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## Towards sustainability of ecosystem services in North-East Nigeria

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### Abstract

Ecosystem services are the very essence of the inhabitants of the North-East Region of Nigeria; hence the sustainability of these services is very important. The concept of sustainability is imprecise and reveals two main underlying issues which are intergenerational fairness and the moral responsibility of the current generation to its descendants on the one hand, and the role of assets provided by nature including forest and marine ecosystems in satisfying both current interests and the obligations we assume to the future on the other. Many benefits from ecosystem services accrue to the six states of Adamawa, Gombe, Taraba, Yobe, Bauchi and Borno in the North-East Region of Nigeria. The economic value of Hadejia-Nguru wetlands which forms part of the Kamadougou-Yobe River Basin of the Lake Chad Basin was estimated at over US\$16 million per year. The estimated value of ecosystem services that can be attributed to inland watersheds and wetlands range between US\$5000 and US\$100,000 per hectare while coastal watersheds and wetlands were between US\$500 and US\$1,000,000 per hectare in 2007. The product of the national average of 0.284 tonnes/person/year of fuel wood consumption and number of inhabitants of 24,051,418 (2006 census projected to 2014) gave an estimated consumption of 6,830,603 tonnes/person/year for the six North-Eastern States. However, there are threats to the sustenance of ecosystem services, some of which include urbanization, progressive industrialization, overgrazing, exploitation of natural resources, depletion of wetlands, watersheds and insurgencies which have drastically reduced production of and accessibility to ecosystem services. These threats can be mitigated through development of framework for assessing demand and supply of these services, restoration of terrestrial and marine ecosystems through biodiversity approach, capacity building and forestry extension services to create awareness among the populace on the importance and value of ecosystem services.

**Keywords:** Ecosystem Services; Threats; Mitigation; Imperiled; Sustainability; Forestry Extension.

### 1. Introduction

Ecosystem services which include provisioning (food, water, timber, fibre) regulating (carbon sequestration, biological pest control, floods, diseases, wastes and water quality), cultural (recreational, aesthetic and spiritual benefits) and supporting (soil formation, photosynthesis and nutrient cycling), are the very essence of survival of most inhabitants of North East Nigeria [1], [2], [3]. Characteristically, this region, experiences diminishing biomass and wide-ranging ecosystems degradation, bush burning, induced by advancement of cultivation, grazing and population pressures that have led to extensification/intensification of cultivation resulting in the contraction and restriction of space and options available to pastoral activities [4]. TEEB, 2010 [5], estimated the monetary values of some regulatory ecosystem services for tropical ecosystems; the value of just four services for Nigeria's 92,376,800 hectares stood over ₦98trillion/year (\$1=₦200). Between 2000 and 2010, an increase in Total Ecosystem Services Value (ESV) in Nigeria rose from ₦665.93 billion (2007US\$) to ₦667.44billion (2007US\$), 97.38% of which was contributed by cultivated land [6]. The value of *provisioning services* increased, while *regulation, support, recreation and culture services* decreased

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amongst which water regulation (-11.01%), gas regulation (-7.13%), cultural (-4.84%) and climate regulation (-4.3%) ecosystem functions are estimated as the most impacted [7]. The increase in the Total Ecosystem Value (ESV) in Nigeria associated with the huge increase in ecosystem services due to cultivated land expansion may make land use changes (i.e., the ever-increasing agricultural expansion in Nigeria (Northeast inclusive) appear economically profitable [8]. Continuous loss of services such as climate and water regulation that are provided by the natural ecosystems can result in huge economic losses that may exceed the apparent gains from cultivated land development [9]. However, there is need to determine the ratio between demand and supply of ecosystem services in Northeast Nigeria. It is necessary to develop a framework for assessing the thresholds for ecosystem services to be able to know when they are imperiled following the suggestion of [10].

The objectives of this paper are to highlight the availability of ecosystem services in North-East Nigeria, the benefits that accrue to the inhabitants through these services, the major threats to the supply and demand of ecosystem services, the approaches to mitigate these threats.

## 2. Study area

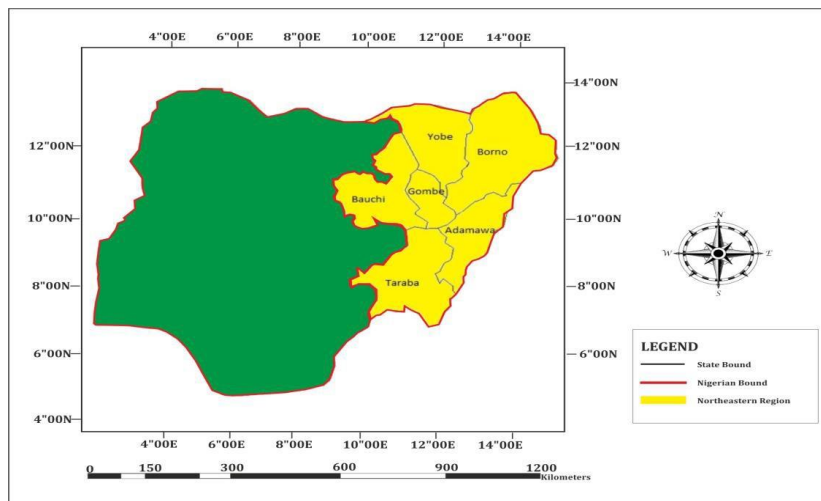
The North East Nigeria has a total landmass of about 279,203km<sup>2</sup> situated within Latitudes 6° 30'N to 14° 00'N and Longitude 8° 30' E to 15° 00' E and a total population of 18,971,965 (according to the 2006 census returns and 24,051,418 if projected to mid-2014) [11]. These figures are distributed among the six states of Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe as follows (Table 1).

**Table 1** Distribution of Land Mass and Population among six North-Eastern States (%)

S/n	State	Landmass (%)	Population (%)
1	Adamawa	12.61	16.64
2	Bauchi	22.07	24.64
3	Borno	24.31	21.88
4	Gombe	6.31	12.40
5	Taraba	19.11	12.13
6	Yobe	15.57	12.23

Source: Tukur and Barde (2013).

The environment is dynamic, complex and responds to the interactions of the biotic and abiotic components in providing services that support life, the continuity or sustainability of ecosystem functions [12], but the nexus of deforestation, anthropogenic activities and climatic variability is taking its toll on this region [13].



**Figure 1** The Northeast Region

### **3. Previous work and methodology**

Secondary data were used in the literature review in writing this article. Desk research was conducted in deriving data from relevant agencies such as International Union of Forestry Organizations (IUFRO), Food and Agricultural Organization (FAO), United Nations Conference on Climate Change and Desertification (UNCCD), International Union on Conservation of Nature (IUCN), United Nations Development Programme (UNDP), World Food Programme (WFP), Nigeria Centre for Disease Control (NCDC), Afforestation Programme Co-ordinating Unit (APCU), World Bank Project, Forest Management Evaluation and Co-ordinating Unit (FORMECU), National Bureau of Statistics (NBS), National Population Commission (NPC), International Programme on Climate Change (IPCC), Also, consulted were relevant proceedings on international workshops, international journals and personal interface with relevant stakeholders on the subject matter. Microsoft Excel was used in some basic calculations.

#### **3.1. Integrated ecosystem services and land use practices**

Inkom et. al., 2017 [14], developed a framework for integrating ecosystem services into modern land use practices using content analysis to search for ecosystem keywords in land use planning policies and act (LUPPA) and to identify existing approaches for mainstreaming the ecosystem discovered. The authors discovered that major planning policy documents focused on planning for infrastructural development with less emphasis on environmental sustainability. This position could have effect on the demand and supply of ecosystem services.

#### **3.2. Human perception of ecosystem services**

Gouwakinnou et. al., 2019 [15], studied and highlighted the perception of inhabitants surrounding two forest reserves, (Alibori-superiour and Ouenon), about the importance of ecosystem services provided to them. They suggested that political-decision making by policy makers should understand biophysical processes involved in determining ecosystem services.

#### **3.3. Role of agencies in ecosystem services assessment**

Some agencies, United States Agency International Development (USAID), Mercy Corps, Action against hunger, Cooperazione Internazionale, Catholic relief services, International Rescue Committee, OXFAM, carried out an assessment of North East Nigeria joint livelihood and market recovery which was conducted between January and August, 2017. Field level qualitative interviews and quantitative enumerator led surveys were carried out in conjunction with high level decision makers in Maiduguri (capital of Borno state) and Abuja (federal capital of Nigeria). Across Borno, Yobe and Adamawa states. They did a nationwide assessment of China by quantifying the provision of threatened species habitat and four key regulating services-water retention, soil retention, sand storm prevention and carbon sequestration-in nature reserves which are the primary category of protected areas in China. They observed that China's nature reserves did not serve moderately well for key regulating ecosystem services. Nature reserves encompass only 10.2-12.5% of the source areas for the four key regulating services.

#### **3.4. Climate change, productivity and ecosystem services**

The relationship between climate change and productivity and by implication demand and supply of ecosystem services is expressed by Girardin et al.,2008 [16]; Le Bauer and Treseder,2008 [17]; McMillan et al.,2008[18]; Ollinger et al.,2008[19]; Phillips et al., 2008[20]; Reich and Oleksyn 2008 [21]; Saigusa et. al.,2008 [22] and Clark et. al.,2003 [23]. According to these authors, productivity as a result of climate change varies with geographic area, species stand composition, tree age, soils (water holding capacity) and effects of CO<sub>2</sub> and nitrogen fertilization and interactions between any of these factors.

#### **3.5. Temperature, forest storage and carbon sequestration**

Increasing temperatures, longer dry seasons and increasing CO<sub>2</sub> concentrations in the atmosphere in the long term, are expected to reduce the capacity of forests to store and sequester carbon possibly converting forests from carbon sinks to carbon sources [24]; [25]; [26] and [27]. Postel and Thompson, 2005 [28], recognized the contribution of forests to water and soil protection, hence the role of water regulation and soil protection may become increasingly important under climate change conditions

#### **3.6. Socio-economic benefits and ecosystem services.**

Some multiple socio-economic benefits such as expected global increase in wood production which may lower prices thereby benefitting consumers; the combination of lower prices and regionally differentiated effects on productivity will cause differentiated effects on productivity on timber harvest related income and employment [29]. Harvests of Non

Wood Forest Products (NWFP) have three major functions: provision of part of the daily necessities of forest dependent people, off-farm income and a safety net in times of adverse conditions for agricultural production [30]. It is also suggested by Osman- Elasha et. al., 2009 [31], that climate change will have impacts on the productivity of NWFPs and that their users will largely be impacted through increased pressure on forest products from people that look for emergency supplies or alternative ways of income.

### 3.7. Climate change and recreational forestry

The impact of climate change on cultural and recreational services of forests have been little studied and difficult to measure [32], but it is reported in some studies on recreational services such as skiing in mountainous areas where skiing at lower altitudes is likely to be affected by temperature increases [33]. The effect of climate change on forest biodiversity and structure in Africa and subsequent effect on attractiveness for tourists of many of the national parks need to be further studied.

### 3.8 Management of biodiversity species for Ecosystem services in North Africa

Countries in North Africa and Near East identified a number of associated biodiversity species that are actively managed for the ecosystem services related to food production, nutrition and sanitation (Table 2). Associated biodiversity species most frequently reported to be actively managed for the provision of ecosystem services in production system in the near east and North Africa.

**Table 2** Biodiversity species managed for ecosystem services in North Africa

Ecosystem services	List of species
Pollination	<i>Honey bees:</i> <i>European honey bee (Apis mellifera)</i> <i>Local honeybees</i> <i>Bumble bees</i> <i>Wild bees</i> <i>Wild butterflies</i>
Pest and diseases regulation	<i>Biological control organisms</i> <i>Fungi</i> <i>Arbuscular mycorrhizal fungi</i> <i>Invertebrates</i> <i>Insects:</i> <i>Eulophid wasp (Aphelinus mali)</i> <i>Chalid wasp (Aphytis melinus)</i> <i>Encyrtid wasp (Capidosoma koehleri)</i> <i>Mealybug ladybird (Cryptolaemus spp)</i> <i>Water hyacinth weevil (Neochetina eichhorniae)</i> <i>Tomato mirid (Nesidiocoris termis)</i> <i>Parasitic wasps:</i> <i>Anagyrus dactylopii</i> <i>Anagyrus indicus</i> <i>Bracon concoloran</i> <i>Arachnids:</i> <i>Phytoseiid mite (Amblyseius idaeus)</i> <i>Plants:</i> <i>Cabbage (Brassica oleraceae)</i> <i>Sunflower (Helianthus annuus)</i> <i>Mexican marigold (Tagetes erecta)</i> <i>Trees:</i> <i>Acacia nilotica</i> <i>Azadirachta indica (neem)</i> <i>Balanites aegyptiaca (desert date)</i> <i>Eucalyptus oblique(messmate)</i> <i>Senegalia senegal</i> <i>Planting disease-resistant crop varieties</i> <i>Cicer arietinum(chickpea)</i> <i>Cucurbita pepo (pumpkin)</i> <i>Lycopersicon esculentum(tomato)</i> <i>Function not specified</i>
	<i>Plants</i> <i>Cedrus libani (cedar)</i> <i>Hordeum spontaneum, H. vulgare (barley)</i> <i>Solanium elagnifolium (silverleaf nightshade)</i> <i>Pests and pathogens</i> <i>Bactrocera oleae (olive fruit fly)</i> <i>Ceratitis capitata (Mediterranean fruitfly)</i> <i>Cydia pomonella (codling moth)</i> <i>Eurygaster integriceps (shield bug)</i> <i>Eurygaster Maura (European tortoise bug)</i> <i>Lobesia botrana (European grapevine moth)</i> <i>Prays citri (moth)</i>

	<p><i>Rhynchophorus ferrugineus</i> (red palm weevil) <i>Spilocaea oleaginea</i> (fungal plant pathogen) Ticks  <i>Tuta absoluta</i> (moth)  <i>Zeuzera pyrina</i> (leopard moth)</p>
Water purification and waste management	<p>Trees <i>Moringa</i> (<i>Moringa</i> spp) <i>Olive</i>(<i>olea</i> spp) <i>Poplar</i> (<i>Populous</i> spp)  <i>Aspen</i> (<i>Populous tremula</i>) Other plants  Field crops Forage legumes  Common reed (<i>Phragmites australis</i>) <i>Sorghum halepense</i> (Johnson grass)  <i>Sparganium erectum</i> (simplestem bur-reed)</p>
Natural hazard regulation	<p>Planting crops and trees  <i>Saltbush</i> (<i>Atriplex</i> spp), <i>Saltwort</i> (<i>Salsosa</i> spp), and cover crops such as barley (for soil erosion and salinity tolerance)  Mediterranean cypress (<i>Cupressus simper virens</i>) and carob tree (<i>Certonia siliqua</i>) around forests for fire control.  Mediterranean saltbush (<i>Atriplex haimus</i>) Grey mangrove (<i>Avicennia marina</i>)  Common juniper (<i>Juniperus communis</i>) Date palm (<i>Phoenix dactylifera</i>) and carob tree (<i>Certonia siliqua</i>) around forests for fire control.  Mediterranean saltbush (<i>Atriplex haimus</i>) Grey mangrove (<i>Avicennia marina</i>)  Common juniper (<i>Juniperus communis</i>) Date palm (<i>Phoenix dactylifera</i>)</p>
Nutrient cycling	<p>Planting crops and cover crops Chickpea (<i>Cicer arietinum</i>) Lentil (<i>Lens culinaris</i>)  Alfalfa (<i>Medicago sativa</i>) Pea (<i>Pisum sativum</i>) Ervil (<i>Vicia ervilia</i>)  Vetch (<i>Vicia sativa</i>).</p>
Soil formation and protection	<p><i>Acacia</i> (<i>Acacia</i> spp)  Mangrove grass (<i>Aeluropus lagopoides</i>) Mediterranean saltbrush (<i>Atriplex halimus</i>)  <i>Cadaba rotundifolia</i>  <i>Ceratonia</i> spp  White saxaul(<i>Haloxylon persicum</i>) <i>Odyseea mucronata</i>  Cactus (<i>Opuntia</i> spp)  Desert bunchgrass (<i>Panicum turgidum</i>) Bulbous bluegrass (<i>Poa bulbosa</i>) Mesquite (<i>Prosopis juliflora</i>)  Bridal broom (<i>Retama monosperma</i>) Saltwort (<i>Salsola</i> spp)  Arabian tamarisk (<i>Tamarix Arabica</i>)</p>
Water cycling	<p>Mediterranean saltbush (<i>Atriplex halimus</i>) Bulbous bluegrass (<i>Poa balbosa</i>) Saltwort (<i>Salsola</i> spp)</p>
Habitat provisioning	<p><i>Acacia</i>(<i>Acacia</i> spp)</p>
	<p>Chickpea (<i>Cicer</i> spp)  Carob tree (<i>Ceratonia siliqua</i>) <i>Dipterygium glaucum</i> Lentil (<i>Lens</i> spp) Alfalfa (<i>Medicago sativa</i>) <i>Persea</i> (<i>Mimusops laurifolia</i>) <i>Pistachio</i> (<i>Pistacia</i> spp)  Mistletoe (<i>Plicosepalus curviflorus</i>) Tamarind (<i>Tamarindus indica</i>) White clover (<i>Trifolium repens</i>) Star fenugreek (<i>Trigonella stellata</i>)  Christ's thorn jujube (<i>Ziziphus spina-christi</i>)</p>
Production of oxygen, gas regulation	<p><i>Acacia</i>(<i>Acacia</i> spp)  Mangrove grass (<i>Aeluropus lagopoides</i>) Garlic (<i>Alliums</i> pp)  Mediterranean saltbush (<i>Atriplex halimus</i>) Grey mangrove (<i>Avicennia marina</i>)  Neem tree (<i>Azadirachta indica</i>) Cabbage (<i>Brassica oleraceae</i>) Carob tree (<i>Ceratonia siliqua</i>) <i>Ceratonia</i> (spp) Chickpea (<i>Cicer arietinum</i>) <i>Cicer</i> spp  Pumpkin (<i>Cucurbita pepo</i>) Alqa (<i>Dipterygium glaucum</i>) White saxaul (<i>Haloxylon persium</i>) Sunflower (<i>Helianthus annuus</i>)</p>

	<i>Barley</i> ( <i>Hordeum spontaneum</i> , <i>H. vulgare</i> ) <i>Common juniper</i> ( <i>Juniperus communis</i> ) <i>Lentil</i> ( <i>Lens culinaris</i> ) <i>Tomato</i> ( <i>Lycopersicon esculentum</i> ) <i>Alfalfa</i> ( <i>Medicago sativa</i> ) <i>Persea</i> ( <i>Mimusops laurifolia</i> )
	<i>Moringa</i> ( <i>Moringa spp</i> ) <i>Odyssea mucronata</i> <i>Cactus</i> ( <i>Opuntia spp</i> ) <i>Desert bunchgrass</i> ( <i>Panicum turgidum</i> ) <i>Datepalm</i> ( <i>Phoenix dactylifera</i> ) <i>Common reed</i> ( <i>Phragmites australis</i> ) <i>Pistachio</i> ( <i>Pistacia spp</i> ) <i>Pea</i> ( <i>Pisum sativum</i> ) <i>Mistletoe</i> ( <i>Plicosepalus curviflorus</i> ) <i>Bulbous bluegrass</i> ( <i>Poa bulbosa</i> ) <i>Poplar</i> ( <i>Populus spp</i> ) <i>Bridal broom</i> ( <i>Retama monosperma</i> ) <i>Mesquite</i> ( <i>Prosopis juliflora</i> ) <i>Saltwort</i> ( <i>Salsola spp</i> ) <i>Silverleaf nightshade</i> ( <i>Solanum eleagnifolium</i> ) <i>Johnsongrass</i> ( <i>Sorghum halepense</i> ) <i>Marigold</i> ( <i>Tagetes erecta</i> ) <i>Tamarind</i> ( <i>Tamarindus indica</i> ) <i>Arabian tamarisk</i> ( <i>Tamarix Arabica</i> ) <i>White clover</i> ( <i>Trifolium repens</i> ) <i>Star fenugreek</i> ( <i>Trigonella stellata</i> ) <i>Ervil</i> ( <i>Vicia ervilia</i> ) <i>Vetch</i> ( <i>Vicia sativa</i> ) <i>Christ's thorn jujube</i> ( <i>Ziziphus spina-christi</i> )
Not specified	<i>Blackthorn</i> ( <i>Acacia mellifera</i> ) <i>White stern thorn</i> ( <i>Acacia polycantha</i> ) <i>Red acacia</i> ( <i>Acacia seyal</i> ) <i>Paper back thorn</i> ( <i>Acacia sieberiana</i> ) <i>Baobab</i> ( <i>Adansonia digitata</i> ) <i>Silk tree</i> ( <i>Albizia aylmeri</i> ) <i>Grey mangrove</i> ( <i>Avicennia marina</i> ) <i>African fan palm</i> ( <i>Borassus aethiopum</i> ) <i>Large-leaved saucer-berry</i> ( <i>Cordia africana</i> )
	<i>African ebony</i> ( <i>Diospyros mespiliformis</i> ), <i>Winter thorn</i> ( <i>Faidherbia albida</i> ), <i>Phalsa cherry</i> ( <i>Grewia tenax</i> ) <i>Sea cucumber</i> ( <i>Holothuria scabra</i> ), <i>Doum palm</i> ( <i>Hyphaene thebiaca</i> ) <i>African mahogany</i> ( <i>Khaya senegalensis</i> ) <i>African bamboo</i> ( <i>Oxytenanthera abyssinica</i> ), <i>Dryzone cedar</i> ( <i>Pseudocedrela kotschyi</i> ) <i>Small-leaved blood wood</i> ( <i>Pterocarpus lucens</i> ), <i>Tamarind</i> ( <i>Tamarindus indica</i> )

Source:-Country report prepared for the state of the world's biodiversity for food and agriculture (FAO, 2019a)

#### 4. Benefits of Ecosystem Services

The estimated monetary values of some regulatory ecosystem services for tropical ecosystems are shown in (Table 3). The value of just four services estimated for Nigeria 92,378,800 hectares stood at over N98 trillion/year (at \$1 = N200).

**Table 3** Estimated monetary values of Ecosystem Services

Ecosystem Service(a)	\$/ha/year(b)	₦/ha/year(c)	₦/ha/year(d) **
Regulation of climate	1,965	393,000	36,304,082,400,000
Water circulation flow	1,360	272,000	25,126,489,600,000
Soil stabilization	694	138,800	12,821,899,840,000
+NTFP+Wood+			
Medicine	1,313	262,600	24,258,147,680,000
Total	5,332	1,066,400	98,510,619,520,000

Source: TEEB, 2010; + NTFP means Non-Tree Forest Products

The Role of ecosystem services in the attainment of Sustainable Development Goals is of high significance. These goals include eradication of poverty and hunger, promotion of gender equality and empowerment of women, reduction of

child mortality and improvement of maternal health, reduction of the spread of diseases and sustenance of natural environmental functions [34]. Government development strategies usually focus more on infrastructural growth while functionality of natural systems are deemed free hence unnoticed. This seems to be partly due to the fact that ecosystem services are often invisible and intangible coupled with a poor understanding of the cause-and-effect nature of environmental changes [35]. Similarly, long-term impacts of destroying ecosystems are sometimes difficult to anticipate or even substantiate, and biodiversity loss and degradation of ecosystems may not have immediate drastic impacts [36].

#### **4.1. Watersheds, Wetlands and Ecosystem Services in North East Nigeria**

Four of the of the seventeen primary watersheds in Africa are located in the Western part of the sub-continent namely the Senegal River Basin, the Volta River basin, the Niger River Basin and the Lake Chad Basin [37]. The Lake Chad basin spreads to over seven countries, two of which are in West Africa, Nigeria, (Northeast), Niger, Algeria, Sudan, Central Africa Republic, Chad and Cameroon [38]. The estimated value of ecosystem services that can be attributed to inland watershed and wetlands ranges between US\$5000 and US\$100,000 per hectare, while coastal watersheds and wetlands were between US\$500 and USD\$1,000,000 per hectare in 2007 [39]. The economic value of Hadejia-Nguru wetlands which forms part of the Komadougou – Yobe River Basin of the Lake Chad Basin in North East Nigeria was estimated at over US\$ 16million per year [40].

Hadejia – Nguru wetlands supports at least 250 species of flowering plants, over 136 types of aquatic flora and fauna, more than 103 fish species and 378 species of birds [41]. Several forests within the wetlands provide a range of natural resources. Fisheries and aquaculture activities account for 50% in the wetlands representing the main source and livelihoods of the indigenous communities and is carried out throughout the year [42]. Blench, 2013 [43], reported that some 19 species are regularly caught in the wetland. The Hadejia – Nguru wetlands contribute to about 6% of inland fish catch in Nigeria with a market value of nearly US\$ 6million per annum [44].

##### *4.1.1. Agriculture, Wildlife and Fisheries in North-East Nigeria*

Agriculture is common to the six states of the North-East Region. Similar crops such as maize, sorghum, millet, groundnuts, and soya beans are cultivated. Livestock rearing and grazing are also practiced.

##### *Adamawa state*

This state is a picturesque environment with alluring mountain ranges on its eastern borders with Cameroon heavily dissected upland plains in the Southern parts and the Benue trough bisecting the state into two equal parts. Abundant agricultural lands are to be found in the many morphological units within the state making the growth of various crops, vegetables and livestock management possible. Several swamps/wetlands, lakes and pools exist to varying degrees. The landscapes support Guinea and Sudan savanna vegetation types though altered in many places due to anthropogenic forces.

##### *Taraba state*

This state shares a number of biophysical characteristics with Adamawa state. It is traversed by the Benue River with many tributaries but being more southerly enjoys higher and longer duration of rainfalls with vegetation of better verdure even though under serious threat from increased agricultural activities and fuel wood harvests. The state also possesses the Mambilla plateau (at more than 1800 metres above sea level), the largest national park (the Gashaka-Gumti-6731 km<sup>2</sup>) and extensive flood plains and marsh land. It has the highest variety of wildlife and flora given its moist forest, guinea savanna and mountain grasslands. In addition to its wide range agricultural potentials, Taraba state possesses high hydro-energy promise [45].

##### *Bauchi state*

This state is next to Borno in landmass and the highest in population within the region. Its wide expanse of plains and open savanna punctuated by isolated ruwares and inselbergs, rivers and flood plains (fadama) have long been supporting cultivation and livestock. The Yankari Game Reserve (2,058M<sup>2</sup>) which was opened to the public in 1962 is regarded as Nigeria's premier wildlife reserve [46].

##### *Gombe state*

This state is the smallest in land mass and the highest in density. Gombe plains have long supported grains, vegetables and cotton production in places with morphological and scenic beauty such as Kalan, Bima rocks, Tangale peak and Bage hills, Cham valley and surrounding hills have all been supporting advanced forms of cultivation and management

including terracing. Dadin Kowa dam is supporting irrigated agriculture on the banks of the Gongola River and in other nearby lowland plains [47].

**Borno state**

This is the largest state in the North-East Region of Nigeria and the second largest in Nigeria with a vast open strikingly uniform plain of sedimentary formation, largely within the Mega Chad Basin [48]. Rivers Yedsram and Alau flowing from south to north now disappear into firkin (dark clayey soils that easily get saturated during rainy season) swamps. The southeastern Mandara mountains and the Biu plateau in the south contrast sharply with the sand dunes of the North and North-West of the state. Lake Chad being one of the largest and most historic endorheic lakes in the world is perhaps the most significant hydro-ecological feature of the North-Eastern tip of Nigeria necessitating the establishment of the Lake Chad Basin Commission by the four countries(Chad, Cameroon, Niger, Nigeria) adjoining it [49]. The lake's fisheries(with 176 species) are said to be of international importance [50] and together with the huge spread of irrigable lands and also the Chad Basin National Park(2,258 km<sup>2</sup>) supporting various birds and lowland/marshy area wildlife, the basin is of economic importance in the region [51].

**Yobe state**

This state has a very large landmass and a very low population. It has the lowest density of only 31 persons/km<sup>2</sup>.It is a state dominated by gently low-lying plains of loose friable soils except in the fadamas/depressions that get saturated during rains and the major water courses and wetlands [52]. The wetlands are of international importance supporting cultivation, grazing, fishing and hunting. The Bade-Nguru sector of the Chad Basin National Park(938km<sup>2</sup>) is also within the state [53].

**5. Dynamics of fuel wood consumption in North-East Nigeria**

Most forest reserves in North East Nigeria are depleted of trees and Non-Tree Forest Products (NFTP) which is exacerbated by the level of poverty in this region. A correlation coefficient of 0.771(significant at 5%) shows that the poorer regions tend to use more wood fuel to meet their domestic requirements [54]. Table 4 shows the average percentage of wood used in 2007 in each of the six geopolitical regions of Nigeria in relation to poverty level. Northern regions of Nigeria (North East inclusive) consume more fuel wood than Southern regions of Nigeria [55].

**Table 4** Poverty rate and percentage of wood as fuel source by geopolitical regions

Region	Poverty rate (%)	Wood as fuelwood source (%)
North-East	72.2	95.9
North-West	71.2	95.3
North-Central	67.2	86.4
South-West	43.0	54.9
South-East	26.7	78.0
South-South	35.1	72.7

Source: NBS (2007)

Table 5, shows removals of wood from the forests according to purposes in Nigeria. Wood removals from forests in 2005 amounted to 86,626,797 m<sup>2</sup> and removals for wood fuel from forests in the year 2005 were 72,710,935 m<sup>2</sup>, the difference being made up by industrial round wood which accounted for 13,915,862 [56]. Wood may also come from areas outside forests like shrub land, savanna and grassland as no data are available on these sources in Nigeria, a reasonable estimate has to be made based on figures from neighboring countries. Neither are data available for Benin, Cameroon or Ghana. The “FRA 2005 Country Report Senegal” presents data on the growing stock on “other wooded land” is about 7% of the growing stock of forests. This can be assumed to be true for Nigeria. Adding 7% to 86,626,797m<sup>2</sup> gives us 92,690,673 m<sup>2</sup> as the total harvest of wood from forest and other wooded land combined.



**Table 5** Removals according to purposes in Nigeria.

Category	M <sup>3</sup> /year	Tonnes/year (Metric)
Total removals	92,690,673	64,883,471
Of which for fuel	72,711,000	50,897,700
Of which for fuel wood proper	56,714,580	39,700,206

Source: FAO (2005)

The shares of fuel wood proper and wood for charcoal production are not known. We can assume it to be about the same as in Chad which is 78 and 22% respectively of all the wood used [57].

UNDP, 2002 [58], gives the share of various energy sources in the total primary energy supply in Nigeria as 10.4% oil, 6% gas, 0.6% hydro and commercial renewable energy 83%. The greater portion of the commercial renewable energy is wood while other agricultural wastes constitute the remaining smaller portion, lower prices, easy accessibility, constraints in the supply of the conventional fuels and growing population are reasons for over-dependence on fuel wood for energy [59]. Daily consumption of firewood by the rural communities in Nigeria is estimated at 27.5 million kg/day [60], and estimated Nigeria's fuelwood consumption in relation to other energy sources at 87%. This implies that majority of the Nigerian rural people will continue to use dried biomass fuels for energy many years to come [61].

### 5.1. National wood fuel consumption

Dividing the total fuel wood consumption of 39,700,206 tonnes/year through the number of inhabitants which is 140,003,542 (2006 census) we get about 0.284 tonnes/person/year which is about 0.776 kg/day [62]. The difference between urban and rural households may be explained by the fact that urban households often have additional sources of energy at their disposal e.g., kerosene, gas, charcoal, agricultural residues, electricity.

### 5.2. Data on some savanna wood species and domestic sources of energy

Average calorific value of savanna wood species is about 4,167 k.cal [63].

Calorific values of kerosene, liquefied petroleum gas, charcoal and electricity are 8, 300, 11,700,600 and 860 k.cal. With fuel use efficiency of 35%, 52.5%, 20% and 75% respectively [64].

With the traditional wood burning stoves in use, fuel end-use efficiency of firewood is about 7.5% [65].

Mechanical equivalent of heat-4.2 joules per calorie

1M<sup>3</sup> solid volume of savanna tree species at about 13% moisture content (dry wood weighs about 600kg [66].

For the purpose of estimation, 100-kg sack of charcoal weighs 335 kg [67].

1M<sup>3</sup> stacked wood volume=1/2 M<sup>3</sup> solid wood volume

Among other sources of domestic energy, firewood was the most highly consumed accounting for about 82% of the estimated total heat of energy of 104 mega joules consumed per person per year in Kaduna state [68]. (Adegbehin and

### 5.3. Fuelwood consumption in North East Nigeria

State-specific consumption figures are not available, but multiplying the national average of 0.284 tonnes/person/year [69] with the number of inhabitants in the North-East which is 24,051,418(2006 census projected to mid-2014 [70], we arrive at an estimated consumption of 6,830,603 tonnes/person/year in the six North-Eastern states of Adamawa, Gombe, Taraba, Yobe, Bauchi and Borno put together. As a result of population growth these consumption figures should be higher now.

## 6. Threats to ecosystem services in North East Nigeria

### 6.1. Over exploitation of forest resources

West Africa original forest has disappeared with small fragments of these natural forests existing in Cote d'Ivoire, Nigeria (including the North East) and Cameroon [71]. Over exploitation of forest resources is a serious factor causing biodiversity losses in Northeast Nigeria, and this scenario is exacerbated by poverty, ignorance and lack of awareness and education about the importance and value of the forest. According to Olagunju, 2015 [72], 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 the amount of its primary forest cover with an annual deforestation rate of 3.67% between 2000 and 2010 [73].

### 6.2. Drought, desertification and ecosystem services

Drought and desertification have direct impact on the availability of ecosystem services in Northeast Nigeria. Some of the causes of these phenomena include climatic variability [74], anthropogenic activities which include deforestation [75], extensive cultivation whereby conversion of 351,000 hectares of land are reduced to desert, overgrazing [76]; [77]. More than 70% of the nation's population depends on fuel wood [78]. Katsina has its over 90% energy from fuel wood [79].

### 6.3. Urbanization

Urbanization, according to Nneji, 2013 [80] is also a factor for desertification; lands are cleared to make way for infrastructure leading to removal of vegetation cover thereby paving way for desertification.

**Table 6** shows various degree of desertification in frontline states of Nigeria. Notably, seven states, Sokoto, Zamfara, Katsina, Jigawa, Kebbi, Borno and Yobe experience severe levels of desertification.

State	Geographical Region	Land area (Km <sup>2</sup> )	Population (2006)			Rate of Desertification
			% of Nigeria	Number	Density (Km <sup>2</sup> )	
Sokoto	Northwest	27,825	3.06	3,702,676	133	Severe
Zamfara	Northwest	37,931	4.17	3,278,873	86	Severe
Katsina	Northwest	23,561	2.59	5,801,584	246	Severe
Jigawa	Northwest	23,287	2.56	4,361,002	187	Severe
Kano	North central	20,280	2.23	9,401,286	464	Moderate
Kebbi	Northwest	36,985	4.06	3,256,541	88	Severe
Kaduna	North central	42,481	4.67	6,113,503	144	Moderate
Borno	Northeast	72,609	7.98	4,171,104	57	Severe
Yobe	Northeast	46,609	5.12	2,321,339	50	Severe
Bauchi	Northeast	41,119	4.52	4,653,066	113	Moderate
Gombe	Northeast	17,100	1.88	2,365,040	138	Moderate
Adamawa	Northeast	38,700	4.25	3,178,950	82	Moderate
Taraba	Northeast	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	2004	

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 top soil lost or soil salinity has reduced crop yields 10 to 50% severe: 10 to 25% of plant community consists of climax species or erosion has removed all or practically all of the top soil or salinity controlled by drainage and leaching had reduced crop yield by more than 50% Loss of Biodiversity and habitat destruction.

The impact of desertification is far reaching and results in habitat destruction and loss of biodiversity as many species are prone to be endangered due to desertification [81], changes in phenology, heat waves [82], [83], cancer [84], vector-borne diseases [85], loss of plants of medicinal importance [86], [87], global warming [88], increased erosion, soil salinization [89], [90], [91], reduced water supply, [92]; [93]; [94], [95], overexploitation of groundwater, reduced agricultural productivity and food insecurity [96], economic loss and reduced economic growth [97], [98], migration, resource use conflict [99], [100], [101], [102], [103], [104].

In West Africa, biodiversity hubs characterize the environmental landscape and are crucial to the livelihood of citizens. In Northern Nigeria forests, vegetation and wetlands are primary providers of ecosystem services.

These hubs are being threatened by agricultural expansion, overexploitation of biological resources, population exploitation of biological resources, population explosion, urbanization and climate change [105]. The utilization of industrial chemicals for agricultural purposes, as well as pesticide discharges are threatening the quality and volume of native flora and fauna species in watersheds and wetlands across sub-Saharan Africa [106]. The size of these hubs have been degraded and reduced in parts of West Africa, Northeast Nigeria inclusive [107].

It was reported that fish catches in the wetlands reduced by 17% due to flooding while invasive *Typhadomingens* is reduced fish catch and prevented fishermen from having access to other parts of the wetland [108].

#### **6.4. Anthropogenic activities, pollution and wetlands**

Akinsola et al., 2000 [109]; Abubakar and Abubakar, 2013 [110], listed the following threats to the optimum functioning of the Hadejia-Nguru wetlands, as over exploitation of natural resources, uncontrolled hunting, population increase, pollution from domestic waste, potash exploration, sedimentation resulting from deforestation, desertification, eutrophication resulting from agricultural run-off, channelization, compaction of soil by pastoralists and their animals which further degrade the wetlands habitats as well as climate change and drought. Olofin, 1993 [111], pointed out that drying out effects of the wetlands and some Pale arctic waders thus paving way for infestation by *entomodesleucotis*. Bird life international, 2015 [112] ranked the status of the wetlands in terms of pressure as “very high” in addition to outdated management plan which is not comprehensive.

#### **6.5. COVID19 pandemic and ecosystem services**

The current siege of COVID-19 globally is a threat to the entire configuration of demand and supply of ecosystem services in Northeast Nigeria. As at 1<sup>st</sup> May, 2020, Nigeria has recorded over 2000 cases with over 40 deaths. All the states in Northeast Region Yobe, Adamawa, Borno, Gombe, Bauchi and Taraba have recorded cases of COVID-19, resulting in lockdowns, curfews, ban in interstate travel, culminating in suggested practices of social standing, reduction in people gathering for social activities, all having concomitant effects on provision of ecosystem services.

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### **7. Mitigating threats to ecosystem services sustainability**

#### **7.1. Assessing Demand and Supply of Ecosystem Services**

Millennium Ecosystem Assessment (MEA 2005) [113], established an understanding of ecosystem services and how human activities affect them [114] and concluded that 60% of ecosystem services were degraded or being used unsustainably. A framework for assessing when, where and how ecosystem services are imperiled in North East Nigeria is crucial. Which of the ecosystem services should we be most concerned about? Fuel wood supply, bush meat, charcoal, medicines from products of tree barks, wild fruits from trees, fishing, livestock and animal husbandry among many other ecosystem services. Hence it is important to establish standard set of criteria to find out when and to what extent provision of ecosystem service is at risk of extinction based on international Union for Conservation of Nature (IUCN) red list classification systems [115]; [116].

The proposed threat categorization framework for Ecosystem services. Description of the criteria for each of the seven proposed threat categories plus a data deficient category showing the critical thresholds where services transition from secure at risk, as risk to undersupplied and undersupplied to lost. Burkhard, 2012 [117] opined that level of risk to

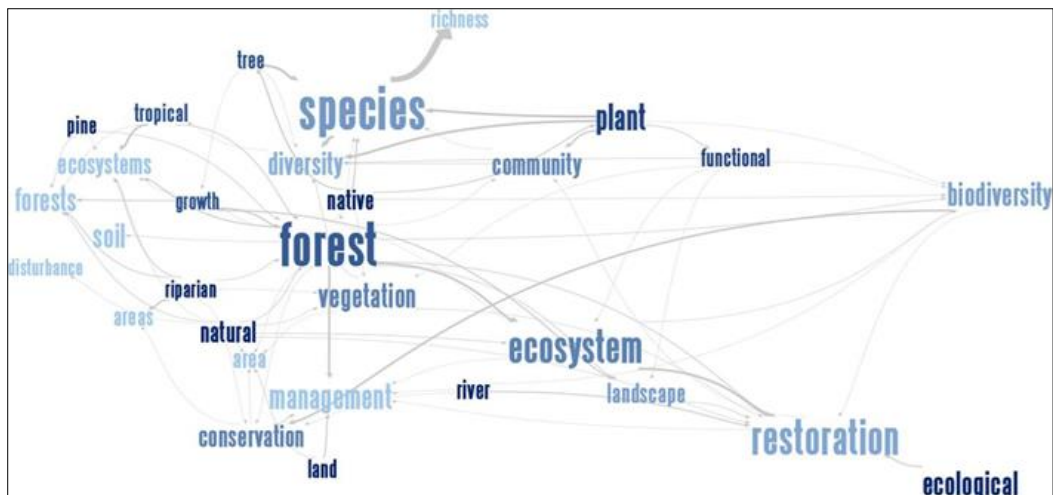
“adequate” ecosystem service provision whether supply meets demand must be evaluated. This is because the absolute level of service provision is not the appropriate metric for evaluating threat [118]. Any threat assessment framework must evaluate both ecosystem service supply (the potential for natural capital to generate benefit for people) [119], and demand (the level of service provision desired or acquired by people [120].

Ecosystem services in North East Nigeria can be categorized in order to establish functional thresholds so as to know which ecosystem services supply and demand are imperiled [121].

**Table 7 Suggested frame work for Ecosystem threat analysis**

Category	Definition	Threshold
Functionally extinct	Service no longer supplied in the region and is practically unrecoverable	Lost
Dormant	Service no longer supplied in the region but is potentially recoverable	
Critically endangered	Current levels of demand exceed supply and the ratio of supply to demand declining or expected to decline.	Under supplied
Endangered	Current levels of demand exceed supply; ratio of supply to demand is stable but supply is declining	
Stable but undersupplied	Current levels of demand exceed supply; neither supply nor ratio of supply to demand declining	
Vulnerable	Ratio of supply to demand is declining or expected to decline such that supply is likely to be insufficient to meet demand within a set time horizon	At risk
Least Concern	Supply currently meets or exceeds demand and does not the criteria for vulnerable	Secure
Data deficient	Inadequate information is available about either or both of supply and demand to assess the level of threat	N/A

Source: Maron et al, 2017; Trends in Ecology and Evolution



**Figure 2** Shows the biodiversity-ecosystem function approach to ecological forest restoration

### 7.2. Applying ecosystem approach

The need to restore ecosystem functions in North East Nigeria cannot be overemphasized. Most of the forest reserves are deforested and have become degraded, hence reforestation of their sites with trees are necessary adopting the example of the ecosystem approach to forest restoration suggested by (Russel, et al., 2004) [122]; Paul et al., 2010) [123].

Some authors Naeem, 2006 [124], Wright et al, 2009 [125], Tree Div Network suggested the biodiversity-ecosystem function (BEF) approach to ecological forest restoration as illustrated in (fig 2). The BEF perspective strongly focuses on restoring the relationship between biodiversity and ecosystem functioning [126]. These suggestions are valuable in restoring ecosystems in North-East Nigeria for the purpose of sustaining ecosystem services.

### 7.3. Mitigating wood shortage problems

Strategies for combating wood shortage in the North-East Nigeria could include the short- and long-term measures. Firewood is a very relevant commodity in provision of ecosystem services in this region and even in the Nigerian nation; therefore, every effort to ameliorate shortage of this commodity is worthwhile.

#### 7.3.1. Short-term measures

In the short term, improved stoves and pressure pot cookers should be provided and distributed to the inhabitants of this region i.e., North-East Nigeria. The traditional African 3-stone hearth loses over 90% of the heat produced [127]. These stoves which can be fabricated locally reduce heat loss and save about 27.5% of firewood input and at the same time reduce the cooking time by about 42.6% [128]. Government should continue to subsidize the prices of non-fuel wood sources, principally gas and kerosene to reduce consumption of fuel wood.

#### 7.3.2. Long-term measures

##### Intensified afforestation

According to Repetto, 1988 [129], the rate of deforestation in Nigeria has been estimated at about 300,000 hectares annually while afforestation rate is less than 10% of the rate of deforestation [130]. This calls for increased rate of afforestation. Promising plantation species such as *Eucalyptus camaldulensis*, *Eucalyptus tereticornis*, *Gmelina arborea*, *Tectona grandis* which have growth rate over ten times that of most indigenous tree species [131], should be planted as fuel wood plantations by individuals and intensified agro forestry practices by farmers should be encouraged as part of finding solution to fuel wood problems in this region.

##### Use of Solar energy

The use of solar energy to generate electricity for lighting, cooking and many other household chores is still at a small-scale use in Nigeria including the North-East [132]. Sun energy is man's oldest and most important source of energy and there is abundance of sunshine in North- East Nigeria. For Nigeria, there is an average yearly incidence of solar energy at about 2,300 Kwh/m<sup>2</sup> of land area. With a projected yearly total demand of about 21 multiplied by 109 Kwh for the remaining part of this century, the entire energy requirement of the whole country could in principle be met by solar if 1% of the available solar energy can be tapped at 0.1% conversion efficiency [133].

##### Other sources of energy

Other sources of energy that can be developed in North-East Nigeria include windmill which can be used to grind grain harvests from the farms and support other activities in the entire ecosystem services value chain.

Biogas technique can also be used for the production of heat energy which can be derived from gas produced from decaying animal wastes/or plant materials.

The use of human wastes which are abundant in good quantity for this purpose needs to be encouraged although there may be problem of acceptance by the public. System services provisions.

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## 8. The Role of forest extension in sustaining Ecosystem Services in North East Nigeria

### 8.1. Co-ordination of research and extension

Forestry extension is vital in the sustainability of ecosystem services in Northeast Nigeria. Improved research and training are necessary to support the process towards sustainability of ecosystem services. Agbogidi and Ofuoku (2005) [134] opined that integrated data analysis on forest management and extension should be properly co-ordinated and synergized in the country including North-East.

## 8.2. Capacity building for indigenous people and institutions

In order to ensure that ecosystem services are sustained in North East Nigeria, there is need to build capacity at all the local governments in the entire region in line with designed extension packages. Institutional and human capacity should be built among indigenous peoples of the region. These extension ingredients are crucial to sustainable ecosystem services and also suggested for North East Nigeria. There is need to invest in environmental protection technologies, public education and poverty reduction.

## 8.3. Investing in forestry protection technologies

- Proper funding of forestry extension packages recognizing extension as a priority.
- Women who are major end users of forest products must be adequately reached by extension services in any of the forest protection development programmes.
- The missing linkages between research and extension organization need to be retraced and strengthened.
- Researchers should not be skewed away from sustainable systems of local subsistence way of life of the local communities, there is need to interface with members of the community in forestry programme planning and implementation.
- Forest valuation should be carried out and mechanisms that will support conservation of forest ecosystems and sustainable forest- based development given a top priority.
- Opinion, religious and community leaders are revered by their subjects in this part of the country and can be encouraged to pass on the message of the value and importance of biodiversity conservation to their subjects.

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## 9. Conclusion

Ecosystem services sustainability is vital to the North East Region of Nigeria due to the many benefits accruing to the inhabitants. Sustainable development goals, such as eradication of poverty and hunger, promotion of gender equality, sustenance of the natural environment, watersheds and wetlands are beneficial to ecosystem services. Threats to ecosystem services supply and demand in this region include (but not limited to) drought, desertification, overexploitation of natural resources, urbanization, progressive industrialization and overgrazing. In order to mitigate these threats, there is need to develop a framework for assessing when, where and how demand and supply of ecosystem services are imperiled. Secondly, restoration of ecosystems is crucial because most forests and forest reserves are badly depleted through over exploitation of trees and non-forest tree products (NFTPs). Thirdly, forestry extension services must be geared up to create awareness on the value and importance of trees and the deleterious effects of their removals and consequent threats to the ecosystems.

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## Compliance with ethical standards

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