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A review of impact of recurrent bush burning on the climate change paradigm: The Nigerian experience

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Abstract
Bush burning is the removal of the natural vegetation cover that protects the soil surface through the use of fire. This exposes the land to the effect of wind, water erosion and ultraviolet radiation. Bush burning has detrimental effect to the environment, health and the economy. It involves the production of air pollution such as carbon monoxide, hydrocarbon, hydrogen sulphide, nitrogen oxide, sulphur, ozone and other oxidants. Particulate pollutants such as dust, fume, mist and smoke are also obtained from bush burning. The sources and effect of these pollutant in relation to carbon sequestration and how they affects agricultural output, the environment, health and economy were discuss in this review. Other effect of bush burning reported in this review are; global warming, habitat destruction, loss of biodiversity, increase erosion, vector-borne diseases, cancer, change in phenology, and economic loss. Loss of plant biodiversity is a significant component of climate change; if these plants are allowed to stay the ecosystem balance will be maintained and favourable climatic condition attained. Recurrent bush burning in northern states of Nigeria is gradually becoming a norm, hence the need for this review to enlighten the general populace and also bring to notice its impact on climate change paradigm.

Keywords: enlighten, destruction, phenology, removal

Introduction
Culturally, bush burning is a practice in most developing nations including Nigeria at the unset of planting season up to the middle of dry season. As more land is being cleared and prepared for cropping annually, bush burning has become the easiest and most convenient method quite often employed in agricultural practices as well as in environmental management. In many areas, the attitude changed to one of total burning (wildfire) and this becomes a major cause of depletion of nutrient status. This necessitates a research of this kind to ascertain the effect of such localized burnings and fires on the soil and its subsequent effect on crop production. The vast majority of area burnt and cleared annually for cropping, to drive game for hunters, to improve grazing condition for livestock and for migration and land settlement lies within the savanna ecological zone (Isah and Adegeye, 2002). This practice invariably results in heating and drying of the soil.

Bush burning has been practiced in many parts of the world and has been accepted as an integral part of the traditional farming system (Hough, 1993). However, Frequent and uncontrolled bush burning has become a major problem in most parts of the world today especially in the forest zones of developing countries (Hough 1993). Bush burning has contributed to deforestation with its attendant problems. Frequent bush burning is generally considered to have negative effects on biodiversity (Tramor and Woinarski, 1994, Bradstock *et al.* 1997 and Egunjobi 1971) [8, 14]. Man's environment is under constant threat from his own activities resulting from expanding population and this remains one of the biggest challenges to the quality of environment. Bush burning, whether the result of a wildfire or a controlled burning, affects not only the appearance of the landscape, but the quality of the soil. The landscape may quickly recover after a fire, with fresh new growth and emerging seedlings. However, bush burning has a negative effect on soil conditions and soil may take much longer to recover, Man has emerged as a very important geomorphic agent and is capable of changing the environment at a much faster rate than many of the natural processes. Bush burning or fire is the chemical reaction between oxygen and fuel which is raised to ignition temperature by heat. The reaction is self-sustaining unless extinguished or the fuel concentration falls below minimum level. Most often bush burning results from a rapid. Exothermic reaction in combination with oxygen and one combustible material Hamid *et al.* (2010) [23] observed that bush burning is part of some countries way of life. Bush burning is one of the major air pollutants that are emitted during bushfire and these include Carbon monoxide, Carbon dioxide, oxides of Nitrogen, oxides of Sulphur, particulates and hydrocarbon as a result of incomplete combustion of cellulose materials (Stern, 1976) [47]. These do not only pose health hazards to man alone but also affect the environment in general. Oxides of Sulphur and nitrogen remain hazardous as they cause respiratory disorder characterized by excessive mucus secretion in the bronchial tubes.

Population explosion, industrialization, urbanization and intensive agriculture have caused tremendous damage to our environment. Man's ignorance of laws of nature and his over-exploitation of natural resources have further aggravated the problem. Fortunately, during the last few years, we have started realizing our past mistakes and begun to make amends to prevent further degradation of our environment. Environment means the surroundings in which we live. It is a life-sustaining system in which various living beings like animals, including man, birds, insects, micro-organisms like algae, fungi, protozoa, amoeba and non-living beings like air, water and soil are inter-related. Like man, his environment too is beautiful.

In managing grasslands, farmers often introduce burning to remove moribund and unpalatable grasses from previous

growing season, to stimulate the re-growth of fresh herbage with higher nutrient content (Snyman, 2003). Burning is also believed to rid the grassland of parasitic insects and to prevent the encroachment of undesirable invasive species (Auld, and Denham, 2006).

The consequence of uncontrolled bush burning is most obvious in areas characterized by torrential rain fall, strong wind and hot solar radiation. This is because even slight disturbance of the vegetal mantle may have very considerable impact on organic matter content and vegetation biodiversity. Egunjobi (1971) reported on different aspects of fire on the forest and savanna vegetation in Nigeria. These works however, concentrated on forest plantations, grass reserves and cattle ranches with no attention paid on arable farms

Bush Burning

More than half of bush burning throughout Nigeria is deliberately lit, costing millions of naira damages annually. The questions which need answers are, what motivates an arsonist and what do they feel when the bush is burning? This feature proffers solutions to the problems. The negative impact of bush burning need not to be over emphasized especially during the hot season in northern Nigeria as apart from environmental pollution and health hazards, bush burning obviously causes immense catastrophes in many quarters. They include bush burning as public nuisance, the suffocating experience felt by people due to the huge smoke soaring in the air during the heat, and the pollution of the ozone layer of the environment. In this regard, the menace is of double tragedy in the sense that while the heat is unbearable, bush burning fires also heat up the soil thereby blazing up its nutrients including the fertilizer elements. Furthermore, the fire is smoldering and all the proponents of the plants as well as the grasses that are useful in conserving the forest, Wildlife and small animals are being destroyed in large proportion.

Primitive man ate uncooked food available from plants, birds or animals within his reach. He ate the raw meat. He drank the water from the rivers. He lived in caves or huts made of mud, wood and leaves of some trees. This sort of living never polluted the environment. When promethenes stole fire, man's travails began. He used it not only to cook food but also as a weapon to destroy the neighbour and the series of air polluted disaster affected millions all over the world (Bhatia, 2002) [7].

Impact of Bush Burning

The atmosphere

The ability of air pollutants, especially particulates, to reduce visibility is well known. The visibility reduction results from light scattering other than obstruction of light. The particles primarily responsible for this effect are quite small in the range of 0.3 to 0.6 micron in diameter (Nsi, 2007) [36]. The major air pollutants that are emitted during bush fire are carbon monoxide, carbon dioxide, oxides of nitrogen, oxides of sulphur, particulates and some hydrocarbon. (Which result due to incomplete combustion of cellulose materials). (Stern, 1976) [47].

Bush burning not only poses health hazard to man alone but also affects the environment in general via the emission of the various pollutants. From the data above, it is glaring that particulates, carbon monoxide, hydrocarbons, oxides of nitrogen a negligible percentage of oxides of sulphur are the major pollutants of bush burning and they all have various effects on man and his environment, like reduction of visibility by particulate matters, especially during periods of air stagnation and causing some respiratory diseases.. Apart from the soil destruction and desert encroachment caused by bush burning, it has also had a marked increase in global warming due to the emission of NO2, SO2, SO3, NO, CO and CO2 gases which have tremendous effect on the ozone layer and also formation of acid rain which deteriorate plant life, damage calcium containing soils and also increase the acidity of surrounding lakes and rivers (Judge, 1991) [28].

Environmental Impact

Bush burning is one of the major air pollutants that are emitted during bushfire and these include Carbon monoxide, Carbon dioxide, oxides of Nitrogen, oxides of Sulphur, particulates and Hydrocarbon as a result of incomplete combustion of cellulose materials (Stern, 1976) [47]. These do not only pose health hazards to man alone but also affect the environment in general. Apart from soil destruction and desert encroachment caused by the effect of bush burning, it also has a marked increase in global warming due to the emission of NO2, SO2, SO3, NO, CO and CO2 gases which have tremendous effect on the Ozone layer. There is also the formation of acid rain which deteriorates plants, damages Calcium in soils and also increases acidity of the surrounding lakes, rivers and soils (Judge, 1991) [28]. (Edwin, 2006) [15] Observed that rampant bushfires cause significant damage in all the ecological zones, and is most pronounced where the savanna vegetation predominates and the incidence also remain the highest.

The changes brought in by physical environmental process on the earth's surface occur in such a way that equilibrium is maintained through negative feed-back mechanism if man does not interfere in the natural state of physical environmental process. Now man has emerged as a very important geomorphic agent and is capable of changing the earth's surface at a much faster rate than many of the natural processes. Thus it is important to study the role of man in changing the environmental processes because these processes affect the energy system, hydrological cycle, chemical element cycle, and sediment cycle which in turn maintain unity of biosphere ecosystem. The external environmental processes originate from the atmosphere and are basically related to solar energy which affects the basic elements of atmospheric processes. Man, by affecting solar radiation and thus the heat energy, may affect the processes of precipitation and air circulation which in turn would affect the environmental processes (Bhatia, 2002) [7].

Global warming

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

Health Impact

Health is the complete state of physical, mental and social well-being of an individual without necessarily the mere absence of disease (WHO, 2003) [53]. Desertification can impact on the public health through increased heat waves, potential to initiate skin cancer and enhancement of favourable environmental conditions for diseased conditions and vectors. Oxides of Sulphur and nitrogen gotten as a result of bush burning remain hazardous as they cause respiratory disorder characterized by excessive mucus secretion in the bronchial tubes. Oxides of sulphur and nitrogen are also hazardous as they cause respiratory disorders and irritant respectively.

Vector-borne diseases

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

Loss of plants with medicinal importance

Desertification has contributed to the loss of plants of potential medicinal properties. Most woody species serve as source of medicine (Kafaru, 1994; Otegbeye and Otegbeye, 2002) [29, 43] especially to local people. These medicinal plants are neither cultivated nor protected against desertification, so they disappear at a rapid rate with good number of them under threat of extinction especially in the arid and semi-arid lands. Madaci (*A. senegalistis*) an indigenous medicinal plant species use to cure various ailments in Maiduguri and some other place in the northern Nigeria is now endangered due to desertification.

Cancer

One of the influences of desertification is deterioration of vegetation cover, such that people especially outdoor workers are exposed to direct influence of the solar radiation. It has been proved that excessive exposure to sunlight can cause skin disease and cancer (Cunningham and Cunningham, 2006) [10]. McMichael and Githeko (2001) [32] made an observation in outdoor workers such as agricultural labourers and farmers, that skin cancer developed on areas most frequently exposed (e.g. hands, neck, and face) to sun. There are regional differences in the type of malignancies that are prevalent in Nigeria. The severity of desertification could be a contributory factor. Skin malignancies have been reported to account for higher percentage of all malignancy cases in the Northern Nigeria compared to the southern Nigeria. For instance, skin malignancies accounted for 6.81% of all malignant cases in Jos (Mandong *et al*., 2001) [31]; a city in the north central with moderate rate of desertification. In Kano (a farther northern city also with moderate rate of desertification), it is 12.7% (Ochicha *et al*., 2004). While in Maiduguri, in the extreme northern part with severe rate of desertification; it accounts for 20.9% (Nggada *et al*., 2003) [41]. These percentages are high compare to the report of cases in 2007 in Lagos State (Southern Nigeria) as documented by Morbid Anatomy Department of the Lagos University Teaching Hospital (LUTH). Skin cancer, accounted for just 5% of all reported malignancies (Ikawo, 2013) [26].

Ecological Impacts

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

Habitat destruction and loss of biodiversity

Diversity is a measure of the amount of variability in the species composition of a community (Don-Pedro, 2009) [13]. Bullock and Le Houérou (1994) assert that many species are prone to be endangered due to desertification. Nigeria drylands contain a large number of species of plants and animals that are important to humankind as a whole, but which are threatened as a result of desertification process occurring in the area. NAP (2000) [39] revealed that some important animal species such as the sitodunga antelope, cheetah, giraffe, lion and elephants in the northern states of Nigeria have become endangered and indigenous plant species especially those with medicinal values e.g. *Mitrogina spp* (known as Giyaya in the area) are now difficult to locate.

Changes in phenology

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

Increased erosion

Soil erosion is the movement and transport of soil by various agents particularly water and wind leading to soil loss. Impoverishment of soil's natural vegetation cover has been a primary cause of soil erosion. When land is deforested, the soil anchorage provided by trees and other plants is lost and the soil is rapidly eroded. Because of the nature of desertification prone area, soil erosion by wind is occurs but erosion by water is more disastrous during the unusual heavy rainfall. Gully erosion, that hitherto was not a major threat in Nigeria has increased, threatening about 18, 400 km2 compared to only about 122 km2 in 1976 and 1978. A survey conducted in Katsina State revealed that 30% of agricultural land has been severely damaged and lost

from further productive use due to erosion which has resulted to crop yield out by 30 to 60%.

Economic Impact

Economic loss and reduced economic growth

Bush burning has economic consequences. It weakens populations and institutions rendering them more vulnerable to global economic factors (Koohafkan, 1996) [30]. Short fall in earned tax receipts occurs due to low productivity, and has consequences on the capacity of government to reimburse their foreign debt and develop national socio-economic programmes. The persistence of desertification reduces national food production and furthers the need to rely on foreign imported products. Also, government expends so much on ameliorating the effects of desertification, revenues which could have been used for other developmental projects. For example, more than 65 and 55% of Sokoto and Borno States are said to be afflicted (Emodi, 2013) [18]. In Gidan Kaura, a village 90 km northwest of Sokoto, sand dunes have been reported to have invaded vast areas of farmland and destroying nearly 300 houses. Villages such as Bulatura, Kaska, Bukarty Toshu, Tubtulova, Yunusari, among others in the extreme northern part of Borno State, have been either completely surrounded by sand dunes or are about to be buried by them. It is estimated that Nigeria loses about $5.1 billion every year owing to rapid encroachment of drought and desert in most parts of the north (Vanguard News Paper, 2010) [53].

Causes of Bush Burning

Nsiah-Gyabaah (1996) [35], Awudu (2002, and Edwin (2006) [4, 15] maintained that bush is burned in order to hunt for games or bush meat and to clear the land for farming. Fire is also a common land management practices in many agricultural areas of some countries including Nigeria where it is used to burn the by-products of some agricultural crops such as Sugarcane waste, wheat or rice stubble and forest residues. Wildlife populations are severely depleted due to bushfire, and animal habitats in unprotected forests and savannas continue to be threatened. Fire is used to chase out, kill and destroy animals habitats such as African hare, antelope, waterbuck, bushbuck, elephant, grass cutter, giant rat (NSBC, 2000) [38]. The cost of bush meat in the region is an indication of the extent to which wild animal populations are severely depleted (Environmental protection Council, 1992). According to Songsore (1994) human activities such as the use of bush burning and bad farming practices have also exposed the environment to land degradation, deforestation, loss of biodiversity and a decrease in soil fertility, leading to low crop yield and large-scale hunger among the people. The causes of bushfires are both natural and anthropogenic. Climatic factors especially dry spells; nature of vegetation and wind speed all play an important role. When there is a prolonged dry season, and where the potential evaporation exceeds the rain fall during the year, the natural vegetation becomes dry and therefore vulnerable to fire incidence. Human activities such as land clearing and burning of bush by herdsmen in order to stimulate germination of new grasses are also causes of uncontrolled and indiscriminate bushfires.

Climate Change

There is now widespread consensus that the Earth is warming at a rate unprecedented during post hunter-gatherer human existence. The last decade was the warmest since instrumental records began in the nineteenth century, and contained 9 of the 10 warmest years ever recorded. The causes of this change are increasingly well understood. The Third Assessment Report of the Intergovernmental Panel on Climate Change, published in 2001, goes further than its predecessors, stating that "*There is new and stronger evidence that most of the warming observed over the last 50 years is likely to be attributable to human activities"*, most importantly the release of greenhouse gases from fossil fuels. Stresses on the climate system are already causing impacts on Earth's surface. These include not only rising surface temperatures, but also increasingly frequent floods and droughts, and changes in natural ecosystems, such as earlier flowering of plants, and pole ward shifts in the distribution of several species. All of these changes are inextricably linked to the health of human societies. Climatic conditions affect human well-being both directly, through the physical effects of climatic extremes, and indirectly, through influences on the levels of pollution in the air, on the agricultural, marine and freshwater systems that provide food and water, and on the vectors and pathogens that cause infectious diseases. As it is now widely accepted that humans are influencing global climate, decision makers are now focusing on the type and timing of actions to limit the rate of change. Attention is shifting to the balance between the possible impacts of climate change, and the economic costs, technological advances and societal adaptations that are necessary for mitigation.

Rising fossil fuel burning and land use changes have emitted, and are continuing to emit, increasing quantities of greenhouse gases into the Earth's atmosphere. These greenhouse gases include carbon dioxide (CO2), methane (CH4) and nitrogen dioxide (N2O), and a rise in these gases has caused a rise in the amount of heat from the sun withheld in the Earth's atmosphere, heat that would normally be radiated back into space. This increase in heat has led to the greenhouse effect, resulting in climate change. The main characteristics of climate change are increases in average global temperature (global warming); changes in cloud cover and precipitation particularly over land; melting of ice caps and glaciers and reduced snow cover; and increases in ocean temperatures and ocean acidity – due to seawater absorbing heat and carbon dioxide from the atmosphere (Arendal, 2005) [2]. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) [32] dispelled many uncertainties about climate change. Warming of the climate system is now unequivocal. It is now clear that global warming is mostly due to man-made emissions of greenhouse gases (mostly CO2). Over the last century, atmospheric concentrations of carbon dioxide increased from a pre-industrial value of 278 parts per million to 379 parts per million in 2005, and the average global temperature rose by 0.74° C. According to scientists, this is the largest and fastest warming trend that they have been able to discern in the history of the Earth. An increasing rate of warming has particularly taken place over the last 25 years, and 11 of the 12 warmest years on record have occurred in the past 12 years. The IPCC Report gives detailed projections for the 21st century and these show that global warming will continue and accelerate. The best estimates indicate that the Earth could warm by 3° C by 2100. Even if countries reduce their greenhouse gas emissions, the Earth will continue to warm. Predictions by 2100 range from a minimum of 1.8° C to as much as 4° C

rise in global average temperatures.

Human beings have been adapting to the variable climate around them for centuries. Worldwide local climate variability can influence peoples' decisions with consequences for their social, economic, political and personal conditions, and effects on their lives and livelihoods. The effects of climate change imply that the local climate variability that people have previously experienced and have adapted to is changing and changing at relatively great speed.

Deforestation

Deforestation, clearance or clearing is the removal of a forest or stand of trees where the land is thereafter converted to a non-forest use. Examples of deforestation include conversion of forestland to farms, ranches, or urban use. Tropical rainforests is where the most concentrated deforestation occurs. About 30% of Earth's land surface is covered by forests [3]. In temperate mesic climates, natural regeneration of forest stands often will not occur in the absence of disturbance, whether natural or anthropogenic. Furthermore, biodiversity after regeneration harvest often mimics that found after natural disturbance, including biodiversity loss after naturally occurring rainforest destruction.

Deforestation occurs for multiple reasons: trees are cut down to be used or sold as fuel (sometimes in the form of charcoal) or timber, while cleared land is used as pasture for livestock and plantation. The removal of trees without sufficient reforestation has resulted in damage to habitat, biodiversity loss and aridity. It has adverse impacts on bio sequestration of atmospheric carbon dioxide. Deforestation has also been used in war to deprive the enemy of cover for its forces and also vital resources. Modern examples of this were the use of Agent Orange by the British military in Malaya during the Malayan Emergency and the United States military in Vietnam during the Vietnam War. As of 2005, net deforestation rates have ceased to increase in countries with a per capita GDP of at least US$4,600. Deforested regions typically incur significant adverse soil erosion and frequently degrade into wasteland.

The year 2011 is 'The International Year of Forests'. This designation has generated momentum bringing greater attention to the forests worldwide. Forests cover almost a third of the earth's land surface providing many environmental benefits including a major role in the hydrologic cycle, soil conservation, prevention of climate change and preservation of biodiversity (Sheram, 1993) [50]. Forest resources can provide long-term national economic benefits. For example, at least 145 countries of the world are currently involved in wood production (Anon., 1994a). Sufficient evidence is available that the whole world is facing an environmental crisis on account of heavy deforestation. For years remorseless destruction of forests has been going on and we have not been able to comprehend the dimension until recently. Nobody knows exactly how much of the world's rainforests have already been destroyed and continue to be razed each year. Data is often imprecise and subject to differing interpretations. However, it is obvious that the area of tropical rainforest is diminishing and the rate of tropical rain forest destruction is escalating worldwide, despite increased environmental activism and awareness. Deforestation is the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development (van Kooten and Bulte, 2000).

Deforestation is primarily a concern for the developing countries of the tropics (Myers, 1994) as it is shrinking areas of the tropical forests (Barraclough and Ghimire, 2000) causing loss of biodiversity and enhancing the greenhouse effect (Angelsen *et al*., 1999). FAO considers a plantation of trees established primarily for timber production to be forest and therefore does not classify natural forest conversion to plantation as deforestation (but still records it as a loss of natural forests). However, FAO does not consider tree plantations that provide non-timber products to be forest although they do classify rubber plantations as forest. Forest degradation occurs when the ecosystem functions of the forest are degraded but where the area remains forested rather cleared (Anon., 2010). Both farmers and hunters in this part of the world use fire as a tool notwithstanding the fact that it is one of the most serious agents of forest destruction especially during the dry season. Most fires are caused either deliberately or by accident and these destroy trees of all sizes including seedlings. Fire hazards are more where the herbs and fallen leaves on the forest floor become dry. Most often animal rearers burn the old grasses to encourage growth of succulent grass for pasture. It has also been suggested that grass lands were sometime forested areas on which man had deliberately set fire to catch game thereby destroying previously existing forest vegetation. Timber loggers also set fire on forest accidentally while smoking or while carrying out any fire prone activity. This most times result in ground forest fires, surface fires and eventually wild crown forest fires.

Effects of Deforestation

The effects of deforestation are most times not felt instantly by the forest ecosystem or the surrounding woodland environment. But over time, the absence of vegetation cover in a previously forested area affects both the living and non-living components of that environment in the following ways.

Soil Erosion

Deforestation exposes forest soils to direct contact with the rains and this enhances the free flow of run off which causes soil erosion. For communities whose sources of drinking water are influenced by water sheds soil erosion results in the increase of the mineral content of the surrounding water bodies and also increases turbidity.

In areas where slops are step or agricultural practice is bad the land may show excessive erosion in the absence of surrounding forests. Erosion galleys eat back further into agricultural land with each rain storm and remove valuable top soil. Soils that are exposed to erosion will no doubt have lower fertility potentials as compared to more stable soils protected by good vegetation cover.

Soil destabilization

Deforestation in desert prone areas destabilizes soil and enhances the encroachment of sand upon agricultural lands. This is most times the case in Northern Nigeria where desertification is a major threat to agriculture as trees that would have been used to stabilize sand dunes are felled to be used as fuel wood.

Migration of animal species

Forest areas which had been the natural habitats of some wild life for years are no longer conducive for such wild animal species to survive when deforestation takes place. Such animals end up migrating to more conducive environments. Sometimes, it may results in the death of such animals and subsequent extinction, as such animals are not able to adapt to their new environment. Typical examples are the migration of elephants and hippopotamus from the Niger Delta as a result of deforestation.

Increase in reflected solar radiation

Wood lands reduce the amount of solar energy reaching the ground, since the upper canopy reflects some incident radiation. The ratio of reflected to incident radiation is called the abedo and is usually greater in land areas without vegetation cover. This is because radiant energy is absorbed by the different plant layers in every vegetation, leaving a very small percentage to be reflected back into the atmosphere. Thus deforested areas will reflect more radiant energy into the atmosphere, which will in turn enhance global warning.

Carbon Sequestration

Carbon sequestration is the process by which atmospheric carbon dioxide is taken up by trees, grasses, and other plants through photosynthesis and stored as carbon in biomass (trunks, branches, foliage, and roots) and soils. The sink of carbon sequestration in forests and wood products helps to offset sources of carbon dioxide to the atmosphere, such as deforestation, forest fires, and fossil fuel emissions. Sustainable forestry practices can increase the ability of forests to sequester atmospheric carbon while enhancing other ecosystem services, such as improved soil and water quality. Planting new trees and improving forest health through thinning and prescribed burning are some of the ways to increase forest carbon in the long run. Harvesting and regenerating forests can also result in net carbon sequestration in wood products and new forest growth. Carbon sequestration is the process involved in carbon capture and the long-term storage of atmospheric carbon dioxide (CO2)*Sedjo and Sohngen, (2012)* [51]. Carbon sequestration describes long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming and avoid dangerous climate change. It has been proposed as a way to slow the atmospheric and marine accumulation of greenhouse gases, which are released by burning fossil fuels, (*Hodrien, 2008*) [24]. Carbon dioxide is naturally captured from the atmosphere through biological, chemical or physical processes. Some anthropogenic sequestration techniques exploit these natural processes, while some use entirely artificial processes.

Carbon dioxide may be captured as a pure by-product in processes related to petroleum refining or from flue gases from power generation, CO2 sequestration includes the storage part of carbon capture and storage, which refers to large-scale, artificial capture and sequestration of industrially produced CO2 using subsurface saline aquifers, reservoirs, ocean water, aging oil fields, or other carbon sinks.

Processes of carbon sequestration

Biological processes

Bio-sequestration or carbon sequestration through biological processes affects the global carbon cycle. Examples include major climatic fluctuations, such as the Azolla event, which created the current Arctic climate. Such processes created fossil fuels, as well as clathrate and limestone. By manipulating such processes, geoengineers seek to enhance sequestration.

Reforestation

Reforestation is the replanting of trees on marginal crop and pasture lands to incorporate carbon from atmospheric CO2 into biomass, (*McDermott, Mathew, 2008*) [33]. For this process to succeed the carbon must not return to the atmosphere from mass burning or rotting when the trees die, *(Gorte and Ross, 2007)* [20] To this end, land allotted to the trees must not be converted to other uses and management of the frequency of disturbances might be necessary in order to avoid extreme events. Alternatively, the wood from them must itself be sequestered, e.g., via biochar, bio-energy with carbon storage (BECS), landfill or 'stored' by use in e.g. construction. Short of growth in perpetuity, however, reforestation with long-lived trees (>100 years) will sequester carbon for a more graduated release, minimizing impact during the expected carbon crisis of the 21st century

Agriculture

Globally, soils are estimated to contain approximately 1,500 gigatons of organic carbon to 1 m depth, more than the amount in vegetation and the atmosphere, (*Batjes and Niels, 1996. and Smith, 2007)* [6, 52]. Modification of agricultural practices is a recognized method of carbon sequestration as soil can act as an effective carbon sink offsetting as much as 20% of 2010 carbon dioxide emissions annually.

Carbon emission reduction methods in agriculture can be grouped into two categories: reducing and/or displacing emissions and enhancing carbon removal. Some of these reductions involve increasing the efficiency of farm operations (e.g. more fuel-efficient equipment) while some involve interruptions in the natural carbon cycle. Also, some effective techniques (such as the elimination of stubble burning) can negatively impact other environmental concerns (increased herbicide use to control weeds not destroyed by burning).

Chemical Processes

Developed in the Netherlands, an electro catalysis by a copper complex helps reduce carbon dioxide to oxalic acid, (*Bouwman, et. al., 2010*) [11]. This conversion uses carbon dioxide as a feedstock to generate oxalic acid.

Mineral Carbonation

Carbon, in the form of CO2 can be removed from the atmosphere by chemical processes, and stored in stable carbonate mineral forms. This process is known as 'carbon sequestration by mineral carbonation' or mineral sequestration. The process involves reacting carbon dioxide with abundantly available metal oxides–either magnesium

oxide (MgO) or calcium oxide (CaO)–to form stable carbonates. These reactions are exothermic and occur naturally (e.g., the weathering of rock over geologic time periods), (*Herzog, 2002*) [25]

$CaO + CO2 \rightarrow CaCO3$
$MgO + CO2 \rightarrow MgCO3$

Calcium and magnesium are found in nature typically as calcium and magnesium silicates (such as forsterite and serpentinite) and not as binary oxides. For forsterite and serpentine the reactions are:

$Mg2SiO4 + 2\ CO2 \rightarrow 2\ MgCO3 + SiO2$
$Mg3Si2O5\ (OH)\ 4+ 3\ CO2 \rightarrow 3\ MgCO3 + 2\ SiO2 + 2\ H2O$

The following table lists principal metal oxides of Earth's crust. Theoretically up to 22% of this mineral mass is able to form carbonates.

Table 1

Earthen oxide	Percent of crust	Carbonate	Enthalpy (Kj/mol)
SiO_2	59.71		
Al_2O_3	15.41		
CaO	4.90	$CaCo_3$	-179
MgO	4.36	$MgCo_3$	-117
Na_2O	3.55	Na_2Co_3	
FeO	3.52	$FeCo_3$	
K_2O	2.80	K_2Co_3	
Fe_2O_3	2.63	$FeCo_3$	
	21.76	All carbonate	

These reactions are slightly more favorable at low temperatures. This process occurs naturally over geologic time frames and is responsible for much of the Earth's surface limestone. The reaction rate can be made faster, for example by reacting at higher temperatures and/or pressures, or by pre-treatment, although this method requires additional energy. Experiments suggest this process is reasonably quick (one year) given porous basaltic rocks, (Matter *et al.,* 2016) CO2 naturally reacts with peridotite rock in surface exposures of ophiolites, notably in Oman. It has been suggested that this process can be enhanced to carry out natural mineralisation of CO2.

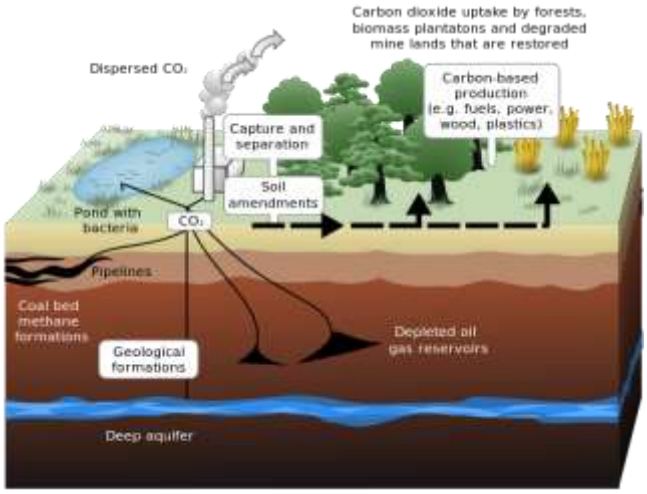

Fig 1: Schematic showing both terrestrial and geological sequestration of carbon dioxide emissions from a coal-fired plant (*Sedjo and Sohngen, 2012*) [51]

Nitrogen Cycle

Nitrogen is one of the primary nutrients critical for the survival of all living organisms. It is a necessary component of many biomolecules, including proteins, DNA, and chlorophyll. Although nitrogen is very abundant in the atmosphere as dinitrogen gas (N_2), it is largely inaccessible in this form to most organisms, making nitrogen a scarce resource and often limiting primary productivity in many ecosystems. Only when nitrogen is converted from dinitrogen gas into ammonia (NH_3) does it become available to primary producers, such as plants.

In addition to N_2 and NH_3, nitrogen exists in many different forms, including both inorganic (e.g., ammonia, nitrate) and organic (e.g., amino and nucleic acids) forms. Thus, nitrogen undergoes many different transformations in the ecosystem, changing from one form to another as organisms use it for growth and, in some cases, energy. The major transformations of nitrogen are nitrogen fixation, nitrification, denitrification, and ammonification. The transformation of nitrogen into its many oxidation states is key to productivity in the biosphere and is highly dependent on the activities of a diverse assemblage of microorganisms, such as bacteria, archaea, and fungi. Since the mid-1900s, humans have been exerting an ever-increasing impact on the global nitrogen cycle. Human activities, such as making fertilizers and burning fossil fuels, have significantly altered the amount of fixed nitrogen in the Earth's ecosystems. In fact, some predict that by 2030, the amount of nitrogen fixed by human activities will exceed that fixed by microbial processes (Vitousek 1997) [54]. Increases in available nitrogen can alter ecosystems by increasing primary productivity and impacting carbon storage (Galloway *et al.* 1994) [21]. Because of the importance of nitrogen in all ecosystems and the significant impact from human activities, nitrogen and its transformations have received a great deal of attention from ecologists.

Ecological Implications of Human Alterations to the Nitrogen Cycle

Many human activities have a significant impact on the nitrogen cycle. Burning fossil fuels, application of nitrogen-based fertilizers, and other activities can dramatically increase the amount of biologically available nitrogen in an ecosystem. And because nitrogen availability often limits the primary productivity of many ecosystems, large changes in the availability of nitrogen can lead to severe alterations of the nitrogen cycle in both aquatic and terrestrial ecosystems. Industrial nitrogen fixation has increased exponentially since the 1940s, and human activity has doubled the amount of global nitrogen fixation (Vitousek *et al.* 1997) [54].

In terrestrial ecosystems, the addition of nitrogen can lead to nutrient imbalance in trees, changes in forest health, and declines in biodiversity. With increased nitrogen availability there is often a change in carbon storage, thus impacting more processes than just the nitrogen cycle. In agricultural systems, fertilizers are used extensively to increase plant production, but unused nitrogen, usually in the form of nitrate, can leach out of the soil, enter streams and rivers, and ultimately make its way into our drinking water.

One common consequence of increased nitrogen is an increase in harmful bush burning (Howarth 2008) [22]. Indiscriminate bush burning have been associated with high

release of nitrogen in the atmosphere. Even without such economically catastrophic effects, the addition of nitrogen can lead to changes in biodiversity and species composition that may lead to changes in overall ecosystem function. Some have even suggested that alterations to the nitrogen cycle may lead to an increased risk of parasitic and infectious diseases among humans and wildlife (Johnson *et al.* 2010) [27]. Additionally, increases in nitrogen in aquatic systems can lead to increased acidification in freshwater ecosystems.

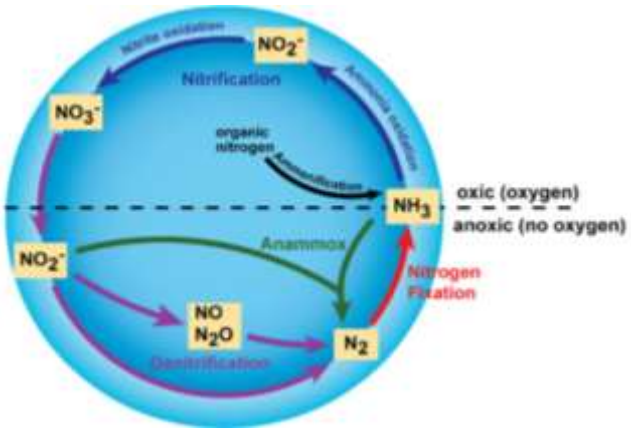

Fig 3: Major transformations in the nitrogen cycle, (Nature Education, 2010).

Regulations on Bush Burning in Nigeria

Prior to the coming into force of the UN Convention to Combat Desertification, certain national and state Laws and regulations, which relate directly or indirectly to desertification control or related matters have been in force in Nigeria. In many situations, these Laws contain provisions that address the causes of desertification such as deforestation, over–exploitation of natural resources, inappropriate agricultural practices, bush burning, etc. Such Laws include the Federal Environmental Protection Agency (FEPA) Decree, the National Parks Decree 101 of 1991 [19], the Environmental Impact Assessment (EIA) Decree No 86 of 1992, the Endangered Species (Control of International Trade and Traffic in Fauna and Flora) Decree, 1985 and the National Water Resources Decree No. 101 of 1993 [19]. (Federal Republic of Nigeria, 1999) [14].

Some of the laws regulating desertification in Nigeria are as follows:

Some government policies regulating bush burning practice in Nigeria

National Agricultural Policy

Within the National Agricultural Policy, there are sub-sectoral policies covering livestock, forestry, food production, and land and water resources. The relevant sections of this policy that are relevant to desertification control include:

- The protection of agricultural land from drought, deserts encroachment, soils erosion and flood;
- Protection and conservation of forests, forest regeneration and afforestation and promotion of alternative sources of energy other than wood;
- Ensuring integrated water resources management approaches that promote rational utilization and conservation and protection of the ecosystem. (Agricultural Policy for Nigeria, 1985) [14].

Nigerian National Environmental Action Plan (NEAP)

With the support from the World Bank, the NEAP was developed as a meaningful framework to assist in the analysis, evaluation, and discussion of the interdependence between the environment and the economy in Nigeria. It also seeks to provide an assessment of Nigeria's environmental priorities and an identification of options for mitigating the impact of environmental degradation in the country. Its implementation gave rise to the World Bank assisted Environmental Management Project (EMP) in Nigeria and helped in strengthening Environmental Agencies at Federal and State levels. It also helped to catalyse the study on costs/benefits of biodiversity conservation, enactment of EIA legislation and the setting up of environmental standards. The implementation of NEAP was also supported by UNDP through the Environment and Natural Resources Management Programme for Nigeria in the form of capacity building and institutional strengthening of Federal and State Environmental Protection Agencies. FEPA. (1991).

National conservation strategy

This is to ensure strategic approach to address environmental and natural resources issues in order to guarantee sustainable benefits to the greatest number of people. The aim is to manage the ecosystems in such a way that they yield greatest sustainable benefit to present generations while maintaining the potential to meet the needs and aspirations of future generations in such a way that essential ecological processes and life support systems are maintained. The strategy focuses on the main resources vegetation and forage resources, water resources, marine and fisheries resources, wild animal's resources, and soil resources. (NCS, 1986).

Legal Framework

Prior to the coming into force of the UN Convention to Combat Desertification, certain national and state Laws and regulations, which relate directly or indirectly to desertification control or related matters have been in force in Nigeria. In many situations, these Laws contain provisions that address the causes of desertification such as deforestation, over–exploitation of natural resources, inappropriate agricultural practices, bush burning, etc

Federal environmental protection agency (FEPA) decree

At the national level, the Federal Environmental Protection Agency (FEPA) was established pursuant to Decree No. 58 of 1988 as amended by Decree No 59 of 1992 and as further amended by Decree No. 14 of 1999 [19]. The Decree places on FEPA the overall responsibility for the protection and development of the environment and biodiversity conservation and sustainable development of Nigeria's natural resources in general. The Agency is also empowered to prepare comprehensive national policy on environment and conservation of natural resources, including procedure for environmental impact assessment for all development projects. Federal Environmental Protection Decree 59, (1992) [19].

State Laws and Regulations

At the state level, there are series of forestry, agricultural and wildlife laws as well as bush burning and grazing

reserve regulations. These categories of laws are directed at controlling the notable causes of desertification earlier enumerated. The most significant of these laws relevant to desertification control are the Forestry Laws most of which, derive their validity from the old Northern Region Forestry Law. Such laws empower each state to manage its forest estates and grazing reserves as well as reforestation of their desert encroached areas. Nevertheless, most of the State Laws especially the Forestry laws are outdated and require review.

Conclusion

The issue of bush burning appears as a central theme in this report because bush burning is one of the challenging 'man versus environment' conflicts. Burning is embedded in the cultural values and traditional farming systems of some people especially in Northern Nigeria. The effects of bushfire on rural livelihoods and on the ecosystem are increasingly becoming extensive and damaging. However, it has been difficult to reduce or completely eliminate bushfires.

The difficulties of eliminating bushfires completely means that there is need for a clear understanding of the causes and effects of bush burning so that bushfire policies can address the undesirable effects with respect to forestry, arable agriculture, rangeland, soil conservation and wildlife.

However, the results of some laboratory analysis indicated that burning has no significant effect on the pH, electrical conductivity, exchangeable sodium percentage, effective cation exchange capacity, percentage base saturation and the amounts of potassium and sodium of the soil while the amounts of organic carbon, total nitrogen and available phosphorus of the soil were seen to be significantly affected as a result of burning. The amounts of organic carbon, total nitrogen, available phosphorus, calcium and magnesium contents of the soil were seen to decrease as a result of burning. (Pantami, *et. al*., 2010). Burning causes reduction in the fertility status of the soil; therefore, farmers should be cautious of the use of fire as a means for land clearance as there might be cumulative negative effects as a result of burning which will lead to far greater loss in soil fertility and that can ultimately affect optimum crop production.

Bush burning can impact on the public health through increased heat waves, potential to initiate skin cancer and enhancement of favorable environmental conditions for diseased conditions and vectors. Oxides of Sulphur and nitrogen gotten as a result of bush burning remain hazardous as they cause respiratory disorder characterized by excessive mucus secretion in the bronchial tubes. Oxides of Sulphur and nitrogen are also hazardous as they cause respiratory disorders and irritant respectively, and many other health challenges.

Education and community awareness material including government regulatory policies needs to focus especially on the threat to the environment and property of inappropriate use of fire, particularly burning which is too frequent, extensive in area, of excessive intensity, badly timed or carelessly implemented.

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