Uncontrolled Bush Burning in the Niger Delta Region of Nigeria: Potential Causes and Impacts on Biodiversity

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Abstract The Niger Delta region of Nigeria is one of the largest wetland and biodiversity hotspots in Africa that inhabit several endemic species. Biodiversity including plants, animals and microbes have several economic importance to human and its ecosystem. Of recent, the intensity of bush burning in the Niger Delta has increased. Bush burning is among the leading cause of decline in composition and abundance of biodiversity. This study evaluated the potential causes of bush burning, impacts on biodiversity and possible options for mitigation in the Niger Delta region of Nigeria. The study found that quest for bush meat (i.e. major source of animal protein), burning of solid wastes, precarious discharge of cigarette remains and deliberate uncontrolled in-situ burning by farmers as the leading cause of bush burning. Bush burning portends adverse effects like; habitat fragmentation, destruction of medicinal plant, extinction of species in the wild, loss of food sources, loss of raw material that can be useful for several art work, wood fuel, construction and shelter materials, and disruption of ecological processes including biogeochemical cycling. The paper concludes by suggesting pasture management, waste management, sensitization, enactment and implementation of bush burning laws and specifying punishment for offenders, and introduction of biodiversity conservation techniques in school curriculum as potential option for mitigation.

Keywords Ecology; Environment; Niger Delta; Wetland

Background
In recent times, the severity of environmental degradation has increased (Ogamba et al., 2016), leading to challenges in the sustainability of the ecosystem including its living (biotic) and non-living (abiotic) component (Ohimain et al., 2014a; Izah and Angaye, 2015; Izah et al., 2015, 2016, 2017a, b). The degradation of the environment have gained alarming status possibly due to change in climatic conditions, emission of greenhouse gases and increased atmospheric temperature (Ohimain et al., 2014a). Environmental challenges which are caused by natural effects (windstorms, land degradation, drought and high temperature, rainfall and flood) and to large extent by anthropogenic effects (such as deforestation, application of chemical fertilizers, bush burning, fuel wood extraction, logging, urbanization/industrialization, climate change) have long term impacts (including shortage of medicinal plant, poverty, hunger, environmental degradation, climate change, sickness, diseases and loss of biodiversity) (Unanaonwi and Amonum, 2014). Majority of the adverse impacts of environmental degradation in the ecosystem is due to population increase, industrialization, urbanization and intensive agriculture (Hamid et al., 2010; Ibimilua, 2013), uncontrolled mechanization, primitive agricultural practices, over exploitation of natural resources, deforestation, over grazing, land fragmentation and extensive use of chemical fertilizers and pesticides (Ibimilua, 2013).

The release of emissions or pollutants into the environment through the activities of human depends mostly on the production/manufacturing activities that are being carried out in such area. Also, some activities of man could infringe on biodiversity and further trigger natural disasters (Izah and Angaye, 2015). Some of these natural effects include flooding, tropical cyclones, earthquakes, drought, precipitation etc (Kolawole et al., 2011). Ibimilua (2013) reported that drought, avalanche, tsunami, volcanic eruption, land slide, earthquake, hurricane and storm are environmental hazards that could lead to loss of biodiversity.
Nigeria has a land mass of 923,768 km\(^2\) which is near 1 million km\(^2\). The Nigeria ecosystem is unique and rich (Meduna et al., 2009). Nigeria is blessed with water resources including freshwater (river, creek, creeklets, ponds, lakes and streams), brackish water/estuarine (fresh and salt water interface) and marine/salt water (Agedah et al., 2015; Izah and Srivastav, 2015; Izah and Angaye, 2016; Ben-Edo et al., 2017a-b; Seiyaboh and Izah, 2017a-c). Nigeria has a wetland which cover 2.6 – 3.0% of the entire land mass (Uluocha and Okeke, 2004; Nwankwoala, 2012). The water resource of Nigeria inhabits several aquatic organisms depending on the type of water body. Some of these organisms include fisheries (fin and shelled fish), some aquatic mammals, reptiles etc (Izah and Srivastav, 2015). Though some of the aquatic organisms especially mammals are either endangered or extinct based on local conservation status in the Niger Delta. Some of these animals include *Trichechus senegalensis*, *Hippopotamus amphibious* and *Lutra maculicollis* (Seiyaboh and Izah, 2017b).

The soil is a distinctive habitat for biodiversity because it either provides the habitat itself or platform in which the habitat is built upon. Typically, biodiversity comprises of all life (plants, animals and microorganisms) forms on earth including genes, individual species, genetic diversity within the species and ecosystem (Meduna et al., 2009; Ibimilua, 2013). Therefore, the tendency to produce food resources, discover new medicine mainly dependent on the bioavailability of the ecosystem. However, due to uncontrolled bush burning, the biodiversity resources which are essential resource for the welfare of mankind are under threat. Generally, bush burning alongside excessive wildlife poaching, urbanization possess a treat to the biodiversity of the Niger Delta.

The Niger Delta region has been severally referred to as biodiversity hotspot with several local and international overwinter species (Ogbe, 2011). The conservation of biodiversity in African parks and protected area are threatened due to their exploitation as bush meat, which are apparently supported by several factors including poor wildlife management, unsustainable hunting practices, logging activities, rural livelihood challenges and construction works (Enuoh and Bisong, 2014).

Typically, Nigeria has two distinctive seasons being dry and raining (wet). Wet season start from April to October and optimum rainfall is usually achieved between June-July. The dry season period is often known as the harmattan period which stretches from November to March of the following year. During dry season (characterized by low relative humidity), the vegetation becomes dry and dusty making it vulnerable to fire outbreak (Jamal et al., 2012).

According to Ambe et al. (2015), bush burning is the unsystematic setting ablaze of the vegetation cover of grassland and forest resources by fire. Bush burning produces emissions such as carbon monoxide, hydrocarbons, hydrogen sulphide, oxides of nitrogen, sulphur, ozone and particulate matters including dust, fumes, mist and smoke (Hamid et al., 2010; Jamal et al., 2012). Smoke is a mixture of complex chemicals and the type of emission is dependent on the type of vegetation being combusted, burning temperature, wind speed and direction (Hamid et al., 2010). Smoke resulting from burning of biomass has wide range of impact on human health including eye and respiratory tract irritation such as breathing difficulty, bronchitis intensified severity of asthma, cancer and premature death (Hamid et al., 2010). According to Hamid et al. (2010), healthy people that are exposed to smoke often recover fast but individuals with cases of cardiovascular and respiratory dysfunction such as asthma, elderly and children could have their situation aggravated.

The two types of bush burning are controlled and wildfire (Jamal et al., 2012). Prescribed or controlled bush burning is the intentional use of fire for management purposes (Hamid et al., 2010). But wild fire is often uncontrolled, causing damage to the ecosystem including its biotic component. Fires have several uses including reduction of wildlife by clearing out inflammable vegetation covers (Hamid et al., 2010).

Depending on the type of fire, they have adverse impact on the environment as well as its biotic components including humans (Hamid et al., 2010). Jamal et al. (2012) simply said that bush burning causes severe catastrophes in many areas such as constituting public nuisance. Bush burning causes soil destruction, desert encroachment and contribute to global warming through the release of emissions which have impact on the ozone layer (Hamid et al., 2010; Jamal et al., 2012).
Bush burning appears to be traditional farming practices of the people with cultural values associated to it in third world nations (Hamid et al., 2010; Unanaonwi and Amonum, 2014). Typically, fire is an important tool for natural vegetation, agriculture, including livestock production, hunting and in other land use systems management (Nigeria Fifth National Biodiversity Report, 2015). Sanyaolu (2015) reported that bush burning have been in practice in several parts of the world and it has been a vital part of traditional agriculture. But in recent times its impact is becoming disastrous in the ecosystem. Hence, this study aimed at assessing the causes and impacts of uncontrolled bush burning in the Niger Delta. The findings of this study could be useful to government agencies, environmentalists and wetland experts.

1 Niger Delta Wetland

The Niger Delta region of Nigeria, which is approximately 70,000 km² has the largest wetland region in Africa (Ogbe, 2011; Ohimain, 2012). The Niger Delta member state include Ondo, Edo, Delta, Bayelsa, Rivers, Imo, Rivers, Abia, Akwa-Ibom and Cross Rivers (Figure 1). The Niger Delta region has distinct ecosystem including barrier islands, estuarine, mangroves, freshwater swamp, lowland rainforest and creeks (Ajao and Anurigwo, 2002; Ogbe, 2011). Typically, wetland are areas with fern, marsh peatland/water with static or flowing surface water (fresh or marine or brackish) which can either be natural or artificial, temporary or permanent with depth of ≤6 meters at low tide (Scott, 1989; Ohimain and Akinnibosun, 2007). Wetland is home of several macrophytes which are adapted to live in anoxic environment (Ohimain and Akinnibosun, 2007). The Niger Delta wetland region has the largest mangrove in Africa and third largest wetland in the world (Spalding et al., 1997; Nwankwoala, 2012; Ohimain, 2012) and it occupies over 50% of the Nigerian coastline lines (Ohimain, 2003).

Wetlands naturally have the ability to break down and assimilate pollutants (Kadafa, 2012a). Globally, wetland plays several roles including social, economic and ecological. Ohimain and Akinnibosun (2007) noted that wetland have become important due to sea rise emanating from climate change. But due to anthropogenic and biogeophysical effects such as population growth pressure, urbanization, pollution resulting from industrialization, mining, oil and gas activities, unrestrained tilling of soil for crop production, over-grazing, logging/lumbering, unmatched land reclamation, dam construction, physical infrastructure, erosion, sea rising, alien invasion, sand storm, desertification, droughts etc., the important roles (such as ecological, economic, socio-cultural, scientific and recreational) played by the wetlands are under threats (Uluocha and Okeke, 2004; Nwankwoala, 2012).
The Niger Delta wetland ecosystem produces a lot of resources that drive the Nigerian economy. Ohimain et al. (2008) reported that the region is the most prolific oil and gas province along the coast of West Africa. The Niger Delta is home to several biodiversity (Iniaghe et al., 2013). The Niger Delta wetland is blessed with several resources including timber, and non-timber products, snails, breeding and nestling ground for migratory birds, spawning ground for fisheries, plants with insecticidal and antimicrobial properties (Ohimain, 2009). Hence the Niger Delta wetland is regarded as biodiversity hotspots due to the abundant presence of biodiversity including endemic species of plants, mammals, birds, reptiles, amphibians found there, with some been endemic in the region (Ohimain, 2009).

The interaction of hydrology, vegetation and soil leads to the development of unique wetland (Ohimain and Akinnibosun, 2010). Due to urbanization and industrialization, the wetland is being destroyed (Ohimain and Akinnibosun, 2010). But these characteristics are being destroyed through several anthropogenic activities such as uncontrolled bush burning. This could be due to the perception of wetland being wasteland in Nigeria and as such being freely destroyed for developmental projects (Ohimain, 2009).

2 Potential Causes of Uncontrolled Bush Burning

Biodiversity is known to play an essential role in the social, aesthetic, psychological, ecological, medicinal, ecotourism, economic, cultural and political aspects of any country (Ibimilua, 2013; Ibimilua and Ibimilua, 2014). Unfortunately, they are currently under pressure resulting from human activities such as logging, grazing, clearance for housing construction and agriculture and illegal marketing of biodiversity resources and bush burning (Ibimilua, 2013). Uncontrolled bush fire in dry season spreads across long distances and sometimes only brought to an end by natural barriers like wide roads, rivers, creeks, creeklets, ponds and streams. Over 50% of bush burning incidence in Nigeria is caused by deliberate act, which have led to the loss of millions of Naira on annual basis (Jamala et al., 2012). Typically, In Nigeria bush burning are caused by several factors including quest for bush meat and elimination of dried vegetation for easy use of herbicides (direct cause), burning of solid wastes, unsustainable discharge of cigarette remains and inadequate demarcation of forest from cleared/brushed area for agricultural purposes (indirect) and oil spill and quest for fresh grazing area (rare).

2.1 Burning of solid wastes

Sustainable solid wastes management is a major threat to sustainable development especially in developing nations. Abah and Ohimain (2010) stated that solid wastes management is a major intractable environmental issue in Nigeria, which often result in the form of piles of indiscriminately disposed heaps of uncovered waste and illegal dumpsites in different locations including highways, street corners in urban areas. Various waste streams disposed in such manner include anthropogenic wastes (i.e. hospital, agricultural, market, workshop and food processing wastes) (Angaye et al., 2015). These wastes are evacuated by state sanitation agencies unto open dumpsites approved by government. But due to urbanization and population growth, the quantity of wastes generated has increased over the years. According to Abah and Ohimain (2010), open dumps causes environmental degradation and public health concern. This is because wastes often contain mixture of hazardous/toxic (radioactive, infectious) and non-hazardous materials and are susceptible to burning (Abah and Ohimain, 2010) especially during the harmattan period. The burning of wastes typically releases pollutant gases into the environment thereby having adverse impacts on the ecosystem.

Recently, it was observed in some Niger Delta states that, the intensity of solid wastes insitu burning increased during the dry season. This typically led to bush burning in the surrounding ecosystem. Due to the nature of the wastes, it often comes with thick gaseous emissions (Figure 2) with noticeable impacts on human within the vicinity of the burning. Such burning could impact on the biodiversity of the dumpsite including microorganisms that causes degradation of the degradable organic constituents of wastes; In addition, rats and insects which feed on these wastes and most importantly plants growing within the vicinity of the dumpsite become adversely impacted.
2.2 Unsustainable discharge of remains of cigarette

Unsustainable discharge of remains of cigar/cigarette could cause bush burning especially in the rural areas, where cigarette remains is highly discharged in an unsafe manner (Nigeria Fifth National Biodiversity Report, 2015). According to Ambe et al. (2015), some bush fires have been traced to careless smokers. A traveler or tourist smoking cigarette may drop remains along the high way, and when it falls in contact with dried vegetation it could lead to uncontrolled bush burning. This could also impact on the biodiversity of the area.

Figure 2 Open combustion of solid wastes in the Niger Delta region of Nigeria

2.3 Inadequate demarcation of forest from cleared/brushed area for agricultural purposes

Nigeria used to be an agrarian economy before oil boom in late 1960s, however, Nigeria abandoned this in its quest for crude oil exploitation. With plunging crude oil price, the country is making intense effort to revive and boost the agricultural sector which the country once abandoned. However, during land preparation for farming, the forest is cleared prior to burning. But the inadequate demarcation of forest zones from cleared area meant for agricultural purposes is another indirect cause of bush burning. Bush fire resulting from inadequate demarcation is usually severe and poses adverse impact on nearby biodiversity especially vegetation. In areas where shifting cultivation is practiced within close vicinity there could be adverse impact on the un-harvested crop such as yam, cassava etc, of the neighboring farmland. Evidence exists of instances where inappropriate demarcation has led to the burning of yam barns and cassava plantations within rural areas.

2.4 Fire resulting from oil spills

The Niger Delta region is the major oil and gas province of Nigeria. According to Ohimain (2011), the Delta contains abundant oil and gas resources, which account for about 90% of Nigeria’s earning. Crude oil contains several fuel fractions or distillates including jet, diesel and heating oil, gasoline, gas oil and other residues. In the oil and gas industry, oil spill occurs during several activities including exploration, transportation (vehicular and pipeline), refining, distribution and sales, illegal bunkering and sabotage. According to UNEP (2011), the major causes of oil spills in the Niger Delta include vandalism, oil blowouts from the well head, accidental and thoughtful releases. About 1.5 million tons of oil has been spilled into the Niger Delta ecosystem and some have been partially cleaned while rendering some areas wastelands (Kadafa, 2012b).
The volatility of crude oil distillates could lead to fire when in contact with sources of fire. Nigeria generally has five major crude oil depots and pump stations including Port Harcourt, Warri (Niger Delta), Mosimi, Kaduna and Gombe (NNPC, 2012). The office area are in charge of Okrika jetty, Bonny export terminal, Markudi, Calabar, Port Harcourt, Aba, Enugu depots (Port Harcourt area), Warri jetty and depot, Benin depot, Abuad, Auchi Lokoja Pump Stations and Escravos Terminal (Warri), Atlas Cove jetty and depot, Mosimi, Satellite (Ejigbo Lagos), Ibadan, Ore and Ilorin depots (Mosimi area), Kaduna, Minna, Suleja, Kano, Gusau depots and Abaji, Izom, Sarkin, Pawa, Zaria pump station (Kaduna area), Jos, Gombe, Yola, Maiduguri depots and Biu pump station (Gombe area) (NNPC, 2016).

According to the Department of Petroleum Resources, In Nigeria, about 4647 oil spill incidence has occurred leading to loss of about 2,369,470 barrels of oil into the environment, with 77% and 23.17% being lost to the environment and recovered between 1976 and 1996 respectively (Nwilo and Badejo, 2005; Kadafa, 2012b). Between this period, about 6% of the oil spills were on land, while 25% and 69% occurred in swamp and offshore environments respectively (Nwilo and Badejo, 2005). Similarly, between 1997 and 2001, about 2,097 oil spill incidents occurred in Nigeria. Between 2006–2010, about 3,203 cases of oil spillage occurred, of which 23% were attributed to equipment failure, operational/maintenance error and corrosion, while 45% was ascribed to sabotage/vandalism (Borok et al., 2013). Also, NNPC (2012) reported that crude oil spill is mostly caused by vandalism and to lesser extent rupture. According to Iniaghe et al. (2013), Nwilo and Badejo (2005), about 50%, 28%, 21% and 1% of oil spills are due to corrosion, sabotage, oil production and mechanical problems (including failure of engineering drills and machines, inability to effectively control oil well, and inadequate care in loading and unloading of oil vessels) respectively. Similarly, Adelana et al. (2011) reported that corrosion of pipelines and tankers, sabotage and oil production operations accounts for 50%, 36% and 6.5% oil spill incidence in Nigeria.

Fire resulting from oil spill incidence is usually severe and it could lead to loss of infrastructures and biodiversity. Ambe et al. (2015) reported that forest wildfires on oil and gas facilities could be devastating and cause innumerable hardship to victims. For instance, in 1999 Jesse community of Delta State (Ambe et al., 2015), Nembe/Brass in Bayelsa state and several others in the Niger Delta region, experienced the loss of lives due to fires from spill. In extension, Nigeria’s oil line explosion killed over 200 people in Lagos state (Adelana et al., 2011).

2.5 Nomadic farming
According to Ambe et al. (2015) nomad is the simplest method of clearing garbage so as to allow for early sprouting of fodder for the animals, which the hunters say, is an approach for hunting. In a study by Tunde and Adeleke (2013), the authors showed that bush burning is mainly associated with agricultural purposes, accounting for about 80%, while other activities such as hunting and intruders (cattle rearers) account for about 8%, and 4% respectively of total bush burning in Asa Local Government Area of Kwara state, Nigeria. Similarly, in Delta state, Otuoku and Isife (2009) identified indiscriminate bush burning as the major cause of conflict between nomadic herders and farmers. Bush burning by nomads is probably carried out to kill the browsing vegetation cover in the dry season and give room for regrowth of green vegetation (Otuoku and Isife, 2009; Nigeria Fifth National Biodiversity Report, 2015). During this process of burning, the fire may spread into adjoining farms (Otuoku and Isife, 2009). This type of bush burning is uncontrolled and could impact seriously in biodiversity of both secondary and virgin forest.

2.6 Quest for bush meat
Bush meat is major source of animal protein in tropical developing countries in Africa. Bush meat consumption is as old as man. Till the present era, different types of trap are used to catch wildlife depending on the type of animal being targeted. Sometimes, hunters use gun to kill wildlife. Wildlife is killed mainly for commercial and subsistence purposes. During the dry season, people intentionally ignite fire on dry vegetation and trap down the wildlife in the area. This type of burning often goes wild affecting non targeted forest.
2.7 Elimination of dried vegetation for easy use of herbicides
In present day agriculture, the use of herbicide for weed eradication has increased. Typically, herbicides are a class of pesticides that are highly toxic to plant and some non-target organisms depending on the constituent of such herbicides. On the ecosystem, they are recalcitrant to degradation by natural processes. Herbicides are applied to vegetation cover to cause the leaves to go dry. But when the vegetation cover is high, human may intentionally light up the forest with fire so as to allow the regeneration of new/fresh vegetation, which herbicides can act on. This could be due to the fact that vegetation killed with herbicides takes longer period to re-grow, while it also kills the grass from the root zone as compared to forest cleared with cutlass or one left un-cleared prior to burning. The burning process causes death of soil flora that is essential for degradation and aeration processes.

3 Potential Impacts of Uncontrolled Bush Burning on Biodiversity of the Niger Delta
Generally, the impacts of uncontrolled bush burning can either be direct or indirect. The impacts of bush burning on biodiversity of the Niger Delta region of Nigeria can be classified into direct (habitats destruction and fragmentation, decline in protein source resulting from bush meat migration) and indirect (Loss of food sources for wildlife). Direct impact of bush burning destroys habitats, causing death and migration of some species. This could ultimately lead to decline in animal protein sources. Again, uncontrolled burning of forest (virgin/primary and secondary forest) could lead to endangerment of the species. Consistent burning on annual basis could lead to extinction of species in the wild of such locality. This is because they have been killed by fire or hunters when their habitat is destroyed. Generally, loss of biodiversity could lead to environmental degradation, disturbance of hydrological balance, deforestation, coastal erosion, loss of medicinal plants and animals and disease outbreak (Ibimilua, 2013), climate change, reduction in ecosystem adaptability, threat to nature-based tourism, loss of soil fertility, pollution, desertification, loss of natural habitat, as well as threat to vulnerable species and extinction of rare ones (Ibimilua, 2013).

3.1 Impacts resulting from emission of pollutant gases
During combustion processes, pollutant gases are released into the atmosphere. Air pollutants cause adverse effects on vegetation including necrosis, chlorosis and alteration in growth (Hamid et al., 2010). Some major pollutant gases that are generated during the burning of biomass include hydrogen sulphide, ammonia, carbon monoxide, volatile organic compounds, suspended particulate matters, oxide of sulphur, nitrogen etc. Again, methane/butane gas could also be released depending on the nature of substrate/feedstock/materials being combusted. Typically, carbon monoxide and methane are the principal gases linked to climate change. Due to potential climate change resulting from uncontrolled burning, biodiversity such as vegetation, mammals, reptiles, amphibians, aves, arthropods and even microorganisms could be impacted (Ohimain and Izah, 2014).

3.2 Impacts resulting from economic importance of biodiversity resources
Biodiversity contributes vastly to the continued existence of humans in diverse forms such as pollinator of plants (insects), proteins and hides and skin for lethal works (animals), medicinal plants and timber resources, source of livelihood (through trading in their resources) (Ohimain and Izah, 2014). According to Ibimilua (2013), biodiversity aids in life-sustaining system of the biosphere, regulation of fresh water, food, fuel, fibre, wood, nutrients, energy sources, educational materials, shelter, clothing, income, construction, utensils, employment (cash, and sustenance), medicine (herbs), ecotourism and tradable goods for teaming people. Some common uses of vegetation found in the forest. Forest vegetation is used as fuel, construction works, food and medicine. Some construction work that timber products are used for include bridge, canoe building, roofing, furniture among others. Unanaonwi and Amonum (2014) reported that United Nation's Food and Agriculture Organization estimated that over 1.5 billion of the 2 billion people (representing 75%) worldwide uses fuel wood for cooking and heating. Forest acts as shelter and food source to several wildlife, changed forest vegetation leads to alteration in composition, depending on change factor, it can lead to migration, death and complete species extinction (Unanaonwi and Amonum, 2014). Thus uncontrolled bush burning could affect the role of biodiversity on the ecosystem. Again, breeding and pollination pattern may vary thereby leading to undesired effects.
3.3 Impacts on vegetation with economic importance

Beside the medicinal uses of these plants, other plants found in the Niger Delta forest include *Elaeis guinensis*, *Raphia vinifera* and *R. hookeri, Irvinga gabonensis* and *Irvinga woumbolu*. *Raphia* species are most used for the production of palm wine in the Niger Delta region of Nigeria, which are consumed by several millions of people. The parts of Raphia palm such as the fronts have economic uses such as broom production, local hut building etc. *Irvingia* sp are also used in soup preparations and as chewing stick. The tapping of palm wine and processing of *Irvingia* sp for food processes are source of livelihood to several families especially in the rural areas. In the Niger Delta the predominant food crops include oil palm, banana, plantain, coconut, groundnut, cassava, yam, maize, rice, pawpaw, pineapple, various types of vegetable, beans, oranges etc. Hence, the destruction of these resources may not only impact on the species itself but also on the human that depend on their products for survival.

Biodiversity is a major source of livelihood in Nigeria as a whole. According to Nigeria Fifth National Biodiversity Report (2015), about 65% of Nigerians are engaged in biodiversity related jobs and occupation (such as farming, fishing, logging, livestock rearing, agricultural and forest resources), marketing, saw-milling and wood processing, manufacturing (paper making, perfume blending, food processing, brewery, distilling, garment and footwear making). The author further reported the biodiversity allied activities that generate employment include oil palm and rubber estates, gum arabic, kola nut, cocoa and forest plantations, tobacco production companies, horticulture and commercial fruit trees. For instance, authors have variously reported that oil palm industry is a source of livelihood to several families especially in the rural areas (Ohimain et al., 2012a, b; Ohimain et al., 2014b). The oil palm industry is predominantly found in southern Nigeria within the wild and around plantations (Nwaugo et al., 2008) especially in the Niger Delta region where several small scale, semi-mechanized and mechanized palm oil mills are located. Hence, unsustainable burning of forest which may spread to oil palm plantation either in the wild or plantations could be adversely affected; this may include their downstream applications.

3.4 Ecological and nutrient cycling impacts

Forest stores about 66% of above ground terrestrial organic carbon and over 50% of the carbon found in the soil (Unanaonwi and Amonum, 2014), which comprises of living organisms including flora and fauna. Keystone species are fast diminishing in the forest probably due to hunting activities (Enuoh and Bisong, 2014) and bush fire (Jamal et al., 2012) into virgin and secondary forest. Bush burning decreases the density of biodiversity on an area and could also lead to loss of organic matter in soil and have stimulatory effects which could serve as a tool to enhance the growth of some plants in directed succession (Sanyaolu, 2015).

Bush burning could lead to disruption in ecological roles. In a review study by Abernethy et al. (2013), hunting of biodiversity could lead to changes in wildlife assemblages, relative seed dispersal success and structure and composition for vegetation, soil quality and carbon balance. On wildlife, in traditional settings where wildlife is hunted with fire it involves setting ablaze of specific forest such that no single animal species escapes (Ambe et al., 2015). This type of fire burns all animals including adults and young, male and female. This leads to reduction in succession chances of that particular species.

Soil harbors several microorganisms including the ones that play essential roles in nutrient cycling (carbon, sulphur, nitrogen) that support all forms of life on earth (Unanaonwi and Amonum, 2014). These cycles play essential role in food production. Therefore the killing of microbes that play essential role in agriculture could also have adverse impact on humanity who depends majorly on food from vegetation for survival and energy. Some of the microbes that play essential role in nutrient cycling include *Azobacter, Beijerinckia, Cyanobacteria, Rhizobium, Nitrosomonas, Nitrobacter* (nitrogen cycle), *Begigattoa, Desulfovibrio* (sulphur cycle) etc. According to Ambe et al. (2015), fire causes superficial depressive effect on soil microbes such as fungi and animal populations in general. Bush burning leads to loss of nutrients and organic matter from the soil and much of the nitrogen and carbon in the soil is volatilized into the atmosphere as oxides of nitrogen and carbon dioxide respectively (Ambe et al., 2015). Unanaonwi and Amonum (2014) reported that changes in vegetation composition often results to changes in flora and fauna populations of the forest ecosystem. Again, loss in
biodiversity such as microorganisms, lead to un-decomposition of material/wastes which could lead to health hazards (Unanaonwi and Amonum, 2014).

3.5 Impacts that could result from the use of plants as antimicrobial agents

Globally, a substantial amount of the world population sought for treatment of various kinds of diseases including microbial-caused disease from traditional medicine practitioners. Authors have variously reported that about 80% of global population obtain health care from traditional medicine practitioners that use plants, forming the basis of primary health care especially in developing countries (Kigigha et al., 2015; Epidi et al., 2016a, b; Kigigha et al., 2016). In the Niger Delta region, most people who do not have access to modern drug mostly patronize traditional medicine practitioners. Again some individuals with protracted ailment which have no modern cure go in search of possible relief in traditional medicine homes. Some pregnant women also patronize traditional birth attendants that typically administer herbs during antenatal, child birth and post natal stages. In all these, plant is the main active ingredient used in treatment. Therefore, wildlife extinction is a major threat to availability of plant species.

In the Niger Delta region of Nigeria, several plants with medicinal properties are endemic in the forest. Some medicinal plants are basically found in homes as ornamentals, forest as weed, depending on the uses in a particular locality. Again some medicinal plant found at home in one area may be found in forests within another area. However, a study conducted by Eludoyn et al. (2015) listed 37 medicinal plants found in both residential and non-residential areas of the University of Port Harcourt in the Niger Delta region of Nigeria. Uzodimma (2013) listed 72 medicinal plants used by the indigenes of Ogii in Okigwe, Imo State Nigeria to treat different ailments that complements orthodox medicine which is expensive and not readily available in the area. Also, some of these plants have been demonstrated to have antimicrobial properties including Vitex grandifolia (Epidi et al., 2016b), Peperomia pellucida (Akinnbosun et al., 2008), Musanga cecropioide (Kigigha et al., 2016), Boerhavia diffusa (Akinnbosun et al., 2009), Anthocleista vogelli (Okon et al., 2014), Anthocleista djalonensis (Okoli and Iroegbu, 2004; Akinyemi and Ogundare, 2014), Anacardium occidentale (Agedah et al., 2010) Alstonia boonei (Epidi et al., 2016a), Alchornea cordifolia (Kigigha and Atuzie, 2012), Carica papaya (Ekaiko et al., 2015) and a host of others. Bushing burning could have adverse impact on the abundance and availability of these medicinal plants.

3.6 Alteration in habitats, and food sources of biodiversity

Niger Delta has several biodiversity but variations depend on the location. For instance, Ohimain et al. (2014a) reported that 45 mammalian species belonging to 21 families; 78 avian fauna belonging to 27 families; and over 56 species of vegetation are found in Wilberforce Island, Bayelsa state, Nigeria. Also, Lameed (2009) reported a total 47 mammalian species, 7 reptilians and 3 amphibians in Kwale forest reserve and the Okpai ecosystem (transit pipeline to Onitsha), Delta state. The author further reported that bird populations vary with location and characteristically 19 species (villages and farmlands), 49 species (forest area), 14 species (river bank and beaches) in Kwale forest with predominant species being African Black kite Milvus migrans and pied hornbill Tochus nasutus were found in all the areas. Hamadina et al. (2007) reported that 36 mammalian species belong to 18 families; 18 reptiles species belong to 12 families; 67 avian species belong to 25 families are found in the Nun River forest reserve of Bayelsa state. Frequent bush burning of vegetation cover that serves as habitat to this biodiversity and food to others could be destroyed causing an imbalance in the ecological roles.

Typically, bush burning destroys birds’ eggs, nest, food sources, rodents such as mice and rats breeding pattern, while insects and other animals such as mammals could be impacted (Ambe et al., 2015) probably due to destruction of their habitats. For instance, wildlife such as monkeys that feed on Musanga (Ohimain et al., 2014a) could be affected when the plant are destroyed by fire, which could lead to their migration from the habitat. Most rodents such as rats and mice inhabit dumpsites, therefore, burning of the wastes which could lead to bush fire that often smoke the rats out of the habitats and sometimes lead to their death. Other predatory wildlife and man that depend on this prey for food could be adversely affected. Table 1 presents some wildlife used as food in the Niger Delta region of Nigeria that could be impacted by uncontrolled bush burning.
ACET (2014) reported that crickets are the most commonly consumed insect in Africa and most marketable in Nigeria. Generally, Okore et al. (2014) reported 20 edible insects [Macrotermes sp. (Termites), Brachytrypes membranaceus (Crickets), Zonocerus sp (including Grasshopper and Praying mantids), Rhynchophorus phoenicis (Palm weevil/ Edible worm), Rhinoceros oryctes (Rhinoceros), Heteroligus meles (Yam beetle), Sitophilus oryzae (Rice weevil), Callosobruchus maculatus (Bean beetle), Derametis maculatus (Fish/hides beetle), Daraba Sceloides laisalis (Egg fruit borers), Gonimbrasia belina (Mopane worm), Apis mellifera (Bees), Musca domestica (House flies), uncertain species of Cotton stainer, aphids and locust] from the Niger Delta region (Abia, Akwa Ibom, Bayelsa, Cross Rivers, Delta, Edo, Ondo and River states) which belong to six orders (Isoptera, Orthoptera, Coleoptera, Lepidotera, Hemiptera and Diptera, Order Coleoptera). The authors further reported that some species such as bean beetle, rice weevil, maggots are consumed unintentionally. In the study region, the occurrence frequency and distribution varies (Okore et al., 2014). In the Niger Delta, especially in the central region (Bayelsa state), Rhynchophorus sp which is found in the decaying trash of palm truck and front are consumed by a large number of people. Insects which generally have high protein content play a dynamic role in degradation. For instance, beetle larvae, flies, ants, and termites clean up dead plant matter and consume agricultural waste or plants that humans and traditional livestock cannot (ACET, 2014). Therefore the burning of their ecosystem could adversely affect their habitat, population, as well as humans who feed on them.

Table 1 Some biodiversity mostly impacted by bush burning in the Niger Delta

| Classification | Species | Nature of impacts | Economic roles |
|----------------|---------|------------------|----------------|
| Mammals        | Different species of Monkeys such as Nigerian white-throat monkey, Red-capped mangabey, Putty nosed monkey | Destruction of their food sources and to lesser extent death | Food, pets |
|                | Black House rat | Smoking them out of their habitat | Food |
|                | House mouse, Spotted-grass mouse | leading dislodgement which could lead to their death by the fire or being hunted by humans | |
|                | Grass cutter/ cane rat | | |
|                | Red River hog | | |
|                | Brush-tailed porcupine | | |
|                | Nigerian musk shrew | | |
|                | Different species of squirrel such as giant forest, red-legged sun, fire-footed rope, red-less tree-squirrel | | |
|                | Tree hyrax | | |
|                | Antelope | | |
|                | Wild rabbit | | |
| Reptiles       | Several different species of snakes such as black necked cobra, Viper, West African Black forest turtle (Pelusios niger) | Death either by fire or humans hunting bush meat in burning forest | Food, and the oil is medicinal |
|                | Serrated hinged – backed tortoises (Kinixys erosa) | Habitat destruction and death | Food and medicine |
| Aves           | Crested Guinea fowl | Destruction of their eggs, food sources and even death | Food |
|                | Black kite | | |
|                | Harrier hawk | | |
| Insect         | Grasshoppers | Disturbing pollination | Food, ecological |
|                | Crickets | Aeration of the soil permeability and porosity | Food, ecological |
|                | Insect larva/ maggot (Rhynchophorus sp) | Destruction of their habitat and death | Food |
| Mollusks       | Snails | Destruction of their habitat, eggs and death | Food |

According to Fa et al. (2015), the level of biodiversity (bush meat) exploitation and possible consumption depend on a particular locality, which are determined mainly by availability, and are influenced by people who purchase, hurt and consume them. Like uncontrolled bush burning, habitat degradation of protected site are also caused by poverty, lack of basic needs, subsistence or commercial agriculture, changing land use policy, population upsurge,
loss of land ownership rights, human-wildlife conflicts, trading of endangered species, non-inclusion of local people in biodiversity conservation projects (Ikpa et al., 2009). Uncontrolled bush burning could destroy biodiversity composition of such an area.

3.7 Impacts on “sacred forest” or “evil forest” that inhabits biodiversity

Some biodiversity have cultural, mythological, spiritual and recreational value (Ibimilua, 2013). In Nigeria today, it appears that traditions are related to nature. Several cultural sites or protected forests exist in the Niger Delta and they harbor biodiversity. According to Nigeria Fifth National Biodiversity Report (2015), social fabric of life (such as food, shelter type, skills and traditional knowledge) lifestyles, customs and norms as well as the allied arts, crafts, songs and folklores, reflect type of biodiversity and natural resources in different communities and societies in Nigeria. For instance, the Ijaws, Itsekiris and the Ilajes of the Niger Delta region are familiar with coastal environment due to the presence of large water bodies in the area as such they are able to swim, build canoe, process sea food (Nigeria Fifth National Biodiversity Report, 2015). Thus, the destruction of biodiversity in the Niger Delta region via bush burning could impact on the life style and social fabrics of the people. Some communities in the Niger Delta practice local conservation-friendly beliefs. Some of this includes the delineation of certain forest as “sacred forest” (forest associated to the gods) or “evil forest” (forest that is believed to harbor evil spirits) (Hamadina et al., 2007). In scared forests, access to and exploitation of its resources are restricted except with permission. Sometimes, the gods have to be appealed before gaining access to these conserved areas. Due to this, the environment of the sacred forest is virtually quiet, hence, it is found to be habitable for most wildlife. Like water, wildfire are non-selective, therefore frequent uncontrolled bush burning could destroy the forest that aid in the conservation of the biodiversity resources of such area.

The practice of totem (wildlife associated to cultural taboos and sometimes sacred) is one whereby a representative animal is not killed for any reason, but when killed accidentally, the person may require spiritual cleansing (Hamadina et al., 2007) are also practiced in the Niger Delta region. These practices aid in the conservation of such biodiversity/wildlife. For instance, in Nun River forest reserve, reptiles such as Crocodylus niloticus, Varanus niloticus (nile monitor lizard), Kinixys erosa (serrated hinge-backed tortoise), Python sebae (rock python), Python regius (Royal python) and Naja nigricolis (blacked-necked cobra) are totem species, while avian such as Tauraco persa (green-crested turaco), Psittacus erithacus (grey parrot), Chrysococcyx klaas (Klaas’s cuckoo), Haliaetus vocifer (West African river eagle), Gypohierax angolensis (palm-nut vulture) are associated with taboo (Hamadina et al., 2007). However, in other area, some of these species are potential sources of bush meat. For instance, Ohimain et al. (2014c) reported unsustainable exploitation of turtle and tortoise along East-West road in Bayelsa and Delta state. Wildfire often destroys the habitat of these species and sometimes results to direct killing. Therefore, wildfire is a major threat to their survival and population just as other ecological problems. But with modernization and industrialization, poverty and hunger, some of these beliefs have been compromised (Hamadina et al., 2007).

3.8 Impacts on fallowing land thereby reducing the nutrient composition

The practice of shifting cultivation and farm fallowing are major threats of uncontrolled bush burning. Wildlife often migrates and inhabit in such fallowing land. When such fallowing area is close to current farm land, the wildlife composition of the fallow land often poses a threat to crops in the farm land. Large herbivorous animals destroy foliage of crops which they mostly feed upon. In an attempt to avert the adverse impacts of the wildlife on crops, farmers tend to set the farm forest ablaze and hunt down the wildlife. This is a common practice among African communities (Ikpa et al., 2009). This often leads to migration of wildlife and possible death of such animals.

3.9 Impacts resulting from oil spill fire

Fire emanating from oil spill could be intense and severe. Major impacts include destruction of wildlife and biodiversity, loss of fertile soil, pollution of air and drinking water, degradation of farmland and damage to aquatic ecosystems (Ogbeibu and Iyobosa, 2013). Generally, Kadafa (2012a, b) reported that oil spills pose great threat
to the environment and can even lead to the total destruction of the entire ecosystem. According to Ambe et al. (2015), wildfire from petroleum products have led to loss of lives, farmland and other infrastructural resources in Jesse community in Delta state, Nigeria (Ambe et al., 2015).

4 Potential Options for Mitigation
Since long, Nigeria have instituted several National policy on Wildlife, Forestry and Protected Areas for conservation, but the achievements are not hopeful (Usman and Adefalu, 2010). According to Usman and Adefalu (2010), the implementation of conservation policy on biodiversity did not yield preferred result as such the biodiversity of the country (including plants and animals) are under threat. Controlling loss of biodiversity is one of the major indicators of environmental sustainability of any ecosystem. This could be achieved through several advanced development of wild fire burning principles, strategies, and planning processes for the mitigation of the adverse impact associated with bush burning.

However, several measures can be put in place to minimize bush burning and the resultant impacts on biodiversity. Some of these strategies include:

- Pasture management, minimization of waste, as well as optimal use of resources through reuse and recycling (Ibimilua, 2013)
- Formulation and implementation of environmental laws, biodiversity legislation, wildlife conservation acts and ecotourism policies by the government that could mitigate biodiversity loss (Ibimilua, 2013; Ibimilua and Ibimilua, 2014)
- The practice of continuous farming should wait for the stipulated period of bush burning which varies from community to community.
- Strict compliance with environmental criteria that has to do with biodiversity conservation as stipulated by International, national, state and local government, private organizations campaigners (Ibimilua, 2013)
- Farmers, hunters, policy makers and implementers, environmental educators, careless cigarette smokers on picnics and general public should be sensitized on the impacts of bush burning and take positive attitude and measures to control the hazard of bush burning (Ambe et al., 2015).
- Enhancement of the legal and political frameworks for conservation management (Usman and Adefalu, 2010).
- Farmers that practice shifting cultivation should liaise with other whose farm land are in the same area, notifying them of the occurrence of bush burning in order to avoid the unattended ignition of cleared area.
- Introduction of biodiversity conversation in school curriculum to enhance information of biodiversity protection (Usman and Adefalu, 2010)
- The government should make use of environmental extension agents to bring to the notice of villagers the hazards of bush burning, and work as police or vigilante groups enforcing rules and regulations to potential offenders (Unanaonwi and Amonum, 2014; Ambe et al., 2015).
- Public enlightenment for the enhancement of public thoughtfulness about wildlife (Ibimilua and Ibimilua, 2014).
- Stringent legislation and law should be decreed against uncontrolled bush burning, and appropriate punishments spelt out for offenders in the courts of law (Ambe et al., 2015).

5 Conclusion
Niger Delta has the largest mangrove ecosystem, biodiversity hotspots in Nigeria. The region has several aquatic ecosystem including freshwater, marine and marine/salt and fresh water interphase known as estuarine/brackish water. Each of these ecosystems has distinctive structure of a typical habitat. The Niger Delta region also has the largest wetland in Africa, which plays social, ecological and economic roles. The degradation of ecosystem by both natural and anthropogenic factor is having an impact on the ecology of the Niger Delta. It’s a well-known factor that industrialization, urbanization, agriculture (deforestation) and modernization are the leading cause of virgin forest destruction. But it appears that the intensity of uncontrolled bush burning have increased in the recent year especially during the dry season. In the Niger Delta region, most of the secondary and virgin forests are under destruction due to uncontrolled bush burning and this may have an impact on the ecology of the ecosystem as well
as its terrestrial biodiversity composition. Some of the notable impact of uncontrolled bush burning includes habitat destruction and fragmentation, loss of biodiversity and decline in their population, loss of essential roles played by the biodiversity on the productivity of the ecosystem etc. Hence, there is the urgent need to preserve the virgin and secondary forest and protect it against wildfire.

Authors’ contributions

The manuscript was carried out by all the authors. Author SC Izah conceived the idea, wrote the initial draft and managed correspondence. Author TCN Angaye provided the figure 2 used in the manuscript and proof read the manuscript. Author AO Aigberua managed literature search, and Author JO Nduka made some technical corrections.

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