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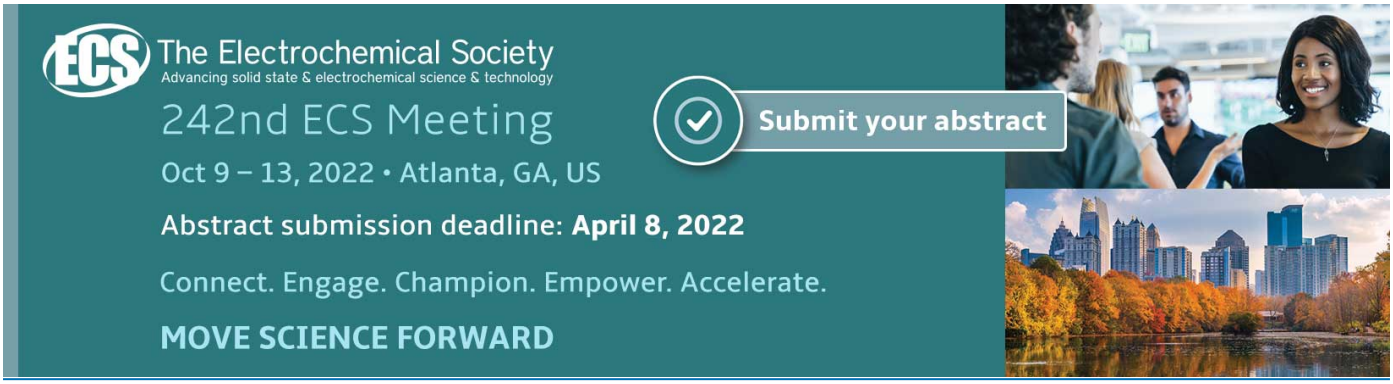

Sustainability and Genetic Diversity of Under-exploited African Plants: A Collection Expedition in Nigeria - Facts, Challenges and Prospects

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Abstract: Plant genetic diversity loss particularly of under-utilized species threatens several developmental goals in Africa. Preferred safeguard strategies and techniques have failed in stemming this situation exacerbated by dearth in global information and poor research attention on such species amongst other pitfalls. The study involved an expedition to; generate eco-geographical and related information on 30 under-utilized species; evaluate the prevailing situations for collection exercises in Nigeria, in the attempt to instigate globally relevant researches, conservation and sustainable partnerships. A two-phased systematic field survey (North and South) employing a 50 km regular transect distance, covering the wet and dry seasons, a cumulative distance of 8168 km, 192 communities in 34 states and the Federal Capital Territory (FCT) of Nigeria. Collection diversity was determined with Simpson's Diversity index (1-D) as well as species abundance. 703 accessions of 30 plants species were collected. 13% of the total species (16% -South; 40% - North) were common to both regions. High diversity (D = 8) was recorded for the collection. The wetter southern states were significantly more diverse (D = 0.7-0.9) than the north. The north west and some south eastern state recorded lesser diversity and the FCT the least (D = 0). 6 species recorded significant species abundance across the study area. The study area is heavily imparted yet houses a considerable diversity of the species surveyed. It is imperative to pursue integrated strategies to harness the plentiful flora as well as cultural resources resident therein. The species studied can be employed to tackle the challenges of climate change, livelihood, economy, food and nutrition security and farmer/grazers/construction activity unrest.

1. Introduction

Plant genetic resources constitute ready sources of raw materials for farmers, breeders and researchers alike in the efforts to increase food production and food quality, generate new medicine prospects as well as floral solutions in response to new conditions such as disease and pest control and management drought, and changes brought about by climate change. Important possibilities exist for improving agricultural production to managing climate change impacts where plant resources are conserve and use in sustainable ways. Consequently, the chances of both present and future generations might be jeopardized by the current loss of genetic diversity due to unproductive land use. Sustainable conservation techniques and strategies required to arrest this trend and safeguard the genetic diversity, would need to combine both *ex situ* and *in situ* techniques[1-3].

Several of the challenges exacerbating the situation amongst others include; global information dearth on African plants diversity, due to poor research attention making it a difficult task engaging such plants for sustainable food security programme. Such global attention will definitely arise if the plants can be accessed through digital molecular reserves, and ultimately drive solution-based research for global relevance as well as attract global partnership. [2-7].

Africa flora is very rich with species that are of great economic value as food, spices, vegetable, beverages and medicine; many of which are under-exploited and underutilized while others are threatened[4-7]. There is therefore, an urgent need to explore and utilize this rich biodiversity through focused researches that could translate to direct benefits for all. In spite of traditional uses of plants for food and nutrition, treatment and prevention of diseases, there is paucity of information about genetic diversity, conservation status and proper documentation of cultural uses of most of the species. Coupled with this information dearth is a more worrisome case of loss of thousands of acreages of forest every year to human and natural cataclysms and the cultivation of a narrow section of the genetic resources of most crop plants[8,9].

Recent Food and Agriculture Organization[1] reports estimated that less than 1% of the 80 000 and more global tree species, have been studied in any depth for their present and future potentials. North-South dichotomy in research focus on global food production, medicine etc, have only driven research in the improvement of plants that are primarily important to the North, relegating majority of African plants to the background, creating "Orphan Plants or crops" of today[10]. The present effort is hoped to instigate global research attention with prospective outcomes that will influence improved hybrids and varieties for food, medicine, ecological remediation, drought and salinity resistance, etc.

As with other parts of the world, only a good knowledge of African crops, endemic indigenously cultivated and constitute an integral part of the way-of-life of Africans stand to present a real solution for sustainable food security in Africa. One of the most important goals of the SDGs is developing global partnership for development and achievement of all the other goals. The outcome of the present work will attract the attention of global bodies like the FAO, UNEP, USAID, DFID, etc; institutions that are concern with generating solutions to global challenges and readily disposed to collaborating with proactive institutions that have created a ready platform for generating global, regional or national solutions[11].

The study is aimed at generating database on the diversity of thirty plants species across the various eco-geographical zones of Nigeria. It is part of a larger effort to produce collection data important for assessment of the level of indigenous plants diversity and in future, generate molecular information that targets local and globally relevant researches on these neglected but extensively versatile Africa plant species.

2. Materials and Methods

2.1. Field Survey

The field survey was carried out in two phases and the areas covered is shown in Figure 1.

Phase I: Northern Nigeria with geographic co-ordinates; 10°09'36.0N - 9°15'18.0N; 12°12'14.4E - 4°16'22.8E. ***North Central***: Benue, Kwara, Nassarawa, Niger, Plateau, FCT; ***North East***: Adamawa, Bauchi, Gombe, Taraba, Yobe; ***North West***: Jigawa, Kaduna, Kano, Kastina, Kebbi, Sokoto, Zamfara.

Phase II: Southern Nigeria with geographic co-ordinates; 8°81'15.0N - 4°89'09.6N; 8°35'30.6E - 3°11'33.4E. ***South South***: Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Rivers; ***South East***: Abia, Anambra, Ebonyi, Enugu, Imo; ***South West***: Ekiti, Lagos, Ogun, Ondo, Osun, Oyo.

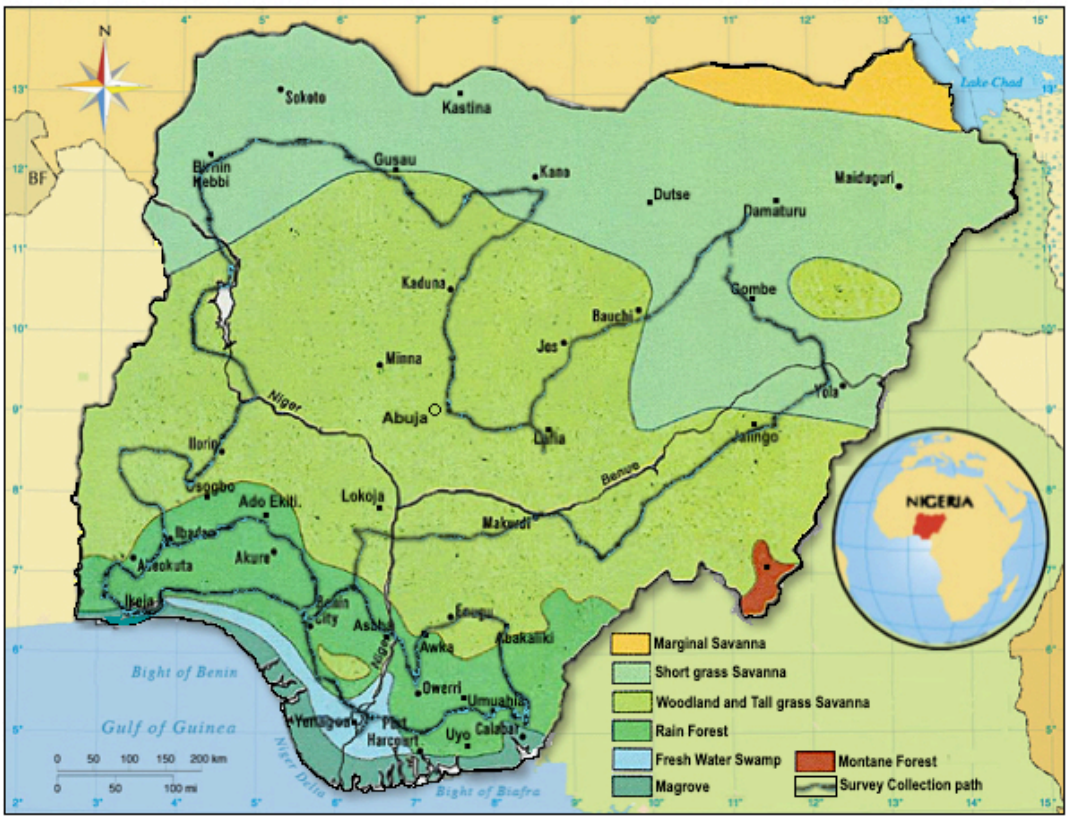

Figure 1. Survey Map for the Sample A modified map of collection Expedition in Nigeria, January – November 2017. Map shows collection path across the agro-ecological zones within the country (Source: Wikipedia)

2.2. Plant Samples Collection

A total of 703 accessions of 30 plants species were collected. Leaf samples were Silica gel dried at the point of collection. Prepared samples were cleaned and stored in a -80◦C cooling facility at the Molecular Research Laboratory, Department of Biological Sciences, Covenant University. Field trips were made to various communities in the different eco-geographical zones and consultations on informed consent basis with the spectrum of stakeholders for ethnobotanical information on the selected plants. Collection and accessory data of accessions (samples) collected across Nigeria, which includes; Accession No., Botanical name, Common name, Local name, Latitude, Longitude, Altitude, Area of collection, Local Government Areas (LGA), and State of collection as well as other cultural related information.

2.3. Sampling

Sampling was carried out using a Systematic sampling on a regular transect distance of 50 km as well as in designated communities where certain plant species are considered endemic. Transect strip lines and a random point layered pre-assigned area plot grid over a map of the area to be sampled. Geographic measurement, mapping and altitude were performed using an integrated set of tools: A Germin Etrex®, Google Map GPS alignment, and Accurate Altimeter® on a rugged Android Tablet.

Table 1. Species diversity and Diversity Index (D) for 30 Species Surveyed in States Across Nigeria

S/N	State	Region	No. of	%	No. of	Diversity

			species	species	Accessions	Index (D)
1	Abia	SE	10	2.27596	16	0.8*
2	Adamawa	NE	6	1.84922	13	0.6
3	Akwa Ibom	SS	13	2.9872	21	0.9**
4	Anambra	SE	19	5.6899	40	0.9**
5	Bauchi	NE	7	1.13798	8	0.8*
6	Bayelsa	SS	5	0.71124	5	0.8*
7	Benue	NC	12	3.41394	24	0.8*
8	Cross river	SS	19	3.98293	28	0.9**
9	Delta	SS	7	0.99573	7	0.9**
10	Ebonyi	SE	15	2.84495	20	0.9**
11	Edo	SS	27	8.6771	61	0.9**
12	Ekiti	SW	6	0.85349	6	0.8*
13	Enugu	SE	13	1.99147	14	0.9**
14	FCT	NC	2	0.42674	3	0
15	Gombe	NE	6	3.27169	23	0.3
16	Imo	SE	10	2.7027	19	0.8*
17	Kaduna	NW	10	3.98293	28	0.7*
18	Kano	NW	5	1.28023	9	0.6
19	Kastina	NW	5	1.56472	11	0.5
20	Kebbi	NW	5	1.70697	12	0.5
21	Kwara	NC	7	2.84495	20	0.6
22	Lagos	SW	7	0.99573	7	0.9**
23	Nasarawa	NC	1	0.14225	1	0
24	Niger	NC	11	6.82788	48	0.6
25	Ogun	SW	26	8.6771	61	0.9**
26	Ondo	SW	14	2.27596	16	0.9**
27	Osun	SW	25	6.11664	43	0.9**
28	Oyo	SW	19	5.54765	39	0.9**
29	Plateau	NC	4	0.71124	5	0.7*
30	Rivers	SS	11	2.27596	16	0.9**
31	Sokoto	NW	5	1.70697	12	0.5
32	Taraba	NE	12	5.12091	36	0.7*
33	Yobe	NE	7	1.99147	14	0.7*
34	Zamfara	NW	6	2.41821	17	0.5
	Cumulative		357	100	703	0.8

SS - South South; **SE** - South East; **SW** - South West; **NC** - North Central; **NE** - North East; **NW** - North West. **, * Significantly diverse states based on the survey indices of; number of species collected within a 50 Km transect and the number of accessions for a given species collected within the state for the 30+ taxa.

The field survey covered a cumulative distance of 8168 km spanning a total of One Hundred and Ninety- Two (192) communities in One Hundred and One (101) Local Government Areas

(LGAs) of Thirty-four (34) states of Nigeria, and the Federal Capital Territory (FCT). The survey spanned from January 2017 to November 2017; covering the wet and dry seasons.

2.4. Data Analysis

Data generated from the survey is analysed for No. of species per region, Total No. of species, Percentage species for per region, percentage species common to both region and species abundance. Bar chart for abundance of species collected (North and South and Study area) with standard deviation (SD) was generated. Significance abundance was tested using one sample *t*-test.

Index of species diversity for the study area was determined using the Simpson's Index of Diversity (1-D). Simpson's Index of Diversity as an expression of the richness and evenness of species across a given area, and a measure of diversity by taking into account the number of species and relative abundance of individual species[12].

$$\boldsymbol{D = 1 - \left(\frac{\Sigma n(n-1)}{N(N-1)}\right)} \quad \text{Eqn 1.}$$

Where:

n = the total number of organisms of a particular species
N = the total number of organisms of all species
***D* =** ranges between 0 and 1 (1 represents infinite diversity and 0, no diversity).

3. Results and Discussion

3.1. Vegetation Spread and Diversity

The expedition covered the various eco-geographical regions of the country ranging from the Swamp, rainforest through the wooded, grassland savanna (Figure 1). The wide range of land cover and environmental conditions prevailing across the various zones and the corresponding related adaptations to these broad range of ecological settings evidently created genetic diversity in the species surveyed (Table 1). Expectedly, the vegetation density in the wetter south was greater than obtained for the drier north (Figures 3 - 4).

This spread pattern of species is clearly environment-ordained and the number of species recorded for the south (25 species), the north (10 species) and the total (30) species collected in the survey reflects the difference in prevailing ecological factors, the plant diversity and spread across the zones. Species common to both regions (North and South) accounted for about 13% (four species) of the total species collected, representing 16% of the species collected in the south and 40% of species in the north (Figure 2). This is representative of the ecological factors prevailing within the, with the north lodged entirely within the wooded and grassland savanna and the southern region mainly of the rain forest sandwiched by the Mangrove-swamp and the marginal end of the woodland savanna.

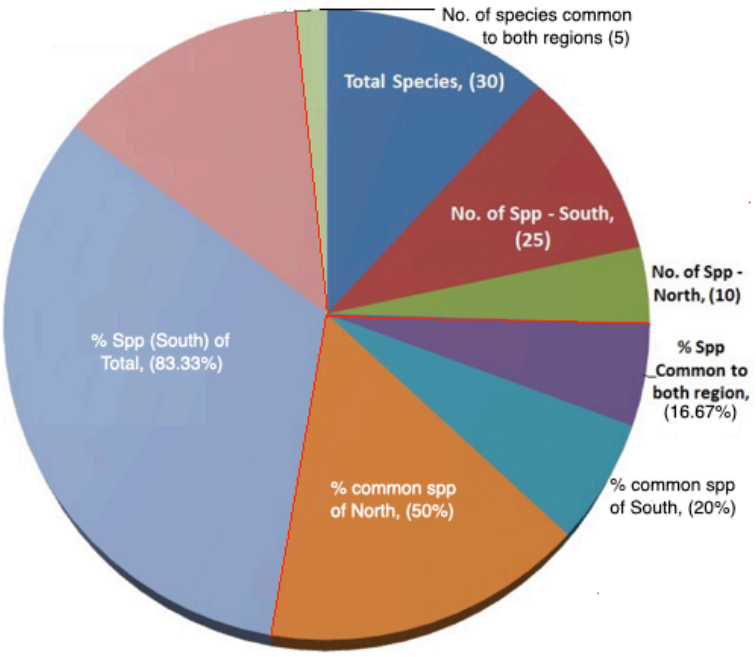

Figure 2. Species No. and percentage proportions for south, north and total collection during the survey (January – November 2017).

The cumulative Diversity index (D = 0.8) recorded for the study area indicate a high degree of diversity of the plant endemic to both regions, particularly the south. Nonetheless, significantly higher diversity (D = 0.7- 0.9) was recorded in the wetter south west and south (Table 1) mostly within the tropical rainforest zones as well as in some of the drier northern states (Bauchi, Benue, Kaduna, Plateau, Taraba, Yobe) spanning the tropical moist deciduous forest to the drier savannah land of the north east and central. The low diversity trend for recorded for the north west and some states in the south east of the study area indicates low diversity of the species collected, which can be attributed to the unfavourable ecological disposition prevalent in the north west and the changing land use system common in the south east (Table 1).

The study area is heavily imparted from various contributors and at various stages of impartation[15]. The level of anthropogenic impartation notwithstanding, the study area encompassing the Western and Central African Rainforest-Savanna eco-zones; showed a good level of diversity for the species studied. The degree of species richness portrayed by the study and the level of species evenness recorded for some of the taxa is indicative of the abundance of species that the study area still houses and the need for both the present and future investigations to continue alongside other studies; to map, document and contrive conservatory efforts that are so imperative.

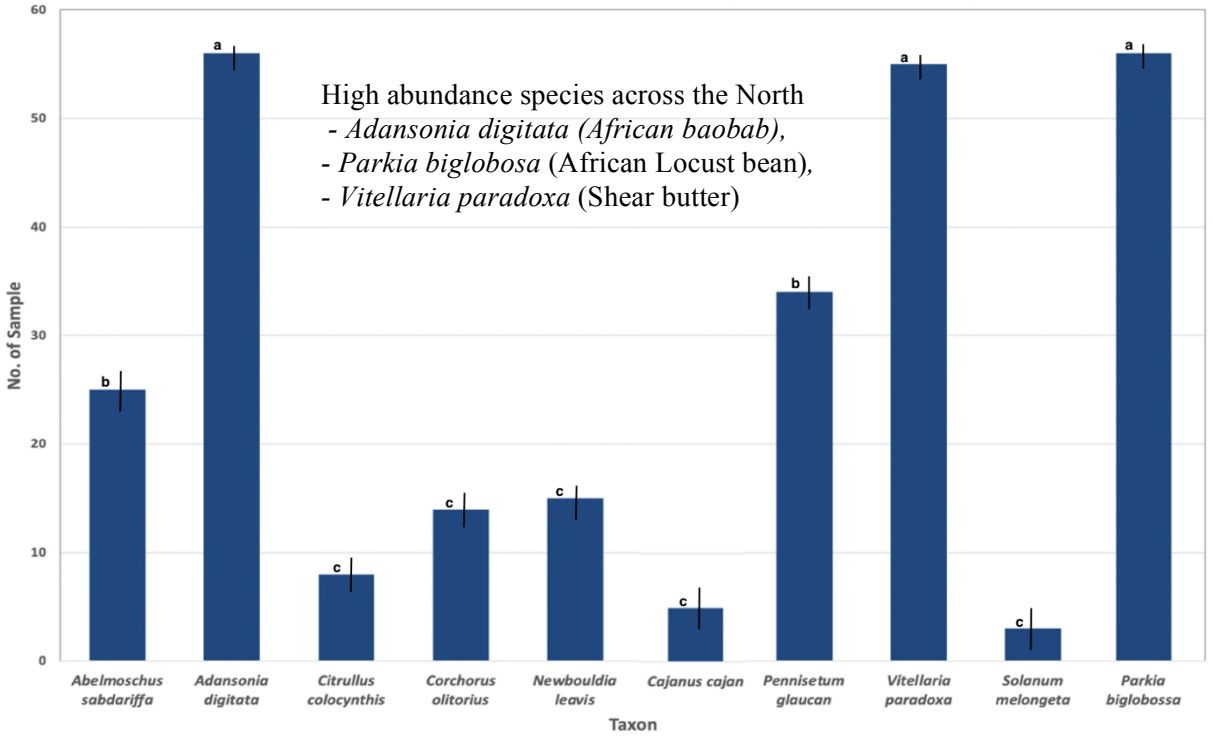

Figure 3. Plant species abundance for collection in Northern Nigeria, January –June 2017. The difference in abundance for the north is shown (a-c). Significantly higher abundance was recorded for the species; *A. digitata, P. biglobosa, V. paradoxa* in the northern region.

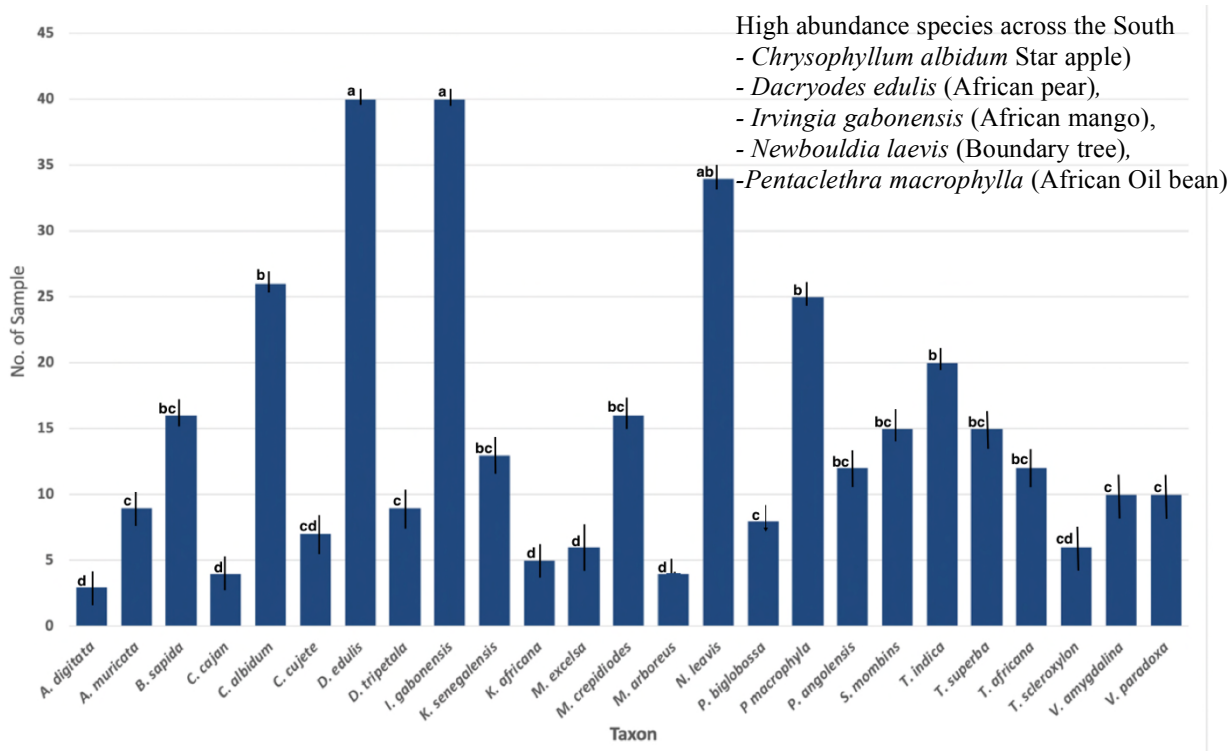

Figure 4. Plant species abundance for collection in Southern Nigeria, July- November 2017. The 5 species; *C. albidum, D. edulis, I. gabonensis*, *N. laevis, P. macrophylla* recorded significantly higher abundance for the southern region.

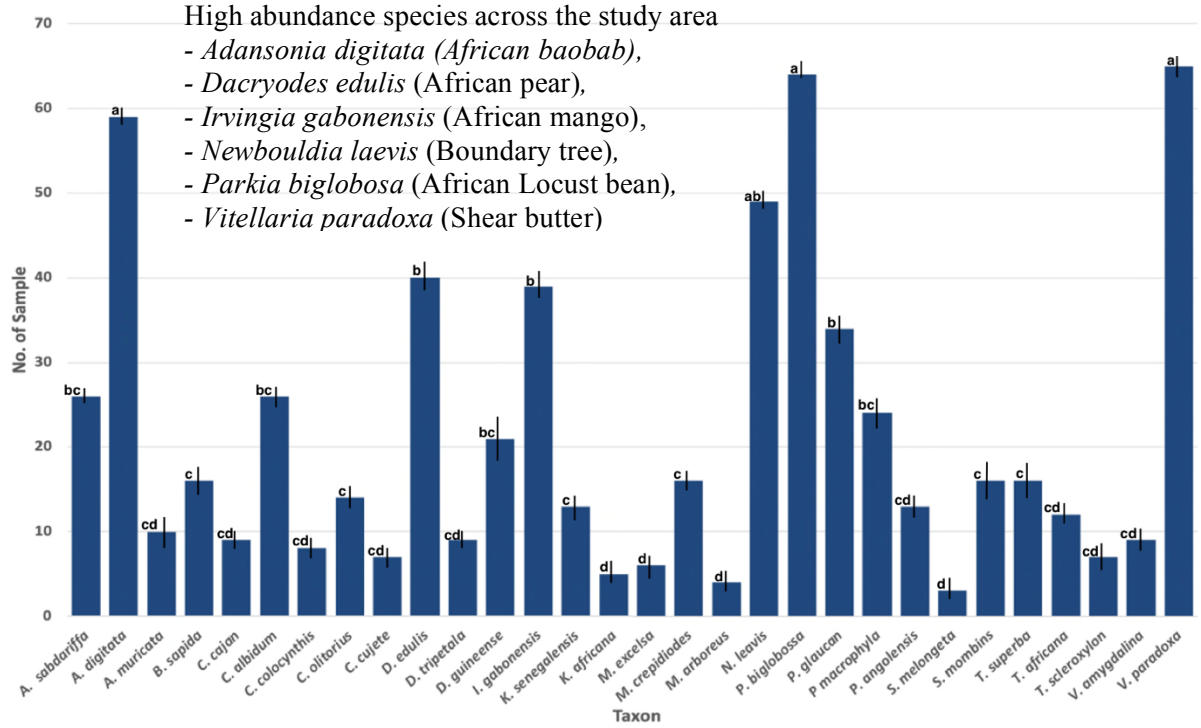

Figure 5. Species abundance for the 30 species collected in North and Southern Nigeria, July-November 2017. The 6 species; *A. digitata, D. edulis, I. gabonensis*, *N. laevis, P. biglobosa, V. paradoxa* recorded significantly higher abundance for the study area.

In the present study, 3 species; *Adansonia digitata* (African baobab), *Parkia biglobosa* (African Locust bean), and *Vitellaria paradoxa* (Shear butter) recorded significantly higher abundance in the north than others (Figure 3). Similarly, 5 species; *Chrysophyllum albidum (*Star apple), *Dacryodes edulis* (African pear), *Irvingia gabonensis* (African mango), *Newbouldia laevis* (Boundary tree), and *Pentaclethra macrophylla* (African Oil bean) recorded higher abundance than others in the south (Figure 4); and 6 species; - *Adansonia digitata (African baobab), Dacryodes edulis* (African pear), *Irvingia gabonensis* (African mango), *Newbouldia laevis* (Boundary tree), *Parkia biglobosa* (African Locust bean), *Vitellaria paradoxa* (Shear butter) cumulatively recorded higher abundance for the study area than other (Figure 5). The relative abundance of these species across the regions and the entire study area make for a strong point for more surveys of this type to garner relevant information and to pursue conservation efforts for preserve the genetic resources inherent in the study species as well as others.

The degree of species richness notwithstanding, the rate of loss of the genetic diversity of the species surveyed as well as others due to several factors amongst them massive changes in land cover use is alarming[16]. This undermine the conservation and sustainable use of these bio-resources together with their intrinsic attributes such as; low water requirements, resistance to prevailing and emerging pest and diseases and adaptation to poor quality soils[6]. These attributes have endeared them to traditional agriculture and livelihood across the various zones surveyed.

Forests, woodlands or even poorly plant populated terrains such as are common to the drier northern range of West Africa are reservoirs of biodiversity fundamental to such regions; and when managed sustainably, can play pivotal roles in sustainable land use, food and nutrition diversity and security, livelihood, poverty alleviation, economic development and the more bothersome emerging challenges of mitigation of climate change. Such efforts will among others conserve and enhance the forest and forest-dependent people's ability to adapt to the inevitable climatic and socio-economic changes and uphold the functioning and survival of biodiversity and forest ecosystems[13,14].

3.2. Awareness on Biodiversity and Cultural Diversity

There is growing awareness of the interactions between biodiversity and cultural diversity and the dependence and survival of communities on these interactions as well as the balance it offers for sustainable engagements. Increasingly, beliefs, livelihoods, cultural practices, knowledge bases, languages, norms and even institutions whether communal or national are drastically transformed or lost when either or both cultural and biological diversity are altered[17]. We lose plant diversity and the correspondent animal and ethno-sociological, cultural and belief systems that have aligned with such. Whichever, disappears first, whether the plant or the human knowledge, predisposes the other to an eventual demise; therefore, increased awareness of the need to pursue a holistic preservation and conservation of our biodiversity (especially crop) heritage at all levels is crucial.

The diversity of plant variants and wild relatives constitutes a major reservoir for novel traits required for future improvements of these crops and others, and the lack of preservation of these heritages will eventually amount to loss of plants and the inherent novel traits housed by the plants that can serve present and future needs. The vanishing of these bio-resources is linked to massive unregulated use of the landscape and the constituent biodiversity, political instability, poor or non-existent conservatory programmes, erosion of cultural heritages that drives crop management diversity preferably amongst indigenous people and local communities as well as market driven demand for only a section of the diversity of crops[9].

It was common place during the survey to find less participation of the younger generation on the conservation of the cultural knowledge that once shaped the management of biodiversity within the zones. This meant that few species were cultivated (Figure 2) and particularly, if such species did not offer the economic rewards to warrant their continued cultivation. Accompanying such dispositions, is the less attention for sustainable use and conservation which hitherto was central to communal management of land, water and biodiversity[18]. Intricately interwoven with this unsettling disposition is poverty, and this has dominated emerging perceptions which has culminated in the conflict between sustainability and survival; resulting in disruption in land ownership systems, land use patterns, communal conflicts and ultimately, erosion and loss of cultural and biodiversity[19].

The species abundance recorded from the study (Figures 3-5) and the potential it holds for reversing the poor ecological and economic conditions of the regions is clearly lost on local communities due mainly to poor or fragmented knowledge resulting from fragmentation of the erstwhile ecological continuity once known by the people. The results in tense interactions between, grazing, farming and construction interests with often unpleasant outcomes.

It is therefore important that a good degree of social and environmental awareness on the importance and conservation of biodiversity and cultural diversity commences and is sustained at various social-economic levels. These efforts must recognise the cultural knowledge that has sustainably shaped biodiversity, water and land use and the role biodiversity has played in the interactions of people and the environment. These knowledges may help to evolve an assortment of views that will promote functional interactions for mitigating climate changes and other challenges such as economic value of biodiversity, consumption and income levels; and human dynamics and demographics that leads to plant species loss[14,20]. This is because land, water and plant use and the interactions resulting from the use of these resources by people are premise upon the prevailing traditions, norms and moral values of the engaging people, because various cultures possess their own set of practices which rely on specific elements of local plants and animal for existence and survival [21,22].

3.3. Economic and Societal Situations

The survey information draws attention to the impending dire state of the society and the economic standing of the communities that depends on these species or a section of the genetic diversity. The emerging unsustainable practices threatens the food security of these communities and even the states with possible negative political, social and economic outcomes, this is because ecosystem services

provide among others information for climate regulation to forest products and thus the survival of people that depend on such forest or plant resources[19-21].

The increasing loss of arable land to other activities such as construction (homes, roads etc) as well as primitive farming, processing and storage methods will pitch as we already have, farming communities against opposing agencies/agents and exacerbate the already poor ecological and political environment conditions. The low diversity trend observed for states in the south east is evident of this observation (Table 1); where poor economic returns from crop cultivation, increase construction activities have led to land loss, environmental degradation and ultimately, biodiversity loss[23,24]. The genetic information generated by the present research provides information that may ameliorate some of these problems through such avenues as;

3.3.1. Crop improvement - To meet increased food demand (both of human and animals) with reduced time, pest and disease resistance, drought hardiness, marginal land (poor soil) tolerance, etc.

3.3.2. Plant enhancement - For contaminated environment, green urban programmes, reforestation, as well as novel products and natural products development. Ultimately the project stands to contribute tangibly to the molecular conservation of indigenous plant species of local and national importance and offer the fledging indigenous biotechnology sector, molecular resources for programmes, projects and products that are endemic species centred and so help to preserve, conserve or restore both plant and cultural heritage of communities This will draw national, regional and global attention to these plants and their resourcefulness and will bolster recognition for such plants, hitherto orphaned, abandoned and under-exploited[25,26].

3.3.3. Climate Change monitoring and management – Observing the ecological alterations across the various ecological zones of the country and the regions, highlights the effect of climatic change on the terrain and the resultant outcomes as they affect local communities[22,27].

These changes can be monitored to help manage the now undisputable incidence of climate change effects and proffer reliable solutions. This is because climate change issues can be further compounded by non-climatic factors such as population displacement, loss of livestock, damage of crops and farmlands, reduction of water, which is becoming a common occurrence particularly in the North east area of the country with a disturbing case of insurgency particularly, of the Boko Haram group[28]. The insurgency has affected farming and other human activities leading in some instances, exile of farmers, disruption of farming activities and destruction of farmland and plant species in the areas affected in addition to adversely affecting the nation's Gross Domestic Product – GDP[28,29]; The exclusion of the state of Bornu from the collection coverage is a clear evidence of the level of poor security in area. Nonetheless, from the study, the North east hold a sizeable diversity of species (Table 1, Figure 3) that can be harness to resolve some of the challenges accompanying the unrest currently prevailing in the region.

In addition, there is the growing conflicts between farmers communities and nomadic cattle herders particularly in central region of the country and this situation is escalating southward[30]. These conflicts are not only threatening lives and livelihood, they also threaten floral integrity, peace and development in the country, which are major hindrances to productive research efforts, government developmental plans and beneficial communal interactions. The current data generated could be deployed by government in such areas to overturn these unsettling situations, if employed farmers, grazers, community empowerment projects. Generating data for reliable projections at all levels and for sustainable solutions that are community-centred, plant genetic diversity preservation and conservation and sustainable use and understanding the emerging changes in eco-geographical settings, biodiversity tenacity and re-shuffling[29-31]. The data will help to re-assess our national and local development and construction projections and engagements and make adequate and sustainable arrangements.

3.4. Changing Ecological Terrain and Species Distribution

The concurrent changes in climate, disturbance regimes and management exert corresponding pressure on ecosystem structure and function at local and national levels, leading to shift in species ranges and ultimately, altering forest distribution, dynamics and forest productivity. The resultant effect is that forest management practices will change intensifying or lowering the effects in some places depending on the prevailing practices. Hence, it is crucial predicting the effects of these global change particularly on terrestrial plant communities[32].

The study outcome projects a number of issues that requires attention from governments, researchers and communities. The need to carry out studies in related areas such as Ethno-botany, Economic botany and Indigenous knowledge about the species to avoid the loss of such knowledge and environmental change studies on altering landscape is imperative and will present a holistic outlook[26]. However, these studies require broader and national outlook resulting in national inventories covering the various eco-geographical zones of the country.

Generally, species with wider spread range recorded higher abundance that other with narrower ranges (Figure 5). A number of these species such as; These include species like; *A. digitata, I. gabonensis*, *N laevis, P. biglobosa* seem to have enjoyed a normal spread through the dry rain forest to the tall and short grass savanna. Some like *V. paradoxa* and *D. edulis* seem to spread further southward and westward respectively, breaking through ecological boundaries and recording significantly higher abundance across the study area (Figure 4-5). Species like *Pentaclethra macrophylla* clearly maintained their ecological confines. Conversely, there is seemingly a reduction in the cropping of a number of variants of some species like *Cajanus cajan*. Such species were previously key members of the conglomerate of plants cropped to a considerable extent by local communities and are now losing acreage space, with significantly lower abundance recorded (Figure 3-5). Regardless of the acreage lost or gained, these underutilised crops constitute a subset of biodiversity that makes up major cropping systems among communities, contributes to dietary diversity, and offers nutritional and food security for the people, alongside other potentials to generate income and empower women[33]. The most worrisome aspect of this scenario is not that these long-time dependable crops are losing space to other plants but the increase use of land for other non-cropping activities, such as housing and related constructions buoyed by population growth.

The effects of these changes are far-reaching for local, regional and national ecological settings. The boundary breaks by some of these species, may point to a definite change in climatic and ecological dispositions that permit spread into previously uncharted territories leading to bio invasions and altered disturbance patterns for several plant species[35]. While this may offer a positive impact in that it allows the growth of such species in such new territories and thus increased acreage; it may also possess a threat to survival of local taxa, both in growth competition and usage. Where the change leading to species encroachment is primarily ecological-based, due to climate change, then plant species previously confined to such ecological settings may face elimination with a wide range of ecological and cultural ramifications tied to land-use changes orchestrated by climate change and plant redistribution.

The present study will impact areas like; biodiversity conservation, medicinal chemistry, natural product chemistry and green chemistry, green energy; environmental protection and desertification reversal, environmental pollution. Planning, budgeting, policy design and implementation regarding biodiversity, crop improvement, climate change, green jobs, cultural heritage conservation, desertification, fisheries etc., will be directly impacted by the outcome of the present work and future studies, hence the need to carry out an extensive nationwide inventories[36].

3.5. Population Growth and Unregulated Expansion

Population growth in industrialized nations is comparatively modest and relatively low with over 80% of the population living in well-structured urban settings. Conversely, developing nations are

considered to be in the mid transition stage of urban growth process, connected with extremely high urban population growth rates[37,38]. With an average national growth rate of 2.85-3.5% and an urban-rural dweller ratio of 1:1[39], the Nigerian flora diversity experiences intense pressure and abuse from human activities. These pressures are exacerbated by continued primitive land use practices in the country, poor water and related resources management, combined with the disturbing indiscriminate constructions across the country, particularly, where there is poor regulatory oversight on construction, wastes disposal and conservation of indigenous species[39]. This was clearly shown in the poor index of diversity (D = 0) recorded in the Federal Capital Territory – Abuja for the species studied (Table 1). These massive unrestraint constructions and related activates are resulting in the loss of indigenous species, while exotic species are planted as part of the re-vegetation plan; an often ill-advised, postscript effort to improve flora density following destructive practices. These unrestraint constructions, whether of dwellings, factories, roads, etc., as well as the unregulated disposal of the various forms of waste is a core threat to the survival of the country's indigenous flora diversity.

The trend is more worrisome when one grasps the degree of lack of knowledge of plants and general biodiversity exhibited by a greater part of the society, and therefore the least concern and attention these bio- resources receives under any form of consideration, whether scientific, governmental, or advocacy.

3.6. Poor Infrastructure and Security

Ecological terrain and poor roads were major challenges. Discontinuity in road network, communication cost and other utilities particularly where the economy is ran based on the market swivel of a single export product – crude oil. The most debilitating of all challenges is the non-existence of information on the vegetation and land use system in the public system; offices, universities, or even the information highway – the internet. Where any exist at all, they are often poorly managed or updated[40].

Direct and indirect consequences of destructive forest use practices resulting from political volatility across the landscape, both by insurgences and counter insurgency measures[41]; fallout from years of poor management of resources combined with a high sense of insecurity, general poor economic state of the nation and poor political leadership has increased the level of tension across the regions and ecological zones and these have directed attention away from progressive scientific works required to achieve the level of success for such national conservatory of knowledge.

3.7. Prospects

As far back as 1996, the *World Food Summit,* of the Food and Agriculture Organization[42] stated that:

> *"the problems of hunger and food insecurity have global dimensions and are likely to persist, and even increase dramatically in some regions, unless urgent, determined and concerted action is taken, given the anticipated increase in the world's population and the stress on natural resources"*

This assertion notwithstanding, Nigeria has yet to generate a concise information database on national biological and cultural diversity or conditions that affect such heritages. The present study highlights the urgent need to drive intense collaborated efforts across local, national and the West – Central African region to produce a robust data (resource) base for plant genetic diversity and land-use to meet the set objectives of generating relevant data that targets globally relevant and far-reaching researches on versatile Africa plant species[40, 42-43]. This will instigate improvements efforts for sustainable developments as they relate to the issues of climate changes, livelihood, economy, food and nutrition security and conservation of these species.

Desert encroachment, deforestation, poor farming practices, conflict and insecurity will exacerbate the increasing threat to plant diversity and in particular the plant species of target in the present survey. Funding and developmental efforts to promote global researches on these plant species, will hopefully constitute a reliable path to evolving regional hub for globally relevant activities through the commencement of a number of national studies to cover the myriads of areas and subjects.

4. Conclusion

The study area houses a sizeable level of plant diversity as shown by the high level of diversity (D = 8) recorded for the 30 species collected. The South West, South, North East and Central regions recorded high level of diversity (D = 0.7 - 0.9) for the species studied. The North West and some states of the South East regions recorded low diversity levels (D = 0.0 – 0.5) due to prevailing climatic conditions (North West) and significant changes in land cover use (South East and the FCT). Six species recorded a considerable spread across the various eco-geographical zones of the study area and can make for good candidates for developmental projects and should be of interest to national and regional, researchers, policy makers and leaders.

The current survey and several of such at various levels in the nearest future albeit; morphological, molecular, nutritional, ethno-botanical and environmental, etc and the resulting scientific information generated from such works represent a major route to the real-time evaluation of challenges regarding loss of cultural diversity, biodiversity. These are the only pragmatic solutions to mitigating the prevailing and emerging consequences of climate change in Nigeria and Africa.

Conflict of Interest: The authors have declared that no financial of otherwise conflicting interests exist for this article.

Acknowledgements: The various individuals, government officials, community heads, farmers, women, interpreters, guides, community liaison persons, security agents and several others that contributed immensely to the success of these trips. The management of Covenant University for the research grant for this work (**CUCRID RG 016.12.14/FS**), and the Biodiversity and Environmental Studies for Sustainable Development (BESSD) Research group of the Biotechnology Cluster.

References

[1]. FAO, IFAD and WFP. 2013. The State of Food Insecurity in the World 2013. The multiple dimensions of food security. Rome, FAO. 56 pages. E-ISBN 978-92-5-107917-1. http://www.fao.org/3/a-i3434e.pdf

[2]. Corlett, R.T. 2016. Plant diversity in a changing world: Status, trends, and conservation needs. *Plant Diversity*, 38 (1): 10-16. https://doi.org/10.1016/j.pld.2016.01.001

[3]. UNCTAD 2017. The Role of Science, Technology and Innovation in Ensuring Food Security By 2030. New York and Geneva, 47p. https://unctad.org/en/PublicationsLibrary/dtlstict2017d5_en.pdf

[4]. Padulosi, S., Thompson, J. and Rudebjer, P. 2013. Fighting poverty, hunger and malnutrition with neglected and underutilized species (NUS): Needs, challenges and the way forward. Bioversity International, Rome. 56p. www.bioversityinternational.org

[5]. Fawzi, M.M. 2013. Traditional Medicines in Africa: An Appraisal of Ten Potent African Medicinal Plants. *Evidence-Based Complementary and Alternative Medicine* 2013, Article ID

617459, 14 pages. http://dx.doi.org/10.1155/2013/617459.

[6]. Meldrum, G., Padulosi, S., Lochetti, G., Robitaille, R. and Diulgheroff, S. 2018. Issues and Prospects for the Sustainable Use and Conservation of Cultivated Vegetable Diversity for More Nutrition-Sensitive Agriculture. *Agriculture*, 8(7): 112. https://doi.org/10.3390/agriculture8070112

[7]. Williams, J.T. and Haq, N. 2000. Global Research on Underutilised Crops An Assessment Of Current Activities And Proposals For Enhanced Cooperation. International Centre for Underutilised Crops, Southampton, UK 50p. http://www.fao.org/docs/eims/upload/216780/uoc_assessment_current_activities.pdf

[8]. McCandless, E. and Karbo, T. 2011. Peace, Conflict, And Development In Africa: A Reader.University for Peace, Switzerland, 573p. ISBN: 978-9977-925-58-5. http://www.africa-upeace.org/images/pdfs/Publications/Peace%20and%20conflict%20development%20in%20Africa%20A%20reader.pdf

[9]. Omonhinmin, A.C. and Idu, M. 2012. Genetic diversity, domestication and conservation Implications of fruit morphometric data analyses for *Dacryodes edulis* in southern Nigeria. *Journal of Plant Development Sciences*, 4(2): 167-173. https://pdfs.semanticscholar.org/d3dc/a5f3b80c551eccb4dad336d3709545f55076.pdf

[10]. Sasson, A. 2012. Food security for Africa: an urgent global challenge. *Agriculture & Food Security*, 1:2. doi: 10.1186/2048-7010-1-2.

[11]. UNESCO, 2005. UNESCO World Report: Towards Knowledge Societies. UNESCO Publishing. 220 pages. ISBN 92-3-204000-X. http://unesdoc.unesco.org/images/0014/001418/141843e.pdf.

[12]. Daly, A.J. Baetens, J.M., and De Baets, B. 2018. Ecological Diversity: Measuring the Unmeasurable, *Mathematics* 2018, 6, 119; doi:10.3390/math6070119 www.mdpi.com/journal/mathematics

[13]. FAO, 2010. FAO, working with countries to tackle climate change through sustainable forest management: Managing forests for climate change. Food and Agriculture Organization, 20p. www.fao.org/forestry

[14]. UNESCO, 2010. UNESCO Biodiversity Initiative. Natural Sciences Sector, UNESCO, Paris cedex 15. 11p. http://www.unesco.org/new/biodiversity-initiative

[15]. WWF 2019. Terrestrial ecoregions: Tropical and subtropical moist broadleaf forests. https://www.worldwildlife.org/ecoregions/at0123. Accessed 27 March, 2019.

[16]. CILSS, 2016. Landscapes of West Africa – A Window on a Changing World. U.S. Geological Survey EROS, 47914 252nd St, Garreston, SD 57030, UNITED STATES. https://eros.usgs.gov/westafrica/; doi: 10.5066/F7N014QZ

[17]. Pretty, J., Adams, B., Berkes, F., de Athayde, S.F., Dudley, N., Hunn, E., Maffi, L., Milton, K., Rapport, D., Robbins, P., Sterling, E., Stolton, S., Tsing, A., Vintinner, E., and Pilgrim, S. 2009. The Intersections of Biological Diversity and Cultural Diversity: Towards Integration.

Conservation and Society, 7(2): 100-112. doi: 10.4103/0972-4923.58642.

[18]. Carabine, E., Venton, C.C., Tanner, T. and Bahadur, A. 2015. The contribution of ecosystem services to human resilience - A rapid review. Shaping policy for development. London: ODI. 44p. www.odi.org

[19]. EFTEC 2005. The Economic, Social and Ecological Value of Ecosystem Services: A Literature Review. London, https://www.cbd.int/financial/values/unitedkingdom-valueliterature.pdf

[20]. Bahadur, A.V., Ibrahim, M. and Tanner, T. 2010. The resilience renaissance? Unpacking of resilience for tackling climate change and disasters, SCR Discussion Paper 1. (2010) : 45p. [SCR Discussion Paper 1]. https://www.gov.uk/dfid-research-outputs/the-resilience-renaissance-unpacking-of-resilience-for-tackling-climate-change-and-disasters-scr-discussion-paper-1.

[21]. Jenkins, M. and Schaap, B. 2018. Background Analytical Study: Forest Ecosystem Services. United Nations Forum on Forests/Global Forests Goals. 41p. https://www.un.org/esa/forests/wpcontent/uploads/2018/05/UNFF13_BkgdStudy_ForestsEcoServices.pdf

[22]. Ojwang, G.O., Agatsiva, A. and Situma, C. 2010. Analysis of Climate Change and Variability Risks in the Smallholder Sector: Case studies of the Laikipia and Narok Districts representing major agro-ecological zones in Kenya. Environment [climate change] bioenergy monitoring and assessment- environment and natural resources management working paper 41. 71p. http://www.fao.org/3/i1785e/i1785e00.pdf

[23]. El-Hefnawi, A.I.K., 2002. Protecting agricultural land from urbanization or managing the conflict between informal urban growths while meeting the demands of the communities Lessons Learnt from the Egyptian Policy Reforms; World Bank Urban Research Symposium: Brazil, 2005. Available online: https://pdfs.semanticscholar.org/0ae6/2e12ee59fc06d649d08c55c25c659004a38c.pdf (accessed on 15 July 2019).

[24]. Thuo, A.D.M. 2013. Exploring Land Development Dynamics in Rural-Urban Fringes: A Reflection on Why Agriculture is Being Squeezed Out by Urban Land Uses in the Nairobi Rural–Urban Fringe? *International Journal of Rural Management,* 9(2) 105-134. https://doi.org/10.1177/0973005213499088

[25]. Frankel, O. H. and Soulé, M. E. 1981. Conservation and Evolution. Cambridge University Press, 327p. doi: https://doi.org/10.1017/S0030605300017853.

[26]. Poudel, R.C., Mo¨ller, M., Gao, L.M., Ahrends, A., Baral, S.R., Liu, L., Thomas, P., Li1, D. 2012. Using Morphological, Molecular and Climatic Data to Delimitate Yews along the Hindu Kush-Himalaya and Adjacent Regions. *PLoS ONE*, 7(10): e46873. doi:10.1371/journal.pone.0046873.

[27]. FAO, 2007. Adaptation to climate change in agriculture, forestry and fisheries: Perspective, framework and priorities. Interdepartmental Working Group on Climate Change. Food and Agriculture Organization of the United Nations, Rome. 32p. http://www.fao.org/3/a-au030e.pdf.

[28]. Adebisi, S.A., Azeez, O.O. and Oyedeji, R. 2017. Appraising the Effect of Boko Haram Insurgency on the Agricultural Sector of Nigerian Business Environment. *Journal of Law and Governance*, 11 (1):14-25. doi: 10.15209/jbsge.v11i1.999.

[29]. Babagana, M., Ismail, M., Mohammed, B. G., Dilala, M. A., Hussaini, I. and Zangoma, I M. 2018. Impacts of Boko Haram Insurgency on Agricultural Activities in Gujba Local Government Area, Yobe State, Nigeria. *International Journal of Contemporary Research and Review*, 9 (12): 20268-20282. https://doi.org/10.15520/ijcrr.v9i12.631

[30]. ICG, 2017. Herders against Farmers: Nigeria's Expanding Deadly Conflict. Africa Report N°252. Brussels, brussels@crisisgroup.org.

[31]. Govindaraj, M., Vetriventhan, M., and Srinivasan, M. 2015. Importance of Genetic Diversity Assessment in Crop Plants and Its Recent Advances: An Overview of Its Analytical Perspectives. *Genetics Research International,* Article ID 431487, 14 pages. http://dx.doi.org/10.1155/2015/431487.

[32]. Lenoir, J. and Svenning, J.C. 2015. Climate-related range shifts: A global multidimensional synthesis and new research directions. *Ecography*, 38(1):15–28. https://doi.org/10.1111/ecog.00967

[33]. Mabhaudhi, T., O'Reilly, P., Walker, S. and Mwale, S. 2016. Opportunities for Underutilised Crops in Southern Africa's Post–2015 Development Agenda. *Sustainability*, 8: 302; doi:10.3390/su8040302.

[34]. Franklin, J., Josep M. Serra-Diaza, Alexandra D. Syphardc, and Helen M. Regand. 2016. Global change and terrestrial plant community dynamics. *PNAS*, 113(14): 3725–3734. www.pnas.org/cgi/doi/10.1073/pnas.1519911113.

[35]. Parrotta, J., Yeo-Chang, Y., and Camacho, L.D. 2016 Traditional knowledge for sustainable forest management and provision of ecosystem services. *International Journal of Biodiversity Science, Ecosystem Services & Management,* 12(1-2): 1-4; https://doi.org/10.1080/21513732.2016.1169580.

[36]. UNFPA, 2007. State of World Population 2007: Unleashing the Potential of Urban Growth. 108p. UNFPA, ISBN 978-0-89714-807-8. https://www.unfpa.org/publications/state-world-population-2007

[37]. Bhatta, B. 2010. Analysis of Urban Growth and Sprawl from Remote Sensing Data. Advances in Geographic Information Science. Earth Sciences, Springer, 172p. ISBN 978-3-642-26287-6. https://www.springer.com/gp/book/9783642052989

[38]. NPC, 2017. Nigeria's population now 182 million. National Population Commission (NPC). http://www.population.gov.ng/ (Accessed 19/07/2019).

[39]. NBSAP, 2015. Nigeria Fifth National Biodiversity Report - December 2015. 75p. https://www.cbd.int/doc/world/ng/ng-nr-05-en.pdf

[40]. Alvarez, M. D. 2003. "Forests in the time of violence: conservation implications of the Colombian war." *Journal of Sustainable Forestry*, 16(3/4): 47-68. https://doi.org/10.1300/J091v16n03_03

[41]. FAO, 1996. The World Food Summit FAO, Rome, 13 - 17 November 1996. http://www.fao.org/3/w3548e/w3548e00.htm

[42]. DEVCO, 2015a. Larger Than Elephants - Inputs for an EU strategic approach to wildlife conservation in Africa – Regional Analysis – Central Africa. 281- 389pp. European Union Directorate-General for International Cooperation and Development. https://europa.eu/capacity4dev/b4life/document/larger-elephants-regional-analysis-section-03-central-africa.

[43]. DEVCO, 2015b. Larger Than Elephants - Inputs for an EU strategic approach to wildlife conservation in Africa – Regional Analysis – West Africa. 196- 277pp. European Union Directorate-General for International Cooperation and Development. https://europa.eu/capacity4dev/b4life/document/larger-elephants-regional-analysis-section-04-west-africa.