Problems and Remediation of Some Polluted Soils in Benue State, Nigeria

S. T. Dayok\textsuperscript{1} and A. T. Gani\textsuperscript{2*}

\textsuperscript{1}Department of Agricultural Science Education, Federal College of Education, Pankshin, Plateau State, Nigeria.

\textsuperscript{2}Department of Soil Science and Land Resources Management, Federal University, Wukari, Taraba State, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author STD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author ATG managed the analyses of the study. Authors STD and ATG managed the literature searches. Both authors read and approved the final manuscript.

ABSTRACT

Exploitation of natural resources is a vital condition of human existence. Population growth leads to competition on the natural resources thus, creating negative impact on the environment leading to the destruction of ecosystems and pollution. The concern here is that human existence is under threat. Benue soils are shallow, underlying clay accumulation with poor internal drainage. This drainage problem often results in problems such as over flooding causing land, water, and air pollution. Crusting is also part of the problems of the soils and may lead to low infiltration and poor seedling germination and emergence. It is hereby suggested that to remedy these problems, land should be used wisely to the benefits of human existence while protecting its value for the use of future generation. Fertilizer and chemicals such as herbicides importation and manufacturing must meet specifications to safeguard the environment. Soil organic matter should be maintained through adequate fertility of the soil and soil survey to avoid failure and to protect the environment. Technology and innovations that fit easily into the existing farming systems should be adopted for...
easy acceptance by farmers. Importations of machines and implement must meet specifications. Indigenous engineers should be encouraged and supported by the government to design machines that are suitable for the soils and the environment.

Keywords: Remediation; environment; ecosystem; degradation; resources.

1. INTRODUCTION

Exploitation of natural resources is a vital condition of human existence. Throughout the history of mankind, humans have worked on natural resources to produce the materials they needed to sustain growing human populations [1]. This primarily refers to food production and development but many other entities from the environment have been extracted [1]. Natural resources are important materials for a stable natural economy and social development. They can be divided into two, the exhaustible such as minerals and the inexhaustible such as forest and grassland [2]. With industrialization and urbanization, the great demands of mankind for natural resources with their large scale exploitation and their consumption has resulted in weakening, deterioration and exhaustion of these resources [1].

In the strive for survival and development, man creates a lot of negative impacts on the environment which ranges from over-exploitation of resources, destruction of ecosystem and pollution [3]. Often the nature of exploitation has been in a non-sustainable manner which is causing increasing concern, as the non-sustainable exploitation of natural resources ultimately threatens the human existence [4,5] and the difficult task faced by both developed and developing nations is how to guarantee the lasting utilization of natural resources at the lowest possible environmental cost, while still assuring the economic and social development.

In the last three decades, global concern has accelerated and focused on anthropogenic activities that alter the natural environment during exploitation of natural resources and the attendant impact on the physical environment. These concerns have translated into several initiatives at the global level intended for adoption at national and local levels ultimately with a view to engendering environmental sustainability [6]. In 1992, the United Nations Conference on Environment and Development (UNCED) held in Rio de Jeneiro, produced an action document tagged agenda 21 [7,8]. The document acknowledged the perpetuation and worsening deterioration of Ecosystems on which we depend for our well-being, amongst other Social Economic disparities between nations. In the last two decades, public interest in land quality has been on the increase throughout the world as mankind recognizes the fragility of Earth's soil, water, air resources and need of their protection to sustain Civilization [9].

1.1 Historical Background

History has it that neglect and abuse of soil resources has led in many instances to human suffering and even to the downfall of countries and civilization. Human tragedy repeated periodically on the bank of Yellow River- China’s Sorrow- provides a well-known example of suffering caused by misuse of the watershed. In many countries from Asia to Near East and North Africa, once green and productive lands have turned barren deserts through the abuse of soil resources. Lands described in the Bible as flowing with Milk and Honey over three thousand years ago are now badly eroded leaving bare hills and bedrock [10,11]. Countries which were granaries of the Roman Empire present the same pictures.

The concept of soil quality was first revealed in 1977 at a conference [12,13] which focused on the risks and benefits associated with intensive agriculture, but the concept was not discussed until 1980s when it was defined based on the ability of soil to support crop growth, including factors such as tilth, aggregation, organic matter content, soil depth, water holding capacity of the soil, infiltration rate, pH changes and nutrient capacity. Larson and Pierce [11] defined soil quality as the capacity of the soil to function in the ecosystem boundaries and to interact positively with the environment external to that system. Land degradation is a concept in which the value of the biophysical environment is affected by one or more contribution of human-induced processes upon the land [12]. Evans [14] defined land degradation as a reduction in the productivity ability of the soil. The world’s productive croplands are in decline due to the pressure of human activities. The soil which is very fundamental to agricultural production is a
dynamic and natural body composed primarily of weathered material along with water, oxygen and organic materials. Soil is a key element of land resource, a vital natural resource that is non-renewable on the human time scale [15] and is a living, dynamic natural body that plays many key roles in terrestrial ecosystems. It is the essence of life and health for the well-being of humankind and animals and the major source of most of our food production. The soil covers most of the land surface with a fragile thin mantle. Soil organic carbon (SOC) is the most often reported attribute and is chosen as the most important indicator of soil quality and agricultural sustainability [16,17]. The process of soil degradation could be physical, chemical and biological [18] and takes the form of structural deformation, eg crusting accelerated erosion, imbalance in water to air ratio which could impede root penetration and development. Chemical degradation includes processes such as fertility depletion, laterization, sodification, aluminium toxicity or limit the ability of plants to pick up needed nutrients in the soil. The biological degradation includes a decline in soil organic matter, soil biomass content and alteration in biological process in the soil. One major consequence of these degradation processes is soil pollution [19].

Environmental issues in Nigeria did not gain official prominence until 1988 Koko toxic waste dumping saga [20,21] which also brought to the fore the exigent need to establish the Nigeria Federal Environmental Protection Agency (FEPA), Federal Ministry of Environment and other relevant agencies, ostensibly to tackle environmentally related issues such as environmental pollution, sanitation, depletion of the ozone layer, desertification, flooding, erosion, poverty, bush burning, deforestation and soil conservation [20]. These are pointers to the fact that issues of environment and soil pollution which forms the basis for this paper has taken a center stage in the development process of the nation.

2. SOIL POLLUTION

2.1 The Concept of Pollution

The committee on pollution defined pollution as undesirable change in physical, chemical or biological characteristics of our air, land and water that may or will harmfully affect human life or that of other desirable species, our industrial processes, living conditions, cultural assets that may or will waste or deteriorate our raw materials resources [22]. Pollution from the above definitions is therefore seen as a disorder within an environment and is a by-product of energy conservation and the use of resources. Evelyn and Tyav [22] therefore see pollution as “a contamination, defilement, a mischief, perturbation and reduction in the value of an object or thing”. Similarly, Jande [9] describe pollution as “to make something dirty or no longer pure, especially by adding harmful or unpleasant substances to it”. This paper therefore will see pollution as a situation where waste-materials and/or harmful substances which can deplete, wear/tear away and affect soil and the entire environment and cause disorderliness to living organisms [23].

2.2 Sources of Pollutants: Distributed and Pointed

Pollutant is a biological or chemical substance which is very dangerous to other organisms when consumed in excess [24]. Contaminants are soluble in hydrological environments regardless of whether the concentration of the soluble reached the level that will cause degradation of groundwater quality [25]. Pollution occurs in a higher concentration while contamination occurs in lesser magnitude. Pollution is a heavy load while contaminant is a light load. Distributed sources of pollution and contamination means that the sources of pollution may not be easily defined mathematically e.g. agricultural pollution where the pollution comes from agriculture during fertilizer application such as nitrate (NO$_3^-$); phosphate (PO$_4^{3-}$) and sulphate (SO$_4^{2-}$) [26]. Pointed sources can be given a definite boundary eg oil spillage, landfill, acid mine waste, human waste, septic tank system etc. A point source originates from a singular location, a line source has predominantly linear alignment and a diffuse source occupies an extensive area that may or may not be defined. Table 1 shows the Mean ± S.D. values of analyzed heavy metals (mg/kg) in soils in parts of Benue State, Nigeria.

2.3 Causes of Soil Pollution

The genesis of soil pollution stems from misuse or unwise use of land resources [30]. The unwise use of land resources results from population build-up. As the population builds up, pressure on land resources to meet the diverse need of man also build up. The pressure of population leads man to undertake various kinds of activities on the land resource not minding the capacity
and suitability of the land (soil) for the intended use [17,31]. Marginal lands are often put into use regardless of their fragile nature. Conservation is not often put into consideration since whatever available space is being exploited. Hauser [32] posited that as the population of a society increases in size, individual members of the society exert more pressure on scarce available resources such as land and other natural endowments for survival. The people directly or indirectly carry out socio-economic activities that pollute the environment/soil, and further cause harm (degradation) to the environment/soil/society. The socio-economic activities according to Hauser [32] include subsistence agricultural activities of people in agrarian societies of Africa, Latin America e.t.c and the commercial and industrial activities of people in urban industrialized societies of Western Europe and North America.

Hauser [32] further argue that development is needed when a society outgrows its resource base and productive system. The author posits that as the established economic system of a given environment/society is proved inadequate and productive system becomes more problematic, societies are therefore driven to change their methods. For instance, as the population of a society outgrows the available resources, especially in agrarian societies, people are forced to migrate to urban centres/cities in search of job opportunities [33,34]. The urban and city dwellers establish and carryout industrial activities that equally pollute the environment. These activities directly and indirectly pollute the environment with its attendant consequences on biodiversity. Empirical evidence has shown that primitive farmers use fire to clear their farmland, modifying the soil by ploughing, alter the drainage by irrigation and introduce or breed new animals and crops. These activities no doubt alter the natural vegetation of the environment. Kelvin and Levis [34] stated that “in recent times, humans have destroyed enormous tracts of natural vegetation, excavated large areas of land, greatly modified the landscape, and even created new lands. The economic importance of vegetation to mankind cannot be overestimated. Apart from the fact that it serves as a primary source of food to man, its provision of the resource base to the building, manufacturing and pharmaceutical industries and as fuel is in-exhaustive [35].

Modern agriculture involves extensive use of fertilizers, pesticides and herbicides to obtain high crop yields. Some of the chemicals applied to farmlands move down with deep percolating water from the root zone and contaminate groundwater. In humid areas, the major contaminant arising from agricultural activities is nitrate whereas Total Dissolved Solid (TDS) and NO₃ are of most concern in arid irrigated areas [36,37,38].

Between ⅛ and ⅜ of water applied for irrigation is consumed by evapotranspiration. The remainder termed irrigation return flow drains to surface channels or joins the underlying groundwater where it increases the salinity of irrigation return flow from 3 to 10 times that of the applied water [1,39]. Groundwater degradation results from the addition of salt by dissolution during the irrigation process from salt added fertilizer or soil amendments and from the concentration of salt by evapotranspiration [40]. Principal cations include calcium, magnesium and sodium, major anions include bicarbonates, sulphate, chloride and nitrate. This is because irrigation is the primary use of water in arid and semi-arid regions, and its flow can be the major cause of groundwater pollution in such regions [41].

When fertilizer is applied to agricultural lands a portion usually leaches through the soil to the water table. The main components of fertilizers are N, P and K. Of these three key nutrients in fertilizer, nitrogen (N in the form of NO₃ is the
one that most commonly cause contamination of groundwater beneath agricultural lands. Phosphorus (P) and potassium (K) fertilizers are readily absorbed on soil particles and seldom constitute a pollution problem. While nitrogen in solution is partially used by plants or absorbed by soils, it is the primary fertilizer pollutants [42,43].

Shallow groundwater may be contaminated locally as a result of leaching of nitrate from livestock wastes. The conversion of nitrogen to nitrate in these wastes take place through biochemical processes. Relatively small source areas like farm manure piles, poultry waste lagoons and feedlots constitute nitrate to groundwater but if these contaminants sources are not directly underlain by aquifer, the contamination is rarely very significant [1]. Contamination of shallow wells in agricultural areas by nitrate and other constituents could also occur because of faulty well construction. If wells are not properly sealed by grout or clay along the wellbore above the screen, contaminated runoff can easily make its way to the aquifer zone near the well screens. Soil amendments are applied to irrigated lands to alter the physical or chemical properties of the soil e.g. lime, gypsum and sulphur are widely used for this purpose. Substantial among of these amendments may eventually lead to groundwater or even surface water by erosion thereby increasing the salinity [44].

Concurrent with the widespread increase in the use of chemical fertilizers has been the rapid development and use of a large number of organic pesticides and herbicides. Pesticides (which are usually chemicals applied to control or mitigate pests) can be significant in agricultural areas as a diffuse source of groundwater and surface water pollution as a result of erosion. The presence of these materials in water even in minute concentration can have serious consequences concerning portability of the water [45,46].

In their report on the causes of soil pollution through agricultural activities, Mackenzie and Mackenzie [34] identified primary causes of land degradation to include; deforestation, overexploitation for fuelwood, overgrazing. Obi [18] identified factors such as excessive cultivation, untimely cultivation, indiscriminate and excessive use of chemicals, intensive row cropping, monoculture and high stocking as a major contribution to land degradation in Africa. On the global basis, soil degradation is caused primarily by overgrazing (35%), agricultural activities (28%) deforestation (30%), over exploitation of land to produce fuelwood (4%) and industrialization [47]. Fig. 1 shows potential interrelated pathways for soil-subsurface chemical contamination, Fig. 2 shows agricultural sources of soil pollution and Fig. 3 is a simplified scheme of processes controlling behaviour (fate and transport) of organic contaminants in soil.

2.4 Problem of Soil Pollution in Benue State

Benue State is within the Southern Guinea Savanna agro-ecological zone of Nigeria and is characterized by distinct wet and dry season. The mean annual rainfall is about 1137 mm with a distribution between April to October. The landform is moderately undulating. The total average evapotranspiration is estimated at about 2,602 mm with a mean annual relative humidity of about 40.7 percent [15]. The people of the state principally engage in agricultural activities. This activities account for a greater percentage of the degradation type which are many but this paper is interested in soil pollution.

Clearing of vegetation in order to produce food and cash crops leave the soil surfaces bare, resulting to increase in the rate of runoff leading to wearing-away of land surface which lead to reduced fertility of the soils, since the topsoils are the richest in soil nutrients and organic matter content. This is noticed more in the resultant gullies at the Southern part of Benue State e.g. Otukpo, Otukpa and Ugbokolo [50]. These gullies serve as channel to runoff which transports eroded soils and deposits them in streams and rivers. The deposition of sediments in streams and rivers results to siltation and accumulation of silt particles. The phenomenon could result in pollution of water for domestic and industrial purposes. It also led to eutrophication of water bodies. Consequently, beneficial aquatic animals are deprived of oxygen for respiration. Again, the sedimentation of particles in streams and rivers may lead to flooding [41]. Flooding has a serious consequence on the environment, economic and social life of the people. On October 9th, 2012, the President of Nigeria Dr. Goodluck Ebele Jonathan in a National broadcast on flood disaster in Nigeria announced that the Federal Government earmarked over Seventeen Billion Naira (17,000,000,000.00) to assist flood victims and flood disaster areas in Nigeria. He categorized the States into groups' base on the severity of the damage in the states. He grouped
the states from A to D in order of intensity and seriousness of the havoc caused by the flood in which Benue State was categorized under group A. Floods may also lead to the displacement of people resulting in flood refugees which could lead to hunger and diseases. People’s livelihoods are being harmed, and people who are already poor are becoming even more impoverished. Some lands become unlivable and water supply is affected.

Fig. 1. Potential interrelated pathways for soil-subsurface chemical contamination [48]

Fig. 2. Agricultural sources of soil pollution [48]
Constant bush burning and rapid mineralization of organic matter is a common feature of low-income agriculture especially in the tropics [51,52]. This results in rapid organic matter depletion. Organic matter is the storehouse of nutrients and soil modification material. Its depletion leads to reduction in soil nutrient status and consequently increases the vulnerability of the soil to crumbling and detachment and transport. It is evident that most croplands in the state are unproductive today due to this phenomenon. The depletion of organic matter may lead to desertification due to lack of soil cover. Naturally, most parts of Benue State belong to the derived Savanna which expectedly should not experience any serious form of desertification [50]. However, the encroachment of marginal lands due to loss of fertile and productive lands because of the quest to increase productivity and also because of the demand for fuelwood and timber. Certain parts of Benue State are excessively deforested and are prone to desertification and its attendant effect. Such effect may include wind erosion leading to air pollution [15].

Acidification and salinization may also be another problem of soil erosion in Benue State. Although no serious report of salinization has been reported in Benue State [15], the downward and lateral transport of soil nutrients in solution due to high torrential rainfall intensity in this region causes soil acidification to crop fields across the state resulting in poor yields. The high evapotranspiration which sometime exceeds precipitation is also potentially a salinization process. Ivara, [53] classified soils of Benue valley to consist of Alfisols, Entisols and Ultisols. These soils are shallow with underlying clay accumulations and poor internal drainage. These soils may also contain plinthite subsurface layers and sometimes protrude to surfaces of soils as out-crops. Due to poor internal drainage of these major soils, infiltration is reduced and in a period of high temperature and evapotranspiration, soil crusting can become an easy feature on some croplands in Benue. Soil compaction is another major problem in Benue State. The lush vegetation in the state is suitable for the grazing of animals especially cattle, resulting in high annual grazing rate. Overgrazing and overstocking may lead to soil compaction. One major problems of crusting and compaction is poor infiltration which could result in runoff and hence erosion and its attendant effects.

Population pressure which is the driving force of misuse of land to improper agricultural practices under constraints such as the saturation of good lands under population pressure which leads settlers to cultivate too shallow or too steep soils, plough fallow land before it has recovered its fertility or attempt to obtain multiple crops by irrigating unsuitable soils [53].

Severe soil erosion affects a significant portion of the arable lands, decreasing the wealth and economic development of nations. It cancels out gains advance by improved crop yields and reduced population growth. As the land resource base become less productive, food security is compromised and competition for dwindling resources increases, the seeds of famine and potential conflict are sown. The effects of soil erosion often significantly pollute receiving water sources since soils, along with nutrients and contaminants associated with soils, are delivered in large quantities to environments that respond detrimentally to their input [54,55].
3. REMEDIATION OF POLLUTED SOILS

Nathanail [56] referred to sustainable remediation as remediation that eliminates and/or controls unacceptable risks in a safe and timely manner, and which maximizes the overall environmental, social and economic benefits of the remediation work. Sustainable management requires the incorporation of the best available techniques, not only during the remediation process itself, but for the whole process, including risk assessment and risk reduction. Best management practices (BMPs) are individual or combinations of management, cultural and structural practices that researchers (academic or governmental) have identified as the most effective and economical way of reducing damage to the environment [57]. Remediation is commonly done on a site-by-site basis, since for every combination of pollutant, soil property, land use, property and liability regimes and technical and economic reality of the site or area, a different technique or combination of techniques may be more appropriate [58]. Remediation techniques can be divided in two main groups: in situ (on the site) and ex situ (removal of contaminated soil for treatment off the site) remediation. Available remediation options include physical, chemical and biological treatments, and these options offer potential technical solutions to most soil pollution [59]. For both in situ and ex situ, the net effect on the contaminants can be categorized as reducing the concentration, reducing the bioavailability without reducing the concentration, encapsulating in an inert matrix, containment, and removal [59]. The management of polluted sites is a site-specific approach that includes characterization, risk assessment and remediation technologies selection, and therefore is mainly focused on local or point-source contamination. Scullion presented a review of the main treatment approaches to remediate polluted soils and their effect on pollutants [60], specifying whether they are degraded, separated from soil components, extracted from the matrix or stabilized (Table 2).

Table 2. Main remediation methodologies and their effects on soil pollutants (✓ = main process, (✓) = subsidiary process limited in extent or in the range of pollutants affected) [60]

| Process treatment                  | Destruction/degadation | Solid separation | Extraction/loss | Stabilisation |
|-----------------------------------|------------------------|------------------|----------------|--------------|
| **Physical remediation methodologies** |                        |                  |                |              |
| Thermal                           | ✓                      | ✓                |                |              |
| Solidification                    | ✓                      |                  |                |              |
| Vapour extraction                 | ✓                      |                  |                |              |
| Air sparging                      | ✓                      |                  |                |              |
| Washing/pump and treat            | ✓                      |                  |                |              |
| Electroremediation                | ✓                      |                  |                |              |
| Particle sorting                  |                        |                  | ✓              |              |
| **Chemical remediation methodologies** |                        |                  | ✓              |              |
| Oxidation                         | ✓                      |                  | ✓              | ✓            |
| Reduction                         | ✓                      |                  | ✓              | ✓            |
| Hydrolysis                        | ✓                      |                  | ✓              |              |
| Solubilisation                    | ✓                      |                  | ✓              |              |
| Dechlorination                    | ✓                      |                  | ✓              |              |
| pH manipulation                   | ✓                      |                  | ✓              |              |
| **Biological remediation methodologies** |                        |                  |                |              |
| **Microbial activity**            |                        |                  |                |              |
| Land farming                      | ✓                      |                  | ✓              |              |
| Biopiling                         | ✓                      |                  | ✓              |              |
| Composting                        | ✓                      |                  | ✓              |              |
| Bioreactor                        | ✓                      |                  | ✓              |              |
| Bioteaching                       | ✓                      |                  |                |              |
| **Plant activity**                |                        |                  |                |              |
| Phytostabilisation                | ✓                      |                  | ✓              |              |
| Phytoextraction                    | ✓                      |                  | ✓              |              |
| Phytodegradation                  | ✓                      |                  | ✓              |              |

Nathanail, P. 2011. Sustainable remediation [61]


4. CONCLUSION AND RECOMMENDATIONS

Soil pollution poses threats to livelihood, the environment and human existence. It is therefore, necessary to ensure that its progression is curtailed and its effects on the environment lessen to enhance sustainable growth and development. This paper examined soil pollution problems and remediation of polluted soils in Benue. The paper observed that for the human to continue to exist, exploitation of natural resources is an essential condition. However, the exploitation of the natural resources has been done indiscriminately leading to land degradation and pollution. The paper recommended some remedies to this problem which include land use planning, government to formulate appropriate fertilizer policy, maintenance of organic matter, development of environmentally sound irrigation practice, working with farmers to adopt new technology and importation of the right types of machines and farming implement.

4.1 Land Use Planning

This involves a systematic assessment of land and water potentials, alternative patterns of land use and other physical, social and economic conditions, for the purpose of selecting and adopting land use options which are beneficial to land users without degrading the resources or the environment, together with the selection of measures most likely to encourage such land uses [54]. Planning precedes study and knowledge on capability, sustainability and limitations of land resource. Planning must be based on an understanding both of the natural environment and of the kinds of land use envisage. There have been many examples of damage to natural resources and of unsuccessful land-use enterprises through failure to take account of the mutual relationships between land and the uses to which it is put. It is a function of land evaluation to bring about such understanding and to present planners with comparisons of the most promising kinds of land use [54]. Land capability assessment should not be confused with suitability assessments which in addition to the biophysical features, does take into account economic, social and/or political factors in evaluating the “best” use of a particular area of land. Land capability classification gives a grading of land for broad-scale agricultural uses, whereas land suitability classification is applied to more specific, clearly defined land uses, such as land suitable for carrots [42,50].

4.2 Appropriate Fertilizer Policy

Indiscrimate importation of fertilizer into the country in an attempt to increase food production may end up doing more harm than solving problems. It is important that fertilizers are imported or manufactured based on proper adequate soil survey report to ascertain the right type(s) of fertilizer needed for soils of Nigeria and for each state and region. In this way the physical, biological and chemical properties of the soil will be safeguarded for sustainable productivity and development [20]. Fertilizers coming into the country must therefore, meet specifications not to cause pollution. Other chemicals such as herbicides, pesticides must also meet specifications. Re-evaluation of fertilizer policy of the country is also the key. Identification of local sources of fertilizer is also important so as to manufacture fertilizers that are environmentally friendly as well as give a good return on investment.

4.3 Maintenance of Soil Organic Matter

Soil organic matter is the storehouse of nutrients and a soil modification material. Farmers should therefore avoid complete removal of vegetation during cultivation. A form of zero tillage or minimum tillage is therefore advocated. Overgrazing of land should also be avoided. Vegetation intercept raindrop impact thereby increases the soil erodibility status and resist and reduces detachability of the soil. Vegetation also reduces the velocity of runoff water and reduces the forces of detachment and transportation by the runoff. The retention time of rain is also increased with vegetation cover and hence the rate of infiltration exceeds runoff hence erosion will be minimal [56].

4.4 Development of Environmentally Sound Irrigation Practice

Irrigation is a delicate project and must be done after a detailed soil survey. In an attempt to obtain multiple crops, farmers may venture into irrigation farming by irrigating unsuitable soils. Only lands that are capable of sustaining irrigation farming should be earmarked for such purpose to avoid failure and erosion hazard.
4.5 Working with Farmers to Adopt New Technology

Researchers and especially extension workers should work directly with farmers to adopt technologies that will safeguard the environment and reduce erosion risk. Farmers must buy into the idea of the new technology innovations introduced in an area. Technologies and innovations that can easily fit into the existing farming systems will be readily welcome and accepted by the farmers [52].

4.6 Importation of the Right Types of Machines and Farming Implements

Only the right types of machines and implements (plough, harrow, ridgers, etc) should be imported for use. Indiscriminate importation of these implements end up destroying the soil and making it vulnerable to erosion. Indigenous engineers must be encouraged and supported to design machines and implements that would suit our soils and environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Awalla COC. Global environmental sustainability. Good Seed publishers, Nsukka, Enugu, Nigeria. 2013;158.
2. Aji GB, Maggai MM. Environmental impact of natural resources exploitation in Nigeria and the way forward. Journal of Applied Technology in Environmental Sanitation. 2012;2:95-102.
3. Friedlova M. The influence of heavy metals on soil biological and chemical properties. Soil and Water Research. 2010;5(1):21-27.
4. Idoko SS, Ityaver ME, Tume C. Environmental implications of unsustainable natural resources exploitation. In: International Research and Development Institute. Frida MN (ed). Proceedings of international conference on sustainable development. Published by International Research and Development Institute (IRDI) in Association with Kan Education Books. 2015;268.
5. Meagher RB. Phytoremediation. An affordable, friendly, technology to resolve marginal lands in the twenty first century; 1998.
6. Ujoh F. An assessment of the environmental impact of lime stone mining and cement production at Yadev, Nigeria. Ph.D thesis. Department of Geography and Environmental Management, University of Abuj. 2013;201.
7. United Nations Organization. A gateway to UN systems work on millennium development gws; 2010. Available:http://www.org/milleniumgoals/environment.shtml (Retrieved May 30, 2013)
8. EC. (Council of the European Communities) directives. 86278 EEC on the protection of the environment and in particular of the soil when sewage sludge is used. Brussel; 2000.
9. Jande GG. Legal mechanism for the control of pollution on the high seas. African Journal of Law and Development Studies. 2005;1(1):1-13.
10. Tyav TT. The Zakibiam Massacre. The Bible – New Internal Version; 2012.
11. Larson WE, Pierce FJ. Conservation and enhancement of soil quality. In: Evaluation for sustainable land management in developing world. Mumonski J, et al., (ed). Procs. Int. Workshop, Chiang Rai, Thailand, Int. Board Soil Res. Manage Bangkok. 1991;175-203.
12. Doran JW, Parkin TB. Defining and assessing soil quality. In: Doran JW, Coleman DC, Bezdicek DF, Steart BA. 9(eds). Defining soil quality for a sustainable environment. Soil Science Society of America Journal. Madison. 1994;3-21.
13. United State Environmental Pollution Agency, USEPA, US Government Office, Washington; 1986.
14. Evans R. Rural land use in England and Whales and the delivery to adjacent seas of nitrogen, phosphorus and atrazine. Soil Use Management. 2002;19:1-7.
15. Chagbe K, Gyata BA. Maximizing effects of land degradation in Benue State for sustainable food production. Mediterrane Journal of Soil Science. 2013; 4(15):93-98.
16. Cox PA. The elements on earth. In organic chemistry in the environment. Oxford University Press Inc. New York. 1995;235.
17. Claire. Understanding soil washing. Contaminated land. Application in real environments. Tech. Rep TB; 2007.
18. Obi ME. Soil physics: A compendium of lectures. Atlanto Publishers, Nsukka, Enugu, Nigeria. 2010;152.
19. Babagana GM, Aji M, Magaji M. Environmental impact of natural resources exploitation in Nigeria and the way forward. Journal of Applied Technology in Environmental Sanitation. 2012;2(2):95-102.
20. Federal Environmental Protection Agency (FEPA). Act of 1990 under Sector 38; 1990.
21. Adamu IC, Angisto IJ, Nyiatagher DT. Metal contamination at dumpsites in Makurdi, Nigeria. M.SC Thesis, University of Calabar. 2005;79.
22. Evelyn MI, Tyav TT. Frame work for land evaluation. Journal of Research in Forestry, Wildlife and Environment. 2014; 4(2):30-42.
23. Henry RJ. An overview of phytoremediation in lead and mercury. United States Environmental Protection Agency Office of Solid Waste and Emergency Response Technology. Innovation Office, Washington D. C. USA; 2000.
24. Farrah H, Pickering WF. Extraction of heavy metal ions sorbed in clays. Water, Air and Soil Pollution. 1978;9(4):491-198.
25. Alloway BJ. Heavy metal in soils. John Wiley and sons. New York. NY. USA; 1990.
26. Odoh R, Agbaji EB, Kagu JA, Thomas SA. Heavy metal speciation in agricultural farmlands in some selected local government areas of Benue State, Nigeria. Scholars Research Library. Archives of Applied Science Research. 2011;3(3):560-573.
27. Christopher IA. Therese NN. Heavy metal contamination of surface soil in relationship to land use patterns: A case study of Benue State, Nigeria. Materials Sciences and Applications. 2010;1:127-134.
28. Cox PA. The elements on earth: Inorganic chemistry in the environment. Oxford University Press Inc., New York; 1995.
29. Bowen HJM. Environmental geochemistry of elements. Academic Press, London; 1979.
30. Wuana RA, Okieimen FA. Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies for remediation. Int. Sch. Res. Netw. Ecol. 2011;402647:1-20.
31. Adamu CI, Nganje TN. Heavy metal contamination of surface soil in relationship to land use pattern. A case study of Benue state, Nigeria. Material Science and Applications. Scientific Research. 2010;1: 127-134.
32. Hauser PM. World population: Retrospect and prospect in national academy of science, rapid population growth: Consequences and policy implementa- tions. Baltimore John Hopkins Press; 1971; 103-122.
33. Kelvin TP, Levis AO. In introduction to global environmental issues. London Butter Tanner Ltd.; 1994.
34. Mackenzie FT, Mackenzie JA. Our changing earth: An introduction to earth system science and global environmental change. Prentice Hall; 1995.
35. Jenny H. The soil resource: Origin and behaviour ECCI, Stud 37. Springer-Verlag, New York; 1980.
36. David LE, Williams OR. Toxicology. In Textbook of clinical occupational and environmental medicine. Philadelphia. 1994;116-117.
37. Aiyesanmi AF. Assessment of heavy metal contamination of Robert Kiri oil fields soils. Nigerian Journal of Soil Science. 2005; 5:45-60.
38. Goyer RA. Toxic effects of metals. Incsrette and Doulls toxicity. Basic Science of Poison. (Eds) Klaassen CD. New York. McGraw-Hill; 1996.
39. Fergusson JE. Chemistry, environmental impact and health effects. Pergaman Press, Oxford. 1990;371-405.
40. Camilla T. Speak up or go under. Our climate in chaos. BBC Focus on Africa Magazine. 2009;20(4):11-12.
41. Etuonovbe AK. The devastating effects of flooding in Nigeria. Hydrography and the Environment. Zimbabwe. 2011;1-15.
42. Adekunle IM, Adetunji MT, Gbadebo AM, Banjoko OB. Assessment of ground water quality in a typical rural settlement in Southwest. International Journal of Environmental Resource Public Health. 2007;4(4):307-318.
43. Cardoso IM, Kuype TW. Mycorrhizas and tropical soil fertility. Agriculture, Ecosystems and Environment. 2006; 116(1-2):72-82.
44. United States Environmental protection agency, electrokinetics and phytoremedia- tion. In: In situ treatment of metal-contaminated soils; State of the practice,
52. EPA/542/R-00/XXX. Environmental Protection Agency. Office of Solid Waste and Emergency Response Technology Innovation, Washington D. C. USA; 2000.

45. FAO. A framework for land evaluation. Natural Resources Management and Environment Department. FAO of United Nations. 00100 Rome, Italy; 1981.

46. Khan AG. Role of soil microbes in the rhizospheres of plant growing on trace metal contaminated soils in phytoremediation. Journal of Trace Elements in Medicine and Biology. 1998; 190(1):63-68.

47. Adejuwon SA. The impacts of climate variability and climate change on crop yield in Nigeria. Paper Presented at Stakeholders’ Workshop on Assessment of Impacts and Adaptation to Climate Change. Obafemi Awolowo University, Ile Ife, Nigeria; 2004.

48. Yaron B, Dror I, Berkowitz B. Soil subsurface change. Berlin, Heidelberg, Springer Berlin Heidelberg; 2012.

49. Raymond AW, Okieimen FE, Vesuwe RN. Mixed contaminant interactions in soil: Implications for bioavailability, risk assessment and remediation. African Journal of Environmental Science and Technology. 2014;8(12):691-706.

50. Idoga S, Adegoye MS, Agbede OO. Characterization, classification and capacity grouping of soils of Makurdi Area. Journal of Agriculture, Science and Technology. 1995;58(182):22-24.

51. FAO/UNEP. Our land our future – A new approach to land use planning and management; 1995.

52. FAO/UNEP. The future of our land: Facing the challenge. Guidelines for integrated planning for sustainable management of land resources. 1999;71.

53. Ivara EE. Characterization, Classification and management of Nigerian soils. 26th Inaugural Lecture, University of Calabar; 2005.

54. Chopra N. Land use planning of southern part of Sonbhadra District, UP, using remote sensing techniques. Interaction Journal of Geometrics and Geoscience. 2012;2:4.

55. Karoca A. Effects of organic wastes on the extractability of cadmium, copper, nickel, and zinc in soils. Geoderma. 2004;112(2-4):297-303.

56. Nathnail P. Sustainable remediation: Quo vadis? Remediation Journal. 2011;21(4): 35–44.

57. Swartjes FA, Rutgers M, Lijzen JPA, Janssen PJCM, Otte PF, Wintersen A, Brand E, Posthuma L. State of the art of contaminated site management in the Netherlands: Policy framework and risk assessment tools. Science of the Total Environment. 2012; 427–428:1–10.

58. Pierzynski GM Sims, JT, Vance GF. Soils and environmental quality. 2nd ed edition. Boca Raton, CRC Press. 2005; 459.

59. Cestti R, Srivastava JP, Jung S. Agriculture non-point source pollution control. World Bank Working Papers. The World Bank. 2003;54.

60. Navari-Izzo F, Quartarei MF. Phytoremediation of metals. Minerva Biotechnologica. 2001;13(2):73-83.

61. Adriano DC, Wenzel WW, Vangonsveld J, Bolan NS. Role of assisted natural remediation in environmental clean up. Geoderma. 2004;122(2-4):121-142.

© 2020 Dayok and Gani: This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here: http://www.sdiarticle4.com/review-history/59367