 to 7.351 mm range. The highest values were observed for RSAL strain with a length gain of 230.74% and the lowest one for CAN strain with 195.71%. The variation of significance of ANOVA test is given by salinity variable with 62.58%, strain variable with 32.17% and interaction between these two variables with 0.24%.

DISCUSSION

In this study, *Artemia* strains from Yucatan Peninsula exposed in culture medium with salinities below 60 g L^{-1} died in metanaupliar stage, because the osmoregulatory mechanisms were correctly functional at 60-120 g L^{-1} salinity range. The length differences between Mexican strains are not due to their habitat origin, but are triggered by salinity variable. Sayg (2004), who worked with parthenogenetic *Artemia* populations, suggested that these differences can be considered as local biotope response and not only salinity intrapopulation response. This was seen in their study in the ploidy level strain and perhaps in larval energy content, in our study.

Other authors such as Chapman (1968); Metalli and Ballardin (1972); Vanhaecke and Sorgeloos (1989) indicate that genetic variability may induce strain damping with respect to extreme conditions such as salinity. Vanhaecke et al. (1984) also found low survival at 35 g L^{-1} and increased survival in salinities above 90 g L^{-1}. Post and Youssef (1977) indicate that *Artemia* culture at salinities <45 g L^{-1} decreases survival; Hammer and Hurlbert (1992) observed that juveniles of different *Artemia* species and strains grow slowly and adults die at < 38 g L^{-1} salinity. However, El- Bermawi et al. (2004) found that Egyptian *Artemia* has a survival of 60% at salinity of 35 g L^{-1}. Comparing data with other species of *Artemia* genus like *A. salina*, *A. sinica*, *A. persimilis* and some parthenogenetic populations of *Artemia* (Browne and Wanigasekera (2000) a 24% survival was observed at 60 g L^{-1} salinity. Van Stappen et al. (2003) found only a 39% survival of *A. tibetiana* at 35 g L^{-1}. Sayg (2004) found a 15% survival of *A. parthenogenetica* at salinities below 80 g L^{-1} from Turkey and Greece; Agh et al. (2008) and Abatzopoulos et al. (2006a,b) did not obtain survival results with *A. urmiana* at 50 g L^{-1} salinity tests. With regard to American Continent *Artemia* species, Medina et al. (2007) found *A. persimilis* survival rates of 5.3% only at 30 g L^{-1} of salinity.

The consulted literatures showed that the salinity range of 80-120 g L^{-1} was considered as the most appropriate to inoculate the hatched nauplii, except with the species *A. tibetiana*. In inoculating the Mexican nauplii at salinities above 120 g L^{-1} culture, Yucatan Peninsula's populations show 100% mortality because at this stage they cannot activate the proper enzymes to avoid osmoregulatory mechanism (Clegg and Trotman, 2002). Dana and Lenz (1986) showed that survival decreases below 20% at salinity above 179 g L^{-1}; and the osmoregulatory apparatus is damaged not only by ion concentration, but also by frequency and time duration of salinity concentration in their own habitat. *A. salina* cultivated in a range of 150-200 g L^{-1} salinity showed 100% mortality; *A. urmiana* showed 100% mortality when it was inoculated at 200 g L^{-1} salinity (Agh et al., 2008; Abatzopoulos et al., 2006b).

Salinity concentrations < 60 g L^{-1} and > 120 g L^{-1} affect the survival of Mexican *Artemia* Yucatan Peninsula's populations; the same result has also been observed for other *Artemia* species: *A. urmiana*, *A. persimilis*, and *A. tibetiana.* It is possible to maintain *Artemia* cultures in a laboratory if salinity increases gradually (10 g L^{-1} every week) to allow the establishment of the enzymatic activity in osmoregulatory mechanism in the culture organisms (Post and Youssef, 1977; Wear et al., 1986; Triantaphyllidis et al., 1995; Van Stappen, 2002; Agh et al., 2008) like in natural habitat. Tackaert and Sorgeloos (1991) mentioned that genetically imprinted factors exist that respond to salinity changes in each *Artemia* species or strain; and they function better at 100-180 g L^{-1} salinity. This can be seen in Mexican Yucatan Peninsula strains, showing 80% of significance variability to salinity tests. This information allows one to make better laboratory culture management of this crustacean where the salinity, temperature and food variables can be controlled (Wear and Haslett, 1987).

In studying the growth of *A. franciscana* Mexican Peninsula's strains at different salinities, there were observed significant differences between salinity tests, the strains and the interaction between these two variables. The same applies with AGR and IGR final data, where the percentage variability with respect to the salinity was between 81-88%; the strain variable was 9-17% and the interaction between these two variables was 1.40-1.89%. The differences between strains are mainly due to the size of the nauplii. This biometry variable was genetically determined (Sorgeloos et al*.,* 1976; Vanhaecke and Sorgeloos, 1980); and therefore this daily growth (in millimeters or percentage) has similar proportion between salinity tests, but the final length was different.

Mexican Peninsula's *A. franciscana* strains increase their total length with <80 g L^{-1} salinity tests. Only few salinity studies were done with *A. franciscana* or other species and their effect on growth increase or decrease and AGR and IGR rates. Amat et al. (2004) found that *A. persimilis* (Argentina) showed a total length range of 9.3-10.2 mm at 70-80 g L^{-1} salinity culture test. El- Bermawi et al. (2004) reported 5.79 mm at 120 g L^{-1} culture salinity and 5.41 mm at 80 g L^{-1} salinity concentration. Rodríguez-Almaraz et al. (2006) said *A. franciscana* from Baja California, Mexico hadn 6.27 to 7.88 mm length range at 115-195 g L^{-1} salinity medium. Medina et al*.* (2007) mentioned 8.8-10.0 mm length range in populations cultured at 120 g L^{-1} salinity. Dana and Lenz (1986) found *A. monica* specie to have 6-8 mm length range at 76-118 g L^{-1} salinities. For *A. urmiana*, Arashkevich et al. (2009) reported a total length of 6-13 mm in a range of 100-110 g L^{-1} salinity. Sayg (2004) reported 8.31-10.92 mm for parthenogenetic population(s) of *Artemia* in 160 g L^{-1} salinity culture test. It is noteworthy that organisms of parthenogenetic population(s) of *Artemia* always are larger than bisexual species.

Vanhaecke et al. (1984) and Sayg, (2004) mentioned that smallest length at 80 g L^{-1} culture salinity (7.93 mm) is caused by malfunction of enzymes and energy levels involved in osmoregulatory mechanism. This increased at 100 g L^{-1} salinity to 8.70 mm, and 9.72 mm at 120 g L^{-1} salinity in Mexican Peninsula *A. franciscana* strains. Above 140 g L^{-1} salinity culture test, Gilchrist (1960); Baid (1963); Triantaphyllidis et al. (1995) and El- Bermawi et al. (2004) indicated that the effect is inversely proportional when the salinity increases. This statement could not be observed in the Mexican Peninsula strains because the nauplii died in these salinity (140, 160 and 200 g L^{-1}) culture test.

With respect to growth rates (AGR and IGR), Sayg (2004) mentioned that length and growth rate are not affected when salinity increase occurs gradually in culture recipes. Triantaphyllidis et al. (1995) indicated that differences in length and growth rates are significant in parthenogenetic populations of Tanggu (China). Abatzopoulos et al. (2006a,b) observed in *A. urmiana* specie that growth rate is not affected with increased salinity.

Although Agh et al. (2008) disagreed with that because they found best growth rate at 75-100 g L^{-1} and those values changed when salinity increased. Mayer (2002), who studied *A. franciscana* populations from Dominican Republic and Puerto Rico, found that length differences are mainly due to geographic isolation and their particularly ecological adaptation to their habitat.

Cole and Browne (1967) and Hontoria and Amat (1992) mentioned that the ionic composition of water affects *Artemia* morphology and length; Vanhaecke and Sorgeloos (1980) mentioned that *Artemia* length responded to its environmental conditions and those changes were considered as local adaptation to its own habitats. In recent works, Asem and Rastegar-Pouyani (2008) mentioned that to find differences in length and growth rates it is better to use the male organisms for *Artemia* populations, which respond with greater variation to salinity increase. Bowen et al. (1985) and Castro (2004) mentioned that due to length differences between *Artemia* strains at different salinities, a long-range time process may provoke speciation process. This might be due to lack of successful interbreeding between strains (caused by length differences between male and females organism), leading to the onset of incipient species or related species

From the above, it is not advisable to generalize the local *Artemia* species or strain obtained with respect to salinity and growth rates whether they are the same species (different strains) or much less different species (Litvinenko et al. (2007); Agh et al. (2008) and Naceur et al. (2009). The knowledge of the best salinity tests that favour the Mexican strains' growth rates under laboratory conditions allows one to manage well natural habitats applications to avoid salt, food and culture time waste. It helps one to get bigger and healthy *Artemia* organisms (biomass), to sell to the aquaculture or aquarist industry near their natural habitats. It can also provide income to those who work in those sites, making it possible for them to own their production systems. It will lead to better management of academic laboratories which make experiments with those populations.

Conclusion

Mexican *A. franciscana* from Yucatan Peninsula habitats died when they were cultivated in 60 g L^{-1} salinity under laboratory conditions. Growth performances increase when salinity increases in culture medium. Better performance is observed at 100 and 120 g L^{-1} salinity concentrations. This information allows one to know better culture management of these *Artemia* populations either in natural habitats or laboratories of academic centers.

Conflict of interests

The authors did not declare any conflict of interest.

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Floristic composition and structural analysis of Gelesha forest, Gambella regional State, Southwest Ethiopia

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The study was conducted on Gelesha Forest, Godere District and Gambella Regional State, Southwest Ethiopia to determine floristic composition and structural analysis of the forest. Systematic sampling method was used to collect vegetation data from 60 plots (20 m × 20 m) for trees and shrubs, 5 m x5 m for seedlings and saplings and 1 m × 1 m for herbaceous plants. Vegetation classification was performed using PC-ord software package. All trees and shrubs with DBH >2 cm and height >2 m were measured for diameter tape. A total of 157 species of vascular plants belonging to 127 genera and 54 families were recorded from Gelesha Forest. Of all the species recorded 33.12% were trees, 19.11% shrubs, and 13.38% woody climbers. The dominant families were Euphorbiaceae and Moraceae (13 species each): 11 and 6 genera, respectively. The density of trees in the forest decreases with increasing DBH classes. Six population distribution patterns were recognized. The Forest has a density of 557.09 stems/ ha and a total basal area of 98.87 m^2/ ha. The forest is characterized by high density of trees in the lower class than in the higher. Phytogeographically, it was more related to the moist evergreen Afromontane forests of the Southwest Ethiopia than other forests in the country.

Key words: Forest structure, Gambela region, regeneration, species diversity, vegetation composition.

INTRODUCTION

A huge proportion of the planet's land surface has been transformed in other land use systems. Although land-use practices vary greatly across the world, their ultimate outcome is generally the same: the acquisition of natural resources for immediate human needs, often at the expense of degrading environmental conditions (Foley et al., 2005). Even though deforestation and forest fragmentation is a global phenomennon, it is severe in the tropica. Tropical forests are deteriorating both in quality and quantity. Approximately half of the tropical closed-canopy forest has already been removed and the land converted to other uses (Wright, 2005). The rapid conversion of tropical forests for agriculture, timber production and other uses has generated vast, human-dominated landscapes with potentially dire consequences for tropical biodiversity (Gibson et al., 2011).

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Ethiopia is located in the horn of Africa between 3°24´and 14°53´ N and 32°42´ and 48°12´ E with a total area of 1,120,000 km^2 (MoA, 2000). Its physical features, range from the depression at Dallol in Afar, which is about 110 m below sea level to the highest peak at Ras Dashen, 4620 m above sea level (EFAP, 1994). Plateau of Ethiopia with an altitude of above 1500 m a.s.l. covers about 40% of the country (Teketay, 2004). Ethiopia has a wide range of habitats due to the different topography of the country. The variation of the physical features coupled with other environmental factors has contributed to the different vegetation types in Ethiopia (Woldu, 1999). The flora of Ethiopia is estimated to be about 6,000 species, of which 10% is considered to be endemic (Hedberg et al., 2009). In Ethiopia, forest cover has been declining steadily. About 35-40% of the Ethiopia's land area was covered with high forests by the turn of 19^{th} century (Breitenbach, 1963). EFAP (1994) indicated that 16% of the land area of Ethiopia was covered with forests in the early 1950's. This number was reported to decline to 3.1% in 1982, 2.7% in 1989 and less than 2.3% in 1990 (EFAP, 1994). Most of the remaining forests of Ethiopia are restricted to the south and southwest parts of Ethiopia, which are less accessible, and less populated (Yeshitela and Bekele, 2003). Even the remnant natural forests in these areas are continuously threatened by human activities (Yeshitela and Bekele, 2003). Different factors are responsible for the declining of forest cover in Ethiopia such as forest clearing for cultivation, overgrazing by domestic animals, exploitation of forests for fuelwood and construction materials all coupled with high rate of human population growth (Senbeta, 2006; Friis, 1992). In addition lack of proper policy framework is also contributing to the decline of forest cover in the country. The estimates of annual rate of deforestation vary from 150,000/ha - 200,000/ha (EFAP, 1994). The Southwestern Ethiopia is rich in remnants of natural forests, but they are disappearing at an alarming rate because of encroachment by agricultural activities and the pressure from investors who are converting the forests to coffee and tea plantations (Bekele et al., 2002).

Gelesha Forest is one of the foresat priority areas (FPA) in Ethiopa with total area coverage of about 12,000 hectares (GDARDO, 2011). The Gelesha Forest is under serious threat due to rapid human population growth, the demand for new settlement area and the expansion of investment for coffee and crop cultivation (Woldemariam and Senbeta, 2006). It has been continuously exploited by the surrounding people for agricultural land expansion, timber harvesting (logging), firewood collection and charcoal production, wood cutting for construction and other purposes.

Therefore, the current study was initiated to assess the floristic composition, structural analysis and to evaluate the status of the forest in comparison to other studied natural forests in Ethiopia to draw the attention of policy makers to this biodiversity assemblage to undertake appropriate conservation measures.

MATERIALS AND METHODS

Description of the study area

Gelesha Forest is located in Godere District, Gambella Regional State, Southwest Ethiopia (Figure 1). The district is located between 7°08'-7°23' latitude and 34°52'-35°25' longitude. It also has an altitude ranging from 500 to 2400 m above sea level, with the natural forest area in the range of 500-1500 (Friis, 1992). The climate of the area is a hot and humid type (Woldemariam and Senbeta 2006), and Meteorological data obtained from National Meteorology Service Agency (Addis Ababa) indicate that Godere District receives high rainfall between mid-March to October and low rainfall from November to February. The highest annual mean rainfall of the study area within twelve years (1998-2009) is 2726.7 mm. The lowest mean monthly temperature is 13.2°C and the highest mean monthly temperature is 33.1°C with an average temperature of 22.2°C.

The soil of the district is reddish brown, well drained and clay in texture (Yeshitila, 2008).

Sampling design and data collection methods

Sampling design

Systematic sampling technique was used for the study. Sampling sites were arranged along transects in different directions according to the topographic nature of the study area. A plot of size 20 m x 20 m (400 m^2) was used for trees and shrubs, and a 5 m x 5 m (25 m^2) plots for seedlings and saplings and 1 m x 1 m (1 m^2) for herbaceous plants. Transect were placed 400 m apart and were laid systematically at every 50 m altitudinal range along transect lines.

Data collection

A complete list of trees, shrubs, woody climbers and herbs were collected from the systematically established plots along each transect. Species occurring within 10 m distance from the plots boundaries were also recorded as present for floristic composition. Plant specimens were collected following standard herbarium techniques. Specimen identification was conducted at Jimma University Herbarium using the Flora of Ethiopia and Eritrea, and the National Herbarium (ETH), Addis Ababa University by comparing with authentically identified specimens.

In each plot, height and diameter at breast height (DBH) were measured for all individual trees and shrubs having DBH greater than 2 cm using a diameter tape. If the tree branched at breast height or below, the diameters were measured separately for the branches and averaged. Trees and shrubs with DBH less than 2 cm were counted. Altitude and geographical coordinates were also measured for each plot using Garmin 72 GPS.

Data analysis

Plant community analysis

Cluster analysis was used to repeatedly cluster the plots into groups, based on the abundance of the species (the number of individuals). Sørensen (Bray-Curtis) was taken as distance measured and Flexible β as group linkage model with a flexible β of -0.25 was used on the vegetation data. For three up to six groups this was executed repeatedly (McCune and Mefford, 2006). After clustering, Indicator Species Analysis (ISA) and a Monte Carlo test were applied to each group to determine the indicator species for

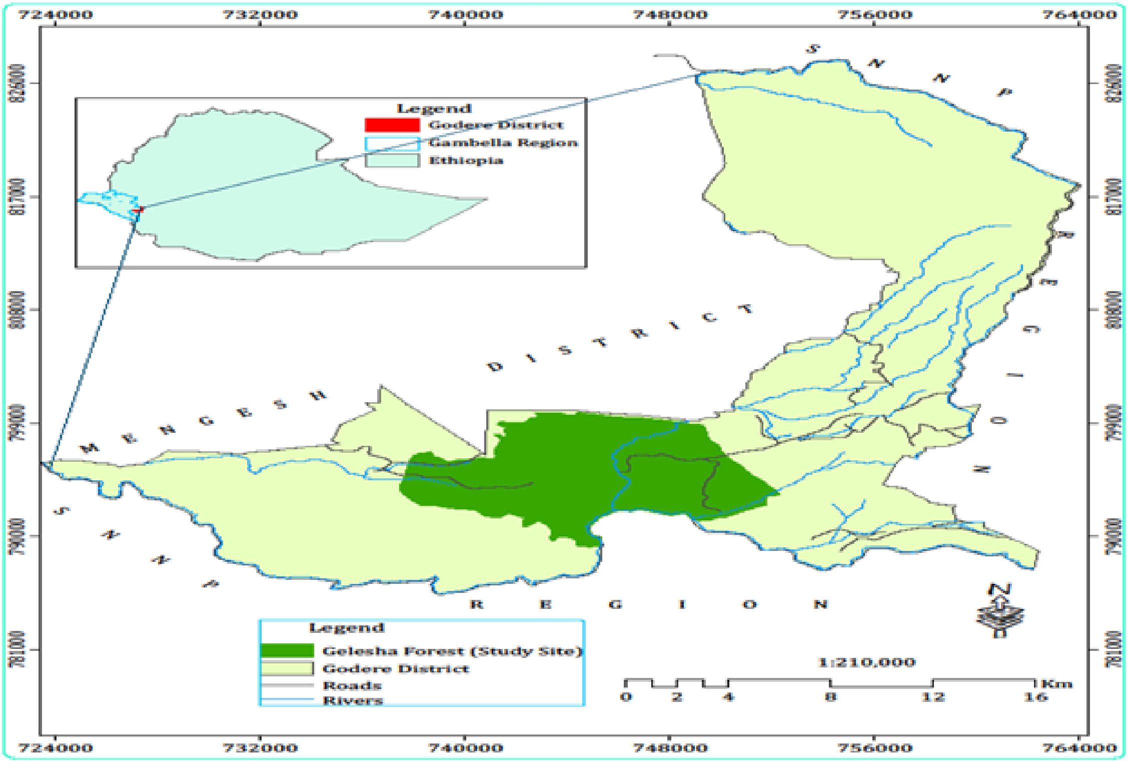

Figure 1. Map of study area: Gelesha natural forest, Godere district, Gambela Region.

each group (Dufrene and Legendre, 1997). For each run, the indicator value for each species and the overall average P-value were calculated. This overall P-value was used to decide the most informative number of clusters and avoid creating additional groups with little improvement to overall significance. The last cluster step adding >0.05 significance to the overall average P-value was selected as the most informative number of groups. Multi response permutation procedure (MRPP) was used to test differences in community composition between groups. The test uses Sørensen (Bray-Curtis) distances as well as a natural group weighing factor $ni/\Sigma ni$ (with ni the number of sample plots in each group).

Structural data analysis

All individuals of species recorded in the 60 plots were used in the analysis of vegetation structure. The diameter at breast height (dbh), basal area, tree density, frequency and important value index were used for description of vegetation structure. The structural analysis were performed using Microsoft excel 2007.

Phytogeographical comparison

Phytogeographical comparison of Gelesha Forest with other forests in Ethiopia was conducted based on woody species composition. The similarity index used for this comparison was Sorensen's similarity coefficient (Ss).

$$Ss = 2a/(2a+b+c)$$

Where, Ss=Sorensen's similarity coefficient; a= is number of species shared by the two forests; b= is the number of species in forest; c= is the number of species in forest (Kent and Coker, 1992).

RESULTS AND DISCUSSION

Floristic composition

A total of 157 species of vascular plants belonging to 127 genera and 54 families were recorded from Gelesha Forest. Euphorbiaceae was the most dominant family with 13 species (8.28%) and 11 genera (8.66%) followed by Moraceae with 13 species (8.28%) and 6 genera (4.72%) and Fabaceae with 12 species (7.64%) and 9 genera (7.09%) (Table 1). Out of the remaining 44 families twenty of them were represented by only one species each. Of all the species recorded 52 (33.12%) were trees, 30 (19.11%) shrubs, 21(13.38%) woody climbers and 54 (34.39%) herbs.

Plant community classification

Four plant community types were identified from the cluster analysis and were named after two species that had higher indicator values. The differences among the groups were tested with multiresponse permutation procedures (MRPP) based on Sørensen (Bray-Curtis) similarities. The test statistic T value for the four communities was -19.725570 at ($P < 0.001$) which show a highly significant difference between the communities. The agreement statistic A was 0.13. The agreement A describes within group homogeneity, and falls between 0

Table 1. Ten (10) most abundant families with their representative genera, species and percentage contribution, Gelesha natural forest, Godere District, Gambela Region.

Number	Family	Number of genera	%	Number of species	%
1	Euphorbiaceae	11	8.66	13	8.28
2	Astraceae	8	6.30	13	8.28
3	Moraceae	6	4.72	13	8.28
4	Fabaceae	9	7.09	12	7.64
5	Poaceae	6	4.72	7	4.46
6	Solanaceae	4	3.15	6	3.82
7	Rubiaceae	5	3.94	5	3.18
8	Sapotaceae	4	3.15	4	2.55
9	Urticaceae	4	3.15	4	2.55
10	Amaranthaceae	3	2.36	4	2.55
Total		60	47.24	81	51.59

Table 2. Indicator Values (% of perfect Indication, based on combining Relative Abundance and Relative Frequency) of each species for each of the four groups and the Monte Carlo test (P*) of the significance observed for each species (bold values indicate indicator species at P*<0.05).

Species name	Community				P*
	C1	C2	C3	C4	
Argomuellera macrophylla	64	22	7	3	0.0012
Manilkara butugi	25	0	22	o	0.1202
Rinorea friisii	19	0	11	0	0.2364
Milicia excels	14	0	11	0	0.2869
Whitfieldia elongate	12	7	9	0	0.3367
Vepris dainelli	10	0	8	0	0.4279
Polyscias fulva	0	49	2	0	0.0142
Vernonia amygdalina	0	31	4	0	0.0166
Oxyanthus speciosus	0	27	0	0	0.0292
Cissus petiolata	0	25	2	0	0.041
Baphia abyssinica	12	7	64	2	0.0002
Pouteria alnifolia	9	0	31	0	0.2256
Antiaris toxicaria	11	0	42	0	0.0354
Blighia unijugata	13	10	0	56	0.0076
Lannea welwitschii	12	9	0	48	0.0154
Alchornea laxiflora	0	2	0	43	0.0284
Croton sylvaticus	0	3	0	40	0.0478

and 1. When all items within groups are identical, A=1 and 0 when the groups are heterogeneous. A plant species with a significant indicator value at P < 0.05 was considered as an indicator species of the group (Table 2). The description of each of the four communities is given below.

***Argomuellera macrophylla* - *Manilkara butugi* community type**

This community type was distributed between the altitudinal range of 1010 and 1153 m a.s.l. It was represented by 30 plots and 58 associated species. *A. macrophylla* and *M. butugi* were the dominant and main indicator species of the community (Table 2). *Rinorea ilicifolia, Milicia excelsa* and *Margaritaria discoidea* were the dominant associated tree species. *Asplenium sandersonii* and *Solanum terminale* were associated with the ground layer.

***Polyscias fulva* - *Vernonia amygdalina* community type**

This community type was situated between the altitudinal ranges of 1060-1082 m a.s.l and contains 4 plots and 19 species (Table 2). *V. amygdalina, P. fulva* and *Oxyanthus speciosus* were the dominant tree species with high indicator values in the community. The associated tree and shrub species in the community includes species such as *Cissus petiolata, Ficus vallis, Diospyros abyssinica, Canthium oligocarpum, Rinorea friisii, Celtis zenkeri, Alstonia boonei, Trichilia prieuriana, Ficus ovata* and *Clausena anisata.* *Pluchea camphoratea*, *Trectaria gimmifera* and *Sida rhombifolia* dominate the ground layer.

***Baphia abyssinica* - *Antiaris toxicaria* Community type**

This community type was situated at altitudinal range from 1020-1130 m a.s.l and represented by seven plots and 58 associated species. *B. abyssinica* and *A. toxicaria* are dominant tree species in the community (Table 2). The associated dominant tree species in the community includes *Trilepisium madagascariense, Pouteria alnifolia, Croton macrostachyus, Albizia grandibracteata, Ficus thonningii, Elaeodenron buchananii, Ficus asperifolia, Morus mesozygia* and *Ficus mucuso.* The herbaceous layer was mainly covered by *Olyra latifolia* and *Oplismenus hirtellus.*

Blighia unijugata - Lannaea welwitschii community type

This community type was distributed between the altitudinal range of 1021 and 1154 m a.s.l and contains 19 plots and 71 associated species (Table 2). This community was characterized by three indicator species; *B. unijugata, L. welwitschii* and *Alchornea laxiflora*. Other associated tree species include *Croton sylvaticus, Erythrococca trichogyne, Mimusops kummel, Dracaena fragrance, Celtis african, Ficus umbellata, Trichilia dregeana* and *Rothmannia unceliformis. Hippocratea pallens* is common climber in the community and *Oplismenus hirtellus* was the herb which covered the ground layer of the community.

Vegetation structure

Tree density

For the description of the structure of Gelesha Forest, 45 woody species with individuals having DBH greater than 2.0 cm and height greater than 2.0 m were used. Tree density with DBH greater than 2 cm in the study area was 557.09 individuals/ha and the number of stems with DBH >10 cm was 315.42 and those with DBH >20 cm was 244.58 individuals/ha.

Concerning tree density of some dominant woody species in the Geleshsa Forest *A. macrophylla* and *B. abyssinica* alone contributed 46.3% of the total density. Eight other tree species, namely *Celtis zenkeri* (6.28%), *Lannea welwitschii* (4.04%), *Blighia unijugata* (3.89%), *M. butugi* (2.62%), *Hippocratea pallens* (2.62%), *Croton sylvaticus* (2.62%), *Erythrococca trichogyne* (2.47%) and *Dracaena fragrans* (2.02%), contributed 20.52% to the total density.

The ratio of density at DBH > 10 cm to DBH > 20 cm is taken as a measure of the size class distribution (Grubb et al., 1963). So, the ratio of individuals with DBH >10 cm (A) to DBH > 20 cm (B) was 1.29 for Gelesha Forest (Table 3). The density of woody species of Gelesha Forest was compared with eight other forests in Ethiopia regarding the ratio of the density of woody species with DBH > 10 to DBH > 20 cm given (Table 3).

Ratio of the density of individuals with DBH greater than 10 cm to individuals with DBH greater than 20 cm in the Gelesha Forest was less than that of Chilimo and Menagesh (Bekele, 1993), Marsha-Anderacha (Yeshitela and Bekele, 2003), Dindin (Shibru and Balcha, 2004), Mana Angetu (Lulekal, 2005), Bibita (Denu, 2007) and Magada (Bekele, 2005), showing that all have higher proportions of small-sized individuals than Gelesha Forest indicating that these forests are in the stage of secondary succession.

On the other hand the ratio in Gelesha Forest was more or less similar with that of Dodola (Hundera et al. 2007) indicating that these forests are in climax stage compared with the other forests.

Table 3. Comparison of tree densities with DBH >10 and 20cm from Gelesha natural forest with other forests.

Forest	DBH class(cm)		Ratio
	DBH > 10 (A)	DBH > 20 (B)	A/B
Menagesha[1]	484.00	208.00	2.30
Chilimo[1]	638.00	250.00	2.60
Masha Anderacha[2]	385.70	160.50	2.40
Dodola[3]	521.00	351.00	1.50
Dindin[4]	437.00	219.00	1.99
Magada[5]	608.00	332.00	1.80
Menna Angetu[6]	292.59	139.78	2.08
Bibita Forest[7]	500.50	265.60	1.90
Gelesha forest[8]	315.42	244.58	1.29

Source: [1]Bekele (1993), [2]Yeshitela and Bekele (2003), [3]Hundera et al., (2007), [4]Shibru and Balcha (2004), [5]Bekele (2005), [6]Lulekal (2005), [7]Denu (2007) [8] Alemu (Present study).

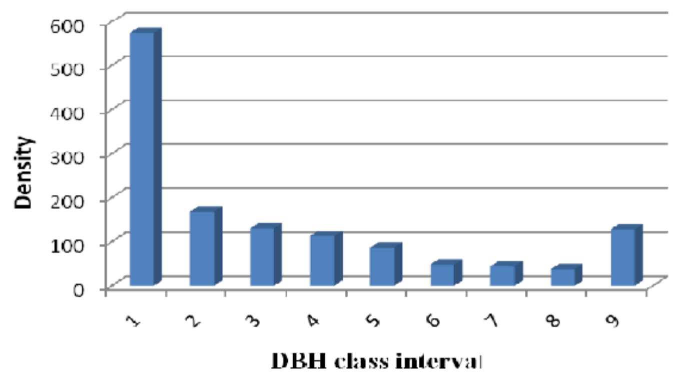

Figure 2. Diameters at breast height (DBH) cm in their class interval (2.1-10 cm = 1, 10.1-20 cm = 2, 20.1-30 cm = 3, 30.1-40 cm = 4,40.1-50 cm = 5, 50.1-60 cm = 6, 60.1-70 cm = 7, 70.1-80 cm = 8 and ≥80 cm =9).

Diameter at breast height (DBH)

The distribution of trees in different DBH classes is given in Figure 2. The density of trees from lower to higher DBH classes showed a decreasing trend. Percentage distribution of trees in different DBH classes in Gelsesha Forest was compared with other forests in Ethiopia (Table 4).

In Gelesha Forest, number of individuals in the lower DBH class (I) was smaller than that of Wof Washa, Menna Angetu, Menagesha, Chilimo, Belete, Denkoro, Magada and Bibita forests. With regard to DBH class (II), the percentage of Gelesha Forest was smaller than that of Denkoro, Magada, Wof Washa, Menagesha, Chilimo and graeter than that of Bibita and Belete but similar with

Table 4. Comparison of DBH of Gelesha natural forest with other eight forests in Ethiopia (I = 10-20, II = 20-50, III = 50-80, IV = 80-110, V = 110-140, VI ≥140).

Forest	DBH Classes (cm)					
	I	II	III	IV	V	VI
Wof Washa[1]	32.6	31.7	14.6	17.7	0.0	0.0
Menagesha[2]	56.9	32.8	06.5	02.5	0.0	0.0
Chilimo[1]	60.8	36.5	02.6	0.0	0.0	0.0
Menna Angetu[3]	32.8	25.5	08.9	02.4	0.7	1.1
Magada[4]	45.4	44.1	06.3	02.6	1.0	0.7
Belete[6]	20.4	20.0	8	6.7	0.0	0.0
Bibita Forest [5]	30.2	24.4	06.2	01.7	0.5	1.4
Gelesha Forest [7]	13.44	25.5	9.95	8.45	1.01	0.5

Source: [1]Bekele (1993), [2]Zewdie (2007), [3]Lulekal (2005), [4]Bekele (2005), [5]Denu (2007), [6]Gebrehiwot (2011). [7]Alemu (Present study).

Table 5. Basal area, density, and percentage contribution of ten (10) tree/shrubs/species in Gelesha natural forest, (Godere District).

Botanical Name	Basal area/ha	Basal area %	Density/Ha	Density %
Lannea welwitschii	22.56	22.8	22.50	4.04
Baphia abyssinica	15.2	15.36	110	19.75
Celtis zenkeri	12.42	12.55	35	6.62
Manilkara butugi	8.83	8.93	14.58	2.62
Cordia africana	7.16	7.24	8.63	1.50
Blighia unijugata	3.87	3.91	21.67	3.89
Morus mesozygia	2.83	2.86	7.08	1.20
Croton sylvaticus	2.32	2.35	14.58	2.62
Milicia excelsa	2.3	2.33	3.75	0.67
Diospyros abyssinica	2.28	2.31	6.67	1.20
Total	79.77	80.64	244.46	44.11

that of Menna Angetu (Table 4). In the DBH class (V) the Gelesha Forest was almost equal to Magada but greater than the rest. This shows that in Gelesha Forest the DBH class from 2-20 cm is about 54.59% indicating that the Forest is characterized by smaller trees than others or showing an inverted J-shape (Figure 2).

Basal area

The basal area of all tree species in Gelesha Forest was 98.87 m^2/ha. The normal basal area value for virgin tropical forests in Africa is 23-37 m^2/ha (Lamprecht, 1989). Thus the basal area value of Gelesha Forest is very high. The highest proportion of basal area in the forest was contributed by *Lannea welwitschii* (22.56%) followed by *Baphia abyssinica* (15.20%), *Celtis zenkeri* (12.42%) and *M. butugi* (8.87%) (Table 5). The trees with highest densities such as *Argomuellera macrophylla*, *Dracaena fragrance* and *Hippocratea pallens* did not contribute much to the total basal area of the forest.

Gelesha Forest is almost similar to Menna Angetu and Wof -Washa Forest, lower than Dodolla, and higher than all the other forests under comparisons with respect to basal area per hectare (Table 6). There is close relationship between basal area and DBH because basal area is calculated from the DBH value. This may be due to variations in the conservation of the forests, exposure to deforestation and geographical location of the forests.

Frequency

The most frequently observed species in the forest were *A. macrophylla* (96.67%), *B. abyssinica* (83.33%) and *Blighia unijugata* (71.67). The frequency distribution of ten most frequent species in Gelesha Forest is given in (Table 7).

Table 6. Comparison of Gelesha natural forest, with other 13 afromontane forests in Ethiopia with respect to basal area per hectare.

Forest	[2]MG	[1]MN	[4]DK	[5]MAN	[6]MA	[1]CH	[1]WW	[7]DD	[8]BF	[9]EG	[10]GD	[3]DN	[1]JB	[11]GL
BA ha^{-1}	68.52	36.1	45.0	81.90	94.22	30.1	101.8	129.0	69.9	84.17	35.45	49.0	47.5	98.87

Source: [1]Bekele (1993), [2]Bekele (2005), [3]Shibru and Balcha (2004), [4]Ayalew et al*.*, (2006), [5]Yeshitela and Bekele (2003), [6]Lulekal et al., (2008), [7] Hundera et al., (2007), [8]Denu (2007). MA = Menna Angetu, MG = Magada, DN = Dindin, MAN = Masha Anderacha, DK = Donkoro, MN = Menagesha, CH = Chilimo, JB = Jibbat, WW = Wof -Washa, DD = Dodolla, BF= Bibita forest (Gura Ferda,), EG=Egdu (MAM), GD= Gedo, GL=Gelesha forest.

Table 7. Frequency distribution of selected woody species in Gelesha natural forest (Freq = frequency, %FR = frequency percent and RFR = Relative frequency. Species are arranged in decreasing order of frequency).

Species	Number of plots	FR	RFR
Argomuellera macrophylla	58	96.67	8.54
Baphia abyssinica	50	83.33	7.53
Blighia unijugata	43	71.67	6.22
Diospyros abyssinica	40	66.67	5.93
Dracaena fragrans	41	68.33	6.12
Celtis zenkeri	37	61.67	5.35
Lannea welwitschii	33	55.00	4.78
Croton sylvaticus	30	50.00	4.05
Manilkara butugi	26	43.33	3.62
Canthium oligocarpum	25	41.67	3.62
Total		638.33	55.57

Importance value index (IVI)

Importance value index combines data from three parameters: RF, RD and RDO (Kent and Coker, 1992). It is crucial to compare the ecological significance of species (Lamprecht, 1989). It was also stated that species with the greatest importance value are the leading dominant in specified vegetation (Shibru and Balcha, 2004). Accordingly, the ten leading dominant and ecologically most important trees in Gelesha Forest are *B. abyssinica, A. macrophylla, L. welwitschii, C. zenkeri, M. butugi, B. unijugata, C. africana, Diospyros abyssinica, C. sylvaticus* and *D. fragrans.* They contribute 200.83 (66.98%) from a total of 300 IVI value. The reason why they have higher IVI value is that they have higher relative density, relative frequency and relative abundance in comparsion with other species in the Forest. Tree species, with their IVI and priority for conservation are given in decreasing order of IVI values (Table 8).

The leading dominant and ecologically most dominant species might also be the most successful species in regeneration, pathogen resistance, preference by browsing animals (least preferred), attraction of pollinators and attraction of seed predators that facilitate seed dispersal within the existing environmental conditions (Kenea, 2008).

Phytogeographical comparison

The result obtained shows Gelesha Forest is one of the most diversified moist evergreen montane forests in the country containing a minimum of 157 species of plants. Direct comparison of the species diversity with other forests is not feasible due to differences in size of forests, survey methods and objectives of the study (Woldemariam, 2003). However, the overall species richness of the vegetation can give more or less a general impression of their diversity and phytogeographical similarity. Accordingly, Gelesha Forest was compared with 11 forests in the country to know the similarity of species in the forests and indicate to which forest type it is related (Table 9).

The overall similarity indices between Gelesha Forest and the other 11 forests in Ethiopia ranged between 0.063 and 0.41(Table 9). Gelesha Forest shared the highest floristic similarity with that of Masha Anderacha (0.41), Yayu (0.4), Bibita (0.35), Sese (0.3), Boginda (0.29) Gurra Farda (0.26), Chato (0.24) and Belete (0.22). The relatively high floristic affinity of the mentioned forests with Gelesha Forest arises from geographical proximity, similarity in altitudinal range, and climatic zones. Geographically, Masha Anderacha, Bibita, Sese and Boginda Forests are located in the Southwestern part of the country. Thus, proximity of the

Table 8. The importance value index (IVI) and priority class for conservation of tree species in Gelesha natural forest.

Species	RF	RD	RDO	IVI	%	Priority
Baphia abyssinica	7.53	19.75	15.36	42.64	14.21	4
Argomuellera macrophylla	8.54	26.55	0.26	35.35	11.78	4
Lannea welwitschii	4.78	4.04	22.8	31.62	10.54	4
Celtis zenkeri	5.35	6.28	12.55	24.18	8.06	4
Manilkara butugi	3.62	2.62	8.93	15.17	5.06	3
Blighia unijugata	6.22	3.89	3.91	14.02	4.67	3
Cordia africana	2.46	1.5	7.24	11.2	3.73	3
Diospyros abyssinica	5.93	1.2	2.31	9.44	3.15	3
Croton sylvaticus	4.05	2.62	2.35	9.02	3.01	3
Dracaena fragrans	5.93	2.02	0.24	8.19	2.73	2
Total	54.41	70.47	75.95	200.83	66.94	-

RD = Relative density; RDO = relative dominance; RF = relative frequency.

Table 9. Comparison of Gelesha natural forest (Godere District) with other 10 forests in Ethiopia based on their similarities/differences Forest.

Forest	Elevation	a	b	c	Sc	Dc	Source
Bibita	900-2000	39	70	76	0.35	0.65	Denu (2007)
Menagesha Suba	2600-2750	5	104	45	0.063	0.94	Zewdie (2007)
Masha Anderacha	1250-2700	44	65	63	0.41	0.59	Yeshitela and Bekele (2003)
Gura-lopho	860 -2502	19	91	75	0.19	0.81	Kumsa (2010)
Chato	1700 - 2350	24	85	70	0.24	0.76	Abdena (2010)
Gedo	1300-3060	21	88	121	0.17	0.83	Kebede (2010)
Boginda		31	78	77	0.29	0.71	Nune (2008)
Gurra Farda	800 -1900	23	86	43	0.26	0.74	Hundera and Deboch (2008)
Sese	1476-1968	32	77	76	0.3	0.7	Belachew (2010)
Yayu	1250-1700	49	60	84	0.40	0.6	Woldemariam (2003)

Ss = Sorenson`s similarity coefficient. a =is number of species shared by the two forests; b= is the number of species in other forest. c= is the number of species unique to the present study.

areas could be one of the reasons for such a high floristic similarity. The altitudinal range of Gelesha Forest (1006-1154 m a.s.l) falls within that of the above forests which also has contributed to the observed similarity. Again Masha Anderacha which is found in the southwest part of Ethiopia has an altitudinal range that includes those of Gelesha. On the other hand, Menagesha Suba Forest is found on higher altitudinal range (2600-2750 m a.s.l) and its observed lowest floristic affinity; this is due to high range of altitude and other environmental factors like rain fall, temperature soil. The dissimilarities between forests may arise from the different sample sizes and methods of the study, altitudinal differences, degree of human impact (anthropogenic) action, over grazing and climatic conditions.

Conclusion

Results of the present study shows that 157 plants species were recorded in Gelesha Forest belonging to 127 genera and 54 families. Euphorbiaceae was the dominant family with 13 species and 11genera followed by Moraceae with 13 species and 6 genera, Fabaceae with 12 species and 9 genera and Asteraceae, with 12 species and 8 genera of all the species recorded trees, 33.12% shrubs, 19.11% climbers, 13.38% and 34.39% herbs.

Four plant communities were identified and described with varying degree of species richness, evenness and diversity. Variability in population structure, which implies vegetation dynamics, was recognized from the analysis of tree species DBH. In addition, density class description of the forest indicated the dominance of small sized individuals asserting Gelesha Forest is in a stage of secondary development.

The density of woody species in Gelesha Forest decreases with increasing height classes and the forest is characterized by high density of trees in the lower class than in the higher. Thus, the forest is in good state of recruitment. The Forest exhibited the highest BA that is 98.87 m^2/ha. Three layers (lower, middle and upper) of tree canopies were identified from the study of vertical stratification of Gelesha Forest. Large proportion of woody species was found in the lower storey 48.48% and middle storey contains 31.42%, while upper storey was contains of which 20.04%.

Phytogeographic descriptions and comparisons of Gelesha Forest with other similar forests showed that it is related more to the moist evergreen montane forests than others as it is characterized by dominant species of moist montane forests.

Recommendations

To promote Gelesha Forest conservation, local communities and other concerned bodies should plant indigenous species on all sides of the forest as it was surrounded by farm lands that may serve as a buffer zone.

The species with low important value index should be given appropriate attention and conserved *in-situ* through the collaboration of local communities, the District Agriculture and Rural Development Office, other interested individuals (Like NGOs) and other stakeholders.

Conflict of interests

The authors did not declare any conflict of interest.

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