ISSN: 2976-7687

Journal of Waste Management & Recycling Technology

SCIENTIFIC Research and Community

Research Article

Open Access

Soil, Water Pollution and Understanding Practices of Indigenous Farmers Tackling The Issues for Adaptation in the Peripheries of Ngaoundere Town City Adamawa Region–Cameroon

Ahmadou Bouba

Department of Geography, Ngaoundere University, Adamawa, Cameroon

ABSTRACT

As a part of the PHD and other national projects program, the study was carried on sequences of periods from 2015, 2018 and finished on December 2023. The peripheries of Ngaoundere city town, head quarter of the region of Adamawa Cameroon were the study areas. The paper described critical level of soils pollution or degradation and how traditional wells for drinkable water are exposed to air, are not protected from animals and human pollutants spread in the local communities. Indigenous farmers face a life-threatening conditions. To accommodate the issues, they adopted and applied traditional experiences for sustainable soil productivity. These include tillage, variety of crops for specific landscapes, irrigating crops in dry season cultivation, intercropping systems, new seeds crops introduction, on plots rotating system with animal fertilizers, encouraging on planting trees all around the villages and the farm borders. Drinking water, they boil the water at 100%, or exposing the water to sun radiation for 2hours in the bucket, or filter the water through a cotton stuff.

Local communities possess an intricate understanding of their local ecosystems that influence crop growth. Their knowledge guides them in selecting and adapting crops that thrive in their specific environments. By carefully observing nature, they have identified resilient varieties that can withstand pests, diseases, and unpredictable climate fluctuations. This selection process often prioritizes native and heirloom crops, which have evolved alongside indigenous communities for centuries. Supporting indigenous farmers' rights, promoting fair trade, and acknowledging the intellectual property rights of indigenous communities are crucial steps towards protecting their traditional crop knowledge and their ecosystem for long term exploitation.

Collaborations between indigenous communities, scientists, and policymakers are essential to create platforms for knowledge exchange, empower indigenous farmers, and integrate traditional practices into modern agricultural systems. By embracing indigenous crop knowledge, societies can build resilient and sustainable food systems that respect biodiversity, cultural diversity, and the rights of indigenous peoples.

***Corresponding author**

Ahmadou Bouba, Department of Geography, Ngaoundere University, Adamawa, Cameroon.

Received: November 05, 2025; **Accepted:** November 30, 2025; **Published:** December 05, 2025

Keywords: Water, Soil, Pollution, Indigenous Practices, Adamawa-Region Cameroon

Introduction and Justification

The peripheries of Ngaoundere town city are areas of agriculture and pastoralism activities. The population is at hundred percent farmers (including livestock keepers) NIS (National Institute of Statistic 2016). With an incidence of 43, 5%, poverty level in the region (NIS up cited). The yield of agricultural products and drinking water or for animals, for irrigating (vegetables, potatoes, cereals, rice etc) in dry season are so polluted and sometime not available . Depending on lands (soil productivity) and availability of water in the localities, the indigenous farmers, with long experiences, have developed malleable practices in agricultural sector for specific landscapes and indigenous experiences to purify drinking water.

Ngaoundere is the head quarter of the Adamawa region of Cameroon and is located in the Vina Division. It links the Northern parts to the Southern part of the territory.

Commonly known as "Africa in miniature", Cameroon is geographically diverse and experiences all the major climates of the continent. Climate change is expected to affect Cameroon's climatic zones differently, and extreme weather events will be more frequent and intense. Cameroon's northern regions are to remain the most vulnerable to climate. Climate change is also an imminent threat to the country's dependence on natural resources and Cameroonians' dependence on agriculture for livelihoods and subsistence. Under current climate conditions, about two million people live in drought-affected areas. Tropical forests cover almost 40% of the country and provide an estimated 8 million rural people with traditional staples including food, medicines, fuel, and construction material. Changes in temperature, rain, and droughts are putting these populations at greater risks for increased poverty and famine.

The socioeconomic impact of climate change shocks is hurting both the structural poor and the close to 40% of vulnerable households in Cameroon. Women, especially those living in conflict areas

or indigenous groups, are more severely hit by climate change because they are accounting for 75% of workers in the informal agricultural sector and are primarily responsible for the welfare of their households and food security.

Soil or water pollution are defined as the presence of toxic chemicals (pollutants or contaminants) , in high enough concentrations to pose a risk to human health and/or the ecosystem. Soil or water pollution is still said to occur when the levels of the contaminants exceed the levels that should naturally be present.

Water pollution involves the pollution of surface waters and/or groundwater, which may cause a series of diseases referred to as water pollution diseases. These could have serious health impacts on human, on animals, on environment and microorganisms of the soil. While we can control (to some extent) the water we drink, the pollution of our water streams may have long-term effects by reducing the "drinkable" water reserves. Additionally, the common filtration methods for water are not efficient for some of the new emerging contaminants which are often not even tested for contaminants.

Water pollution travels slower than air pollution but still may affect large areas (agricultural and pastoral lands and their productivity) [1].

There fore, the paper attempts to present how indigenous crop knowledge is crucial for sustainable agriculture. As modern agricultural practices increasingly dominate, the valuable wisdom of indigenous communities is at risk of being lost. Recognizing the importance of safeguarding this knowledge, efforts are to be made to document, to promote, and revitalize traditionalactices.

These practices prioritize the regeneration of ecosystems and soil health, with a focus on improving the natural capital of the land. Key principles of regenerative agriculture include minimizing soil disturbance, keeping the soil covered with vegetation or mulch, diversifying crop and animal systems, and integrating livestock with cropping systems. These practices not only improve the long-term sustainability of farming but also contribute to enhanced food security.

Food security, as defined by the United Nations (2022), exists "when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food. That meets their dietary needs and food preferences for an active and healthy life. Achieving food security is not only a moral imperative but also a fundamental pillar of global stability and peace.

Regrettably, millions of people around the world still face food insecurity, with a complex interplay of factors such as poverty, environmental degradation, and unsustainable farming practices contributing to this crisis.

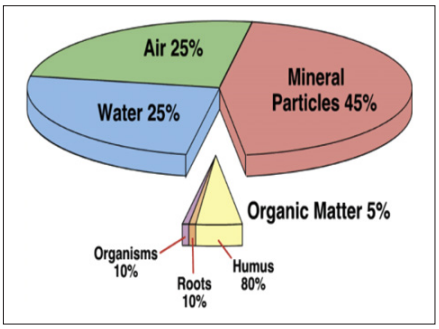
In a world grappling with the challenges of a growing global population, environmental degradation, and the impact of climate change on agriculture, the need for sustainable and regenerative farming practices has never been more urgent. Regenerative agriculture is a holistic approach to farming that focuses on revitalizing the land, enhancing soil health, and fostering biodiversity, all while producing nutritious food. This innovative approach holds great promise for addressing food security concerns worldwide. This review gives some issues on the impact of polluted soil and water.

Literature Review

The role of soils on human health is widely recognized among the scientific community. Soil pollution often has a long-term impact vary from area or locality to one another. Pollution is the largest source of premature death in the developing world, causing approximately three times more deaths than HIV/AIDS, tuberculosis and malaria combined (WHO 2019).

Polluted environment leads to the outbreak of diseases around us, yet people tend to have no idea or awareness of this grave issue at hand. Pollution in any form; whether in the water we drink, the air we breathe, the land where we grow our food or the increasing noise, we hear every day contribute to many health hazards and therefore lower the quality of life of individuals.

Irreversible loss of biodiversity is at an accelerating rate actually worldwide. According to the Millennium Ecosystem Assessment, (MEA 2022) the main sources of biodiversity loss are land use changes, unsustainable use and exploitation of natural resources; invasive alien species; global climate change; and pollution soil degradation has become a global issue and is largely due to land conversion from forests and grasslands to intensive agricultural practices. Land conversion depletes soil organic matter values, releasing large amounts of carbon dioxide into the atmosphere, contributing to global climate change and reducing soil fertility and soil health [2]. Degradation of the world's arable land and top soil might be a significant issue for the future. Human beings are in close contact with the environment and the natural resources on which our well-being depends. All components of the environment - water, air, land, organisms are interconnected and interrelated. Soil is the key link in the functioning of ecosystems. The component elements of the soil have interrelating function and have different percentages see photo below.



Soil components elements;

Ninety-five percent of our food is produced directly or indirectly from the soil, including both plant and animal products that depend on the nutrients provided by the soil (FAO, 2015).Soil regulates the exchange of gases with the atmosphere and contributes to both the storage and release of greenhouse gases, such as CO2, N2O or CH4, but also of volatile and gaseous contaminants such as mercury, radon, volatile organic contaminants Soils accumulate less than 1 percent of the global water, but this tiny amount is essential to sustain terrestrial ecosystems. Soils filter water from rainfall or irrigation, store water, support plant growth water needs, and allow the redistribution vertically and horizontally to ground and surface water bodies, thus regulating quality and quantity (O'Green, 2013). Contaminants can move relatively freely between environmental compartments, from soils to plants and animals, to the atmosphere, and to water bodies and vice versa. Therefore, a polluted soil environment poses a risk to our health including plants, animals and bacteria etc.

There are four main routes of human exposure to soil contaminants: i) accidental ingestion of contaminated food, dust, and polluted soil particles, ii) intentional ingestion of soil, iii) inhalation of soil particles, contaminated dust and vapors, indoors and outdoors, and iv) dermal contact . The negative impact of soil pollution on human health is underestimated, mainly because of the lack of information in the least developed countries, where there is little or no investment in pollution identification and quantification, and risk assessment. This is also the case in many developed countries, where measures to assess and control or remedy polluted soils are not of a precautionary nature and are only implemented after damage has been detected.

Geophagy or intentional soil ingestion is the most common type of pica, an eating disorder that involves eating items that are not typically thought of as food and do not contain significant nutritional value. The average daily soil intake of a geophagist is about 50 g of soil, although it can vary between 5 and 70. Geophagy has occurred for millennia in different human communities around the world, but also in other species. Well-documented cases are predominantly in the tropics, especially in sub-Saharan Africa, and in aboriginal communities in Australia and the Pacific and associated to people with a weaker immune system, pregnant women and children, or people suffering anemia and other micronutrients deficiencies.

The ingestion of soil particles, especially clays, can be beneficial as a food detoxifier due to absorption of pathogens, cations, and other toxicants or by preventing the absorption in the body and satisfying certain micronutrient deficiencies. Nevertheless, exposure to trace elements, radionuclides, organic contaminants such as pesticides or PAHs, and antimicrobial resistant bacteria may be increased by the ingestion of polluted soil particles. However, there are few detailed assessments of the quality of sold soil preparations, the bioavailability of contaminants, and the potential health risks posed by the ingestion of polluted soil particles .

Health effects reported in geophagists and attributed to the consumption of contaminated soil particles vary from oxidative stress and acute or chronic toxicity to cancer and neurological disorders. In the case of geophagy during pregnancy, the ingestion of associated contaminants can also have detrimental effects on the foetus such as growth retardation or premature births.

Inhalation of Soil Particles, Contaminated Dust and Vapors, Indoors and Outdoors

Inhalation of soil contaminants is more frequent in the case of occupational exposure. This may include workers from polluting industries exposed to inorganic and organic contaminants as vapors from soil and via dust, farmers exposed to agrochemical vapors and droplets, workers in landfills and pollution remediation companies exposed to soil contaminants during handling, transport and burial/digging work. Exposure conditions, contaminant concentrations and bioavailability are highly variable and include a regulatory component in terms of personal protection measures. Occupational exposure is beyond the scope of this report and is not addressed in detail.

The general population can also be exposed to soil contaminants by inhalation. Urban soils and the urban indoor and outdoor environment may contain locally released contaminants (such as those sourced from vehicle exhaust gases, lead containing paints, textile chemicals, household chemicals, etc.) but also global contaminants that can be found far from the emitter, posing a risk to the 55.7 percent of the world's population living in urban environments (World Bank, 2019). In addition, residential areas neighboring industrial sites can be affected by industrial emissions, affected by smelter-derived emissions. In both cases, trace elements deposited in soils and urban dust pose a risk to local populations, for whom inhalation of polluted dust represents a minor, but still considerable, route of exposure.

Contaminated soil particles can be mobilized during outdoor work in gardens or farms, by wind erosion, or even brought indoor on shoes and clothing from the working environment or parks.

Children are particularly vulnerable to the inhalation of contaminated soil particles because of their playing habits, which lead them to spend more time in contact with the soil .Mobilized soil particles can transport various contaminants that can be absorbed differently in the respiratory, digestive and gastrointestinal system.

Dermal Contact or Exposure to Polluted Soil

It occurs during recreational activities, gardening, farming , construction-related activities, but also from contact with household items in/on which contaminated dust has been deposited. Children are again the most vulnerable to this exposure pathway due to play habits in open spaces and poor hygiene.

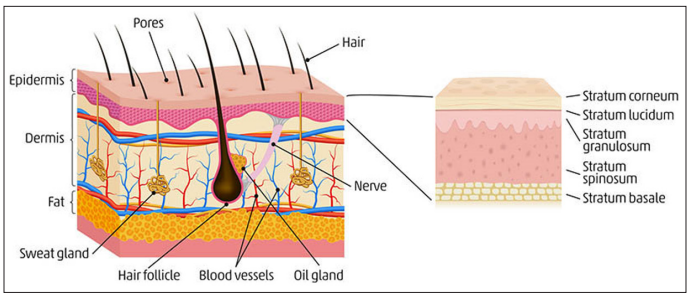


Photo Dermal parts more exposed to pollutants

Source: Ebling and Montagna 2013.

Dermal exposure to soil contaminants can cause skin diseases, such as dermatitis caused by irritation or allergies, hives, acne or even cancer. But systemic effects can also be observed if the skin barrier is bypassed, such as when contaminants enter and spread through the circulatory system. The health risk caused by exposure through dermal contact depends on the concentration of the contaminant in the soil and the form in which the contaminant is found (bound to soil particles, dissolved in solution, etc.).

The time of exposure (frequency and duration of contact); toxicokinetic considerations; and intrinsic receptor factors such as the surface of the exposed skin, the dermal adhesion of the solid particles to the skin, the thickness of the liquid films on the skin, and/or the residue transfer factors (US EPA, 2015). Numerous studies have analysed the dermal absorption of multiple contaminants, such as pesticides, trace elements, plasticizers, among others, using *in vivo* tests with experimental animals or *in vitro* or *ex vivo* tests with human corpses and skin of other mammals, and several models have been developed However, probably due to the complexity and variety of existing models and testing methods (WHO, 2014), most existing studies on dermal exposure do not consider any of the key variables for understanding and estimating potential risk from this route of exposure. Soil can have both a positive and negative impact on human health.

Healthy soils provide the necessary nutrients and clean water to plants in order to produce the population nutritious food. Often we only focusing on the quality of the final processing stages without considering the health of the soil that is required to sustain the 95 percent of food produced from the soil (FAO, 2015). We shall take account of the entire life cycle of the food we eat.

Nutrient from a poor soils result in plants that are deficient in macro and micronutrients, which can result in major nutritional deficiencies that primarily affect the development and survival of children. Currently, about 2 billion people are estimated to suffer from micronutrient deficiencies worldwide .

Healthy soils are also the source of multiple antibiotic compounds and other chemicals used to produce various medicines and vaccines. Recently, a new family of antibiotics produced by soil microorganisms with no known resistance has been identified. which clearly illustrates the great potential of soils to support the management of drug-resistant diseases that kill about 700 000 people every year currently, and are estimated to reach 10 million deaths per year by 2050 (WHO 2019).

Specific intensive agricultural practices that have led to soil degradation include frequent tillage events, failing to incorporate organic matter into a soil management plan, and monoculture cropping (Imbrenda et al). Tillage is vertically disruptive to soils and can break down soil aggregates, defined as a cluster of soil particles held together by organic matter, plant roots, polysaccharides from bacteria, and fungal hyphae. These aggregates protect soil carbon from microbial attack and are instrumental for soil carbon accumulation and sequestration. To this end, tillage harms soil's physical, chemical, and biological health.

Other intensive agricultural practices include relying solely on external sources of fertilizer, such as inorganic nitrogen fertilizer, rather than replenishing the soil with organic matter inputs. Plastic waste represents roughly 10 percent of the six million tons of waste produced every day in Cameroon, and its effects are extremely hazardous as some of it still gets burned.

In Cameroon, the law No.96/12 Of 05 August 1996 Relating to Environmental Management , lays down the general framework for environmental management The fundamental principles regulating environmental pollution are established in this law. In an attempt, to regulate environmental pollution in Cameroon, this law provides a special fund herein known as the "National Environmental and Sustainable Development Fund". The objectives of this "Fund" are to contribute to the financing of environmental auditing; provide backstopping for sustainable developments projects; provide backstopping for environmental research and education; support programs promotion clean technologies; encourage local initiatives on environmental protection and sustainable development; support legalized association involved in environmental protection. These structures carry out significant activities in this domain and backup the actions of ministries involved in environmental management.

This law prohibits any activity endangering the quality of air or provoking any form of modification of its characteristics thus possibly producing harmful effects on public health and property. Such as discharging pollutant into the air, especially smoke, toxic, corrosive or radioactive dust or gases beyond the limits lay down by the enabling instruments of this law, or by special instruments as the case might be, and discharging odors which, by virtue of their concentration or nature, are particularly inconvenient to man or animals.

While the Law No.2016/017 of 14 December 2016 on the Mining Code is not left out in the fight against environmental pollution. This code defines mining operation as non-industrial and semi mechanized non industrial mining activity. Relating to the reconnaissance, exploration, mining, treatment, or transportation of mineral substances, excluding liquid or gaseous hydrocarbons and surface water. Any mining and quarry operation undertaken must comply with the laws and regulations in force relating to sustainable environmental protection and management.

Apart from the non-industrial mining license, the exploration permit and the license for non-industrial quarry mining for domestic purposes, the granting of mining titles, quarry licenses and permits shall be subject to prior conduct of environmental and social impact assessment, a hazard and risk assessment and provision of an environmental management plan as provided for by the laws and regulations in force in matters relating to the protection and sustainable management of the environment.

The operator shall be responsible for restoration and rehabilitation and closure of mining and quarry sites. The former mining sites must be restored to stable conditions of security, agro-sylvo-pastoral productivity and appearance close their original state or conducive to any new and sustainable development deemed suitable and acceptable by the authorities in charge of mines, the environment and any other relevant authority.

Recently, over six people died in Buea in Cameroon's Southwest Region after the burning of plastic on the road by a hygiene and Sanitation Company. It released so much smoke that caused vehicles to collide.

In Douala, Cameroon's commercial capital and where the country's major plastic producers are based, gutters stink as plastic waste blocks drainage systems. While in Yaounde, Cameroon's Political capital, plastics repeatedly cause floods when it rains and destroy property and houses. According to Greenpeace, hundreds of Cameroonians die or are left displaced every year by flooding caused by blocked drainage channels.

Photo at the left,local NGOs collecting and selecting waste mater for recycling. At the right, polluted water and waste blocked the water channel and the house nearby is ready to collide due to the intensive soil humidity.

The images above show environmental pollution (at the left), the deposit of waste matter, neither population or council agents HYSACAM in charge responded for collect. While at the right the photo gives a deplorable situation of soil and water pollution. The house could not more support the weight of the walls because of the soil on the ground is degraded or polluted. Under the bridge, the black waste water coming from the surrounding houses cannot move because the solid wastes have obstructed the channel way. As consequence, the deposit site become lodgings for many

contagious diseases to the nearest population.

According to the law N° 98 /005 of april 1998 in Cameroon , related to water management (annexe 6), in its article 7, alinéa (1) , in view of preserving water quality , all water source should be protected from pollution (alinéa 2) for the public uses .Therefore (UN-WATER/WWAP, 2006) have been created. For this concern " Directive-Cadre sur l'Eau (DCE), l'Office International de l'Eau (OIEAU), le Groupe des Organismes de Bassins Européens (EURO-RIOB), etc can go through water control all over the world.

The conference of Rio de Janeiro of 1992 has pointed out that the thread and pressure on the environment and water resources, agric lands have becoming catastrophic. So strict measures should be taken to avoid global negative impact on natural resources and human live. Water or soil may commonly be polluted by main types of pollutants (dissolved or suspended in soil or water). These include:

Chemicals: including natural or man-made (xenobiotic) chemicals that gets into a water body (by being dissolved or dispersed in the water) and reaching concentrations that raise serious health concerns [3]. Similar to the case of air pollutants, the presence of such pollutants in water is not always obvious and may not be detected by our senses. Common problematic chemicals getting into water are pesticides, chlorinated solvents, petroleum chemicals, mercury, dioxins and other persisting organic pollutants

Living Organisms: As long as they are induced by human activity; some waters unaffected by human activity may still be naturally polluted with some of these organisms such as.

Pathogens: Including a variety of living organisms (usually from animal waste, viruses, bacteria, fungi and intestinal worms. Their presence in water, many times, remains unnoticed.

Algae: some types of algae are toxic and may overgrow due to the presence of nitrates and phosphates in runoff water (especially agricultural runoff); such overgrowth is usually referred to as "red tides" or "brown tides". Their toxins may affect the food chain, including fish and birds, and ultimately humans. Oxygen depletion in polluted water is another serious problem responsible for killing fish all over the world.

Excessive Fertilizers and Pesticides

Fertilizers are indispensable for increasing food production but their excessive use has occasioned much concern as a possible environmental threat. Excessive use of fertilizers is causing an imbalance in the quantity of certain nutrients in the soil. This imbalance adversely affects the vegetation. Excess use of alkaline fertilizers like sodium nitrate, basic slag, etc. may develop alkalinity in soils.

The word pesticides includes any form of chemical used for the control of unwanted herbaceous plants (herbicides), woody plants (arboncides), insects (insecticides) or any chemical that has biocidal activity affecting rodents, arachnids or any other population. Although their success in controlling pests on a short-¬term basis cannot be denied, but their long-term effectiveness in controlling pests or their overall effects on ecosystems (including human health) and environment has to be seriously questioned.

(a) Increasing concentration of pesticides residues as they move up the food chain; and

(b) Rapid evolution of new breeds of pests that are immune to the pesticides applied.

Moreover, excessive use of these pesticides, results in an increase in the level of resistance by certain pests and it may kill some useful species like earthworm which are very helpful in maintaining soil fertility. Thus, the use of pesticides leads to decline in the fertility status of soil.

Overgrazing

Increase in livestock population results in overexploitation of pastures. Due to this, grass and other types of vegetation are unable to survive and grow in the area, and lack of vegetation cover leads to soil erosion. Millions of people in Africa and Asia raise animals on pastures and rangelands that have low carrying capacity because of poor quality or unreliable rainfall Pastoralists and their rangelands are threatened by overgrazing.

Poor Drainage of Soil

Salts dissolved In Irrigation water accumulate on the soil surface due to inadequate drainage, especially during flood.

Desertification: Desertification is a widespread process of land degradation in arid, semi- arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. The UNO Conference on Desertification (1977) has defined desertification as the "diminution or destruction of the biological potential of land, and can lead ultimately to desert like conditions."

The major causes of desertification are mismanagement of forests, overgrazing, mining and extracting resources from the sub soil. Degradation of vegetative cover is caused by water erosion; wind erosion; salinization; reduction in soil organic matter and Excess of toxic substances.

Changes in Climate

It can intensify desertification and land degradation. These processes are aggravated by variations in weather, and climate change can increase such variability. If climate change continues unabated, the potential increase in the frequency and intensity of droughts would reinforce the variability of dry-land ecosystems. The increasing rate of desertification will be a threat to food security.

Soil Erosion

Accelerated soil erosion by water and wind is the major land degradation process and this is a consequence of changed relationship between environmental factors which occur as a result of human interventions [4]. Adverse changes in physical, chemical or biological characteristics of the soil result in reduced fertility and soil erosion. Other kinds of land degradation are as water-logging, chemical contamination, acidification, salinity and alkalinity etc.

Land degradation results from the combined effects of processes such as loss of biological diversity and vegetative cover, soil loss nutrient imbalance, decline in soil organic matter and decrease of infiltration and water retention capacity. Soil erosion means the removal of top fertile layer of the soil. Soil erosion by wind and water is the most common and extensive.

Erosion is called top sheet soilremoval or cut off. If it continues unchecked, numerous finger-shaped grooves may develop all over the area as a result of the silt-laden run off. This is called rill erosion. Gully erosion is an advanced stage of rill erosion because the unattended rills begin to attain the form of gullies, increasing their width, depth and length. It causes land degradation through huge loss of top fertile soil along with plant nutrients through runoff water [5]. It reduces the depth of soil where it takes place, depletes the ground water table, limits the moisture storage capacity and feeding zones of the crops, deteriorates the soil organic matter, destroys soil structure and impairs fertility due to nutrient losses.

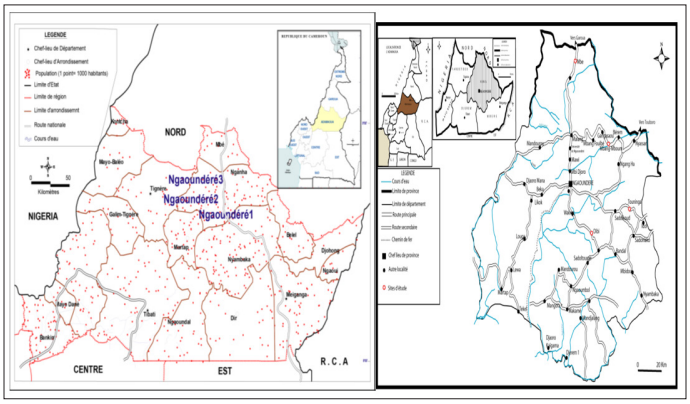
Many factors contribute to water-logging. These include inadequate drainage, improved balance in the use of ground and surface water, planning crops not suited to specific soils. Water-logging is most the serious problem in Haryana, Punjab, West Bengal, Andhra Pradesh and Maharashtra.

Landslides

The sudden movement of the soil and the weathered rock material down the slope due to the force of gravity is called a landslide. Land-slides are common in mountainous regions especially those which are situated along the river banks or near the coastline. The flow of water continuously goes on doing the eroding work which results in landslides sooner or later. Especially when the rivers are in flood they greatly add to landslides. Human activities (infrastructure building, agricultural land expansion, habitat, and mining)lead to landslides.

Study Areas

Adamawa region is located between the 6th and the 8th degree of the northern latitude and between the 11th and et the 15th degree Est longitude INC, 2020 (Institut National de la Cartographie). Adamawa region is limited from the Southern Cameroon by the Eastern and the Southern regions and from the Northern part by the North region. Our study is carried out in the Vina Division where is located Ngaoundere, the head quarter of the region. The Vina division has the largest area with (17 247 km square and 26, 8% of the region.



At the left Map: peripheries localities of Ngaoundere town city; subdivisions of Ngaoundere 1, 2, Map at the right: the three study areas with red marks Source :**ONACC 2019**.

The annual water precipitations is (1500 à 2000 mm per year. The temperature is cool, with an average of 220°C. The minimum levels are (10-19°C) from December to January while the maxima (27-34°C) are observed in March.

Source:file:///C:/Users/name/Desktop/photo%20%20verger%20bureau/RAPPORT-MONOGRAPHIE-ADAMAOUA_VF.pdf

Agriculture is a vital sector that sustains our society. Sustainable agriculture has emerged as an important approach to ensure the long-term viability of this industry. It encompasses various practices and types, such as organic farming, agroforestry, and hydroponics. Sustainable agriculture prioritizes environmental stewardship, resource conservation, and the use of innovative technologies. The study areas are with red marks. Only one (Mbang-Mboum) of them is not included. They are in the periphery of Ngaoundere town. The population of these villages are almost agriculturers and livestock keepers. They complain of the low soil fertility, poor yield crop and water shortage soon as the rains stop (ending October) the rivers dry out, the majority of bore holes no give water and the traditional wells give soil stream these ten past years.

Material and Methods

The main sources of data

Materials

Documentation

- The pedological maps done by the following authors: l'Atlas du Cameroun (1954), of Bachelier (1957), of Martin et Segalen (1966), of Humbel (1971) and Rippstein (1985) and completed our field work observation constituted the data base of information on type soil pollution or degradation
- Thesis, journals, documents of the administrative officers (rapports administratifs) from the libraries from the sub divisions and from the Vina Division.
- Third source: internet research, internationaldiscussion with colleagues

Human Resources

We worked as a team with the colleagues of the Ngaoundere University (Geography department) and those of the IRAD Institute of Research. All of the time, we receive Bsc, Master students from higher professional Institutions and from Universities to supervise them in their practical reports for their thesis.

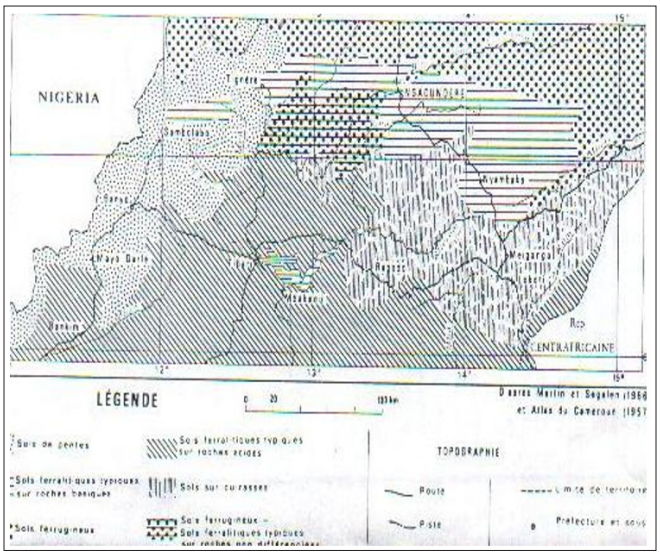
Method Approaches

Field Work

- Participative discussion, direct interview and questionnaires
- Meeting and ideas conversations with local traditional authorities, local Head officers (for agriculture, for livestock and water sectors) contributed a lot for data collection in the village areas- observing the farms, rivers, houses and compounds etc
- Exchanging interviews with the NGOs, Cooperatives delegates of the villages

Results and Discussion

From the authors we cited in the introduction and our field work observation, the following results on soil groups have been obtned;



Sources : Atlas Du Cameroun De (1954), Réalisée Par Martin Et Segalen (1966), Humbel (1971), Laplante Et Bachelier (1957) Et Ripptein (1985)

Figure 1: Pedologic Map of the Vina Division

Ferratic basaltic soil are found in Dibi and Tourningal localities while the ferragenous soil in Mbe locality

Photo red brown soils at Tourningal and at Dibi localities (these are ferralitic soil on basalt

The image at the right shows an unprotected soil, no vegetative cover, it is affected by external and internal erosion, with holes containing water runoff and soil chemicals are completely destroyed and polluted. So the land is not more convenient for agriculture neither for pastoralism. The photo at the left shows at the back some few trees while at the front the vegetative cover has disappeared after overgrazing, the soil is beginning to erode. As affected by erosion and over exploitation, the soils could not be used for farm or for animals grazing. These issues are man-made activities. This problems push the farmers to go to new lands and expanding agricultural lands but with law yield productivity.

Man-Made Activities in the Peripheries of Ngaoundere

Agricultural development means expansion of agricultural land increase in agricultural productivity and net agricultural production. It is due to development of modern scientific techniques, advanced technologies, increased production and use of chemical fertilizers, expansion in irrigational facilities, development of high yielding varieties of seeds, that pollution has proliferated.

Mining Activities Cameroon is one of the countries in Central Africa that is endowed with many mineral resources such as gold, diamond, rutile, iron ore, bauxite. Gold production in Cameroon dates back to 1934 with a production peak of 717 kg in 1942.

From that date till now gold mining is still artisanal and is located in the East, South and part of Eastern Adamawa regions. The village of Mbé one of the study area where gold mining is undertaken now (photos below) by the local indigenes for livelihood. Apart from abject poverty that characterizes the gold mining communities; major socio-economic and mining can be considered as one of the human activities which negatively influence the environment

Source field work December 2023. Gold mining site at Mbé sub-division

At the right it is a Worker's camp. Strangers specialised in the gold search are camping here with their families. They come from Tchad, Central African Republic, Mali, Burkina, Niger and Nigeria, only few Cameroonian. At the left , we see deep holes digging for gold search . The soil here is completely polluted with different pollutants. The land cannot be more for agricultural neither for rearing animals. Even the water sources are polluted and cannot be drinkable since highly contaminated with pollutants.

The following pictures show expansion lands for roads and habitat at the left. At the right, the soil is affected by both water and wind erosion impacts. In fact , the soil structures are completely modified and so can achieve its function properly at normal.

When soil structure is modified, it function can not be effectively carried out. The habitats and even organisms living in, are morever destroyed . Millions of organisms live in a tea spoon soil.

Organism	Number of Individuals per Teaspoon of Soil	Primary Role
Bacteria	5 to 500 million in agricultural soils; 20 million to 2 billion in forest soils	Consume readily decomposable materials
Fungi	Up to 40 miles of fungal hyphae	Consume hard to decompose organic matter
Protozoa	100 to 100,000	Feed on bacteria and each other
Nematodes	5 to 500 with high variability among soils	Feed on bacteria, fungi, and plant roots
Microarthropods	Several species	Feed on fungi, plants, and organic matter

Types of Soil Pollutants

Soil pollution consists of pollutants and contaminants. The main pollutants of the soil are the biological agents and some of the human activities. Soil contaminants are all products of soil pollutants that contaminate the soil. Human activities that pollute the soil range from agricultural practices that infest the crops with pesticide chemicals to urban or industrial wastes or radioactive emissions that contaminate the soil with various toxic substances.

Biological Agents

Biological agents work inside the soil to introduce manures and digested sludge (coming from the human, bird and animal excreta) into the soil.

Agricultural Practices and Pollution

The soil of the crops is polluted to a large extent with pesticides, fertilizers, herbicides, slurry, debris, and manure. Radioactive substances such as Radium, Thorium, Uranium, Nitrogen, etc. can infiltrate the soil and create toxic effects. Urban waste consists of garbage and rubbish materials, dried sludge and sewage from domestic and commercial waste. Steel, pesticides, textiles, drugs, glass, cement, petroleum, etc. are produced by paper mills, oil refineries, sugar factories, petroleum industries and others as such.

Photo Polluted Soils with Different Conducts

At the left, at Mbe locality, this area is expanded by the council office for new market building. At the right, it is an over exploited grazing land at Wakwa near Ngaoundere town city. The above images present how the soil is polluted or degraded at the left , it is covered with plastic, pieces of clothes, papers, broken bottles, plastic bags and etc.

At the right, the grazing parcel is overexploited , no more herbs, the soil is compacted and plants can no more grow on it. The animals can only feed on these polluted items. Probably the soil pollutants can be as follow There is a large variety of pollutants that could poison the soil. Examples of the most common and problematic soil pollutants are the following:

The 11 elements constitute 99.9% of the atoms in the human body. These are typically divided into major and minor elements. The four major elements, H, O, C, and N, make up approximately 99% of the human body, and seven minor elements, Na, K, Ca, Mg, P, S, and Cl, make up another 0.9% of the body (Combs 2005). Approximately 18 additional elements called trace elements are considered essential in small amounts to maintain human life.

However, human health experts do not universally agree on the exact number and identity of these trace elements. Out of the approximately 29 elements considered essential for human life, 18 are either essential or beneficial to plants and are obtained from soil, and most of the other elements can be taken up from the soil by plants (Brevik 2013a). The exceptions include H, O, and C, which plants obtain from air and water (Kirkby 2012). Therefore, soils that provide a healthy, nutrient-rich growth medium for plants will result in plant tissues that contain most of the elements required for human life when the plants are consumed (Combs 2005; Committee on Minerals and Toxic Substances in Diets and Water for Animals, National Research Council, 2005).

Negative Health Effects of Heavy Metals

Exposure to heavy metals through soil contact is a major human health concern. Arsenic is a metalloid, but it is commonly grouped with the heavy metals. The heavy metals of greatest concern for human health include: As, Pb, Cd, Cr, Cu, Hg, Ni, and Zn (Fergusson 1990). Heavy metals enter soils naturally through the weathering of rocks, but they have also been introduced into soils through human activity. Heavy metals are the by-products of mining ores, and they are present in mine spoils and in the immediate surroundings of metal processing plants. Heavy metals are released into soils from landfills that contain industrial and household wastes and from sewage sludge that comes from wastewater treatment plants.E-wastes, or wastes associated with electronic appliances, are an increasing source of Pb, Sb, Hg, Cd, and Ni in the soil [6]. Urban soils are particularly susceptible to significant accumulations of heavy metals from automobile exhaust, coal burning, erosion of metal structures, and refuse incineration. In agricultural settings, the use of fertilizers, manures, and pesticides has also contributed to the accumulation of heavy metals in soils. Arsenic has been used in pesticides, and the build-up of arsenic in orchard soils is problematic since it may persist for decades. The heavy metals with the most toxicity in humans, including Cd, Pb, Hg, and As, are those with no biological function that disrupt enzymatic activities commonly affecting the brain and kidneys (Hu 2002).

Effects of Soil Pollution

Soil pollution affects plants, animals and humans alike. While anyone is susceptible to soil pollution, soil pollution effects may vary based on age, general health status and other factors, such as the type of pollutant or contaminant inhaled or ingested. However, children are usually more susceptible to exposure to contaminants, because they come in close contact with the soil by playing in the ground; combined with lower thresholds for disease, this triggers higher risks than for adults. Therefore, it is always important to test the soil before allowing your kids to play there, especially if you live in a highly industrialized are Humans can be affected by soil pollution through the inhalation of gases emitted from soils moving upward, or through the inhalation of matter that is disturbed and transported by the wind because of the various

human activities on the ground. Soil pollution may cause a variety of health problems, starting with headaches, nausea, fatigue, skin rash, eye irritation and potentially resulting in more serious conditions like neuromuscular blockage, kidney and liver damage and various forms of cancer.

Soil acts as a natural sink for contaminants, by accumulating and sometimes concentrating contaminants which end up in soil from various sources. Tiny amounts of contaminants accumulate in the soil and - depending on the environmental conditions (including soil types) and the degradability of the released contaminant - can reach high levels and pollute the soil. If the soil is contaminated, home-grown vegetables and fruits may become polluted too. This happens because most of the soil pollutants present in the soil are extracted by the plants along with water every time they feed. Thus, it is always prudent to test the soil before starting to grow anything edible. This is especially important if your garden is located near an industrial or mining area, or within 1 mile of a main airport, harbor, landfill, or foundry.

Air pollution has detrimental effects on the environment, contributing to climate change and harming human health. It leads to the formation of smog, acid rain, and depletion of the ozone layer. A green environment is essential for our well-being, providing clean air, biodiversity, and natural resources.

Deforestation, a major cause of environmental degradation, disrupts ecosystems, reduces carbon sequestration, and threatens wildlife habitats. Plastic pollution poses severe risks to marine life, contaminating water bodies and harming ecosystems. Water pollution from industrial waste, chemicals, and sewage has adverse effects on aquatic ecosystems and human health. Noise pollution disrupts wildlife habitats, impacts human health, and disturbs ecological balance. Global warming, primarily caused by greenhouse gas emissions, leads to rising temperatures, melting ice caps, and sea-level rise. Climate change has far-reaching effects on ecosystems, weather patterns, and vulnerable communities. E-waste, if not properly managed, releases hazardous substances into the environment, posing health risks. It is crucial to promote a clean and green environment, mitigate climate change, reduce pollution, and adopt sustainable practices to protect and preserve our planet.

Biodiversity, the variety of life on Earth, is under significant threat due to various factors. This article aims to explore the major threats to biodiversity, including habitat destruction, climate change, invasive species, overexploitation, pollution, deforestation, urbanization, and agricultural practices. Understanding these threats is crucial for developing effective conservation strategies.

Habitat destruction poses a significant threat to biodiversity worldwide. It occurs through activities such as deforestation, mining, and urban expansion. As natural habitats are cleared, numerous plant and animal species lose their homes, leading to population declines and, in some cases, extinction. Key drivers of habitat destruction include land-use changes, industrial activities, and infrastructure development. Protecting and restoring habitats, implementing sustainable land-use practices, and promoting protected area networks are essential for mitigating this threat.

As we mentioned in the introduction, the population surrounding Ngaoundéré city town are at 90 % farmers including animal keepers. Early November as the rains go out, the villagers start to firer the bushes for clearing for agricultural lands, to generate the new herbs for animals, hunting.

Wildfires are one of the most devastating and terrifying forces of nature. They are unpredictable and most of the time uncontrollable. They draw strength from the wind, and are particularly devastating in areas prone to drought like the Northern part of Cameroon. Wildfires are burning events that occur in natural or semi-natural landscapes such as forests, shrub lands, or grazing lands including savannahs. They are a major natural hazardand an important source of air pollutantswhich can impact air pollution thousands of kilometers downwind. Old growth forest stands can be consumed in minutes leaving nothing but skeletal remains. Or the fire may leave the tree canopies untouched, but scour the forest floor consuming understory vegetation. Fires fill the sky with heat and gloom, raining ashes and brands of fire for miles. In a matter of hours wildland fires can change entire landscapes. Their effects are mostly destructive on soil components and on biodiversity.

Food and Water Pollution int the Localities

The woman is selling exposed food by road side (cake, groundnut, dried fruits).

Water Pollution

While the **most common water pollution diseases** involve poisoning episodes affecting the digestive system and/or causing human infectious diseases, water pollution may cause a large variety of health diseases including:

Photo . Polluted water from a natural lake; Source : field work 2023 at Dibi locality.

Here is a lake, the water is not used by population for drinking, but it is for animals and washing clothes and utensils. It is highly polluted and can contaminate a variety of diseases. Infectious diseases caused by **pathogens** (usually microorganisms) from animal fecal origins, of which the most common occur in developing countries, including: Typhoid, Giardiasis, Amoebiasis, Ascariasis, Hookworm Diseases caused by **polluted beach water**, including:Gastroenteritis, Diarrhea, Encephalitis, Stomach cramps

and aches, Vomiting, Hepatitis, Respiratory infections Liver damage and even cancer (due to DNA damage) – caused by a series of chemicals (e.g., chlorinated solvents, MTBE)

Kidney damage caused by a series of chemicals Neurological problems - damage to the nervous system – usually due to the presence of chemicals such as pesticides (e.g. DDT) Reproductive and endocrine damage including interrupted sexual development, inability to breed, degraded immune function, decreased fertility and increase in some types of cancers – caused by a series of chemicals including endocrine disruptors Thyroid system disorders (a common cause is exposure to perchlorate, which is a chemical contaminating large water bodies such as the Colorado River) Increased water pollution creates breeding grounds for malaria-carrying mosquitoes, which kill 1.2-2.7 million people a year A series of less serious health effects could be associated to bathing in contaminated water (i.e. polluted beach water) including:Rashes, Earaches, Pink eyes Water pollution can affect us:

Directly: Through consumption or bathing in a polluted stream (such as consumption of municipal water, as well as bathing in polluted lakes or beach water).

Indirectly: Through the consumption of vegetables irrigated with contaminated water, as well as of fish or other animals that live in the polluted water or consume animals grown in the polluted water. This is many times more dangerous than being directly affected through consumption of water, because some pollutants bioaccumulate in fish and living organisms (their concentration in fish could be several orders of magnitude higher than their water concentration). Additionally, the toxins from the brown tide are strong and can travel via air, affecting homeowners close to the beach.

Health and Environmental Effects of Polluted Water

The following photos show the types of water sources observed in the villages . They depend on water collected from the traditional wells,for drinking and from the rivers for aniamals and house hold uses. Some times the water from river can be drunk

Photo bore whole at (Dibi) site and a traditional wells dried out and abandoned at (Tourningal, village) According to the villagers, this bore hole have not functioned at all because the stream has not been reached after the 50 meters deep. The project could no more continue. While at the right hand, it is an old well with 70 years old, no more water supply it is abandoned. The following images show the irrigating water for vegetables (edible leguminous) are exposed to air and animals discharges and to water runoff. The photos below represent the water used for irrigating vegetable or for animal drink are completely polluted

Photo 1. The water from rivers is running and is polluted by many pollutants. Sources: field work 2023

Photo. Temporary well in the bush 2. Traditional Source: field work 2015 2018 2023

The Most Common Ways Polluting Water Include

Waste disposal: directly into water streams, onto the soil from which contaminants may leak into the groundwater; Urban and agricultural runoff; Animal waste could also add dangerous pathogens (usually microbial groups, viruses and intestinal parasites).

From air via acid rain - water can get polluted with air contaminants (that have sometimes traveled long distances – such as the case of Hg) that reach the land and water via acid rain. During precipitation, air pollutants may get dissolved in the water drops and, as a result, they may acidify the water - which is why polluted rainwater is referred to as “acid rain”.

Photo. traditional wells Sources: Field work 2015 – 2018- 2023

Their dresses, the environment, the soil even their water containers are polluted. They are highly exposed to many diseases.

Indigenous Strategies for Sustainable Management

Facing the problems of soil pollution or degradation, they adopt sustainable practices like crop rotation, integrated pest management, and precision farming that can minimize the negative

impact of agriculture on the environment. Moreover, sustainable agriculture promotes biodiversity, reduces agricultural waste, and enhances food security. It is crucial to embrace the concept of sustainable agriculture to secure a sustainable future. The photos show seed selection and seed conservation.

Photo seed maize selecting and safeguarding practices

The boy is selecting and conserving seeds to plant in the coming rains. Once, they harvest , the grains are put on a plastic and under mosquito net to prevent them against insects, rats and humidity. At the other hand, they leave the matured maize plants on the farm till the time of planting. In this case, the farm should be controlled and keep away from birds, thieves and insects Enhancing knowledge of crop adaptation and in water-use efficiency, for crop root systems, and stress tolerance, conservation tillage, and efficient water management to promote crop resilience as used in the village of Mbé where yam is highly produced. The photo below at the left present the way of conserving seed maize for future planting. The seeds are safe from insects and humidity attacks. The boy is taking off the grains and the parts in the bucket are used for cooking as fire wood. While at the right, are the empty maize sticks after harvesting left for animals to feed on and to be giving up to the soil in raining season for fertility increase.

Instead to apply chemical fertilizer (NPK), the farmers put the soil around the plants (tillage). The photos above show at the left, the yam planted on “billions” grow on the branches as support. The soil around the plants keep on the humidity for days and the plants grow well. At the right, the red beans plants mixed with other speculations are yet to join the supports. The soils assembled round the plants increase fertility, humidity and reduce erosion. Below we see variety of seeds (crop fitting with specific landscapes). The following are variety of crop seeds. They are essentially cultivated for consuming but the excess can sale. Including; maize, ground nut, red beans, white bean or (niébé), and seeds (black color) for vegetables.

All these require traditional experiences to accommodate the impact of soil pollution hat is not more productive. These crop are cultivated in small and specific landscape.

Photo newly introduced variety of zea maize

This variety of maize is not for” cous-cous” but specifically to be fried commonly called (puff corn) mixed with sugar. It is highly productive and are introduced in the village in 2019 according to the GIC delegate (initiative common group head). It comes from South Africa Traditional Methods to prevent drinking water from pollutants consist to pass the water on the cotton material as to filter it before drinking.

Or boiloing water at 100° degree and after cooling it before drinking or exposing the water at sun radiation for 1 hour or two before drinking (this method is well done at the dry season by april, march).

Conclusion

As they are poor, the peasant's practices are based much on the traditional experiences. Because the industrial agriculture is a modern farming approach that involves large-scale production, high financial means, technology, and monoculture and relies on synthetic inputs like fertilizers and pesticides to maximize yields.The intensive nature of agriculture can lead to food safety concerns. Crowded conditions in factory farms increase the risk of disease transmission among animals, potentially affecting the safety of meat products. Moreover, the use of antibiotics in livestock can contribute to antibiotic-resistant bacteria in the food chain In contrast, here traditional farming often involves smaller, diversified farms, crops that rely on natural methods and local resources. Their practices contributes to environmental issues such as soil erosion, water pollution, and greenhouse gas emissions. The extensive use of chemicals can harm ecosystems and reduce biodiversity, impacting both wildlife and human health. Organic farming, agroforestry, and regenerative agriculture focus on soil health, biodiversity, and responsible resource management. Supporting these alternatives can contribute to a more sustainable and resilient food system. Biodiversityis essential for the survival and prosperity of all species, the variety of life on Earth, including humans. Biodiversity provides us with food, clean water, air, and resources for economic development. However, human activities are causing a rapid loss of biodiversity. One way to combat this is through sustainable tourism by generating income for protected areas and providing a financial incentive for conservation.

Communities living near areas of high biodiversity often have a deep understanding of the local environment and its needs. Their involvement in tourism can ensure that activities are conducted sustainably and that benefits are shared equitably. Community-led tourism initiatives can also empower local people, improve living standards, and support traditional cultures. There are numerous examples worldwide where communities have successfully leveraged tourism for conservation and development. For instance, in Costa Rica, community-based rural tourism initiatives have contributed to forest conservation and improved livelihoods. Similarly, in Kenya, community-owned conservancies have helped protect wildlife while providing income and employment to local people.Biodiversity conservation and sustainable tourism are closely linked.

While community-driven sustainable tourism holds great promise, it also faces challenges. These include ensuring fair distribution of benefits, managing visitor impacts, and building capacity within communities. However, with appropriate support and policies, these challenges can be overcome. By harnessing (joining) the power of communities, we can promote a form of tourism that not only conserves our precious biodiversity but also brings tangible benefits to local people.

Communities living near areas of high biodiversity often have a deep understanding of the local environment and its needs. Their involvement in tourism can ensure that activities are conducted sustainably and that benefits are shared equitably [7-15].

World bank 2022 . Report towards a People-Centered Green and Resilient Cameroon

Annexe

Table 1 : Standard Concentration Values of Chemicals When Over or Under there Will be Abnormality)

Parameters	Deficiency <	Standard conc. Values for normal growth <	Toxicity
Na	-	60	+
K	-	320	+
Cl	-	200	+
Cd	-	0.01	+
Cr	-	0.05	+
Hg	-	0.005	+
Zn	-	5	+
Pb	-	3	+
N03	-	300	+
P04	-	300	+
PH	-	7.50	+

References

1. Udayakumara EPN, Gunawardena P (2021) Modelling soil erosion and hydropower linkages of Rantambe reservoir, Sri Lanka: towards payments for ecosystem services. Mod Earth Syst Environ 8: 1617-1634.
2. De Zoysa U, Gunawardena A, Gunawardena P (2020) Localising the transformation in the new normal a domestic resource mobilization framework for sustainable development goals in Sri Lanka. https://www.unescap.org/sites/default/d8files/knowledge-products/ecopy%20-%20LOCALISING%20THE%20TRANSFORMATION%20IN%20THE%20NEW%20NORMAL.pdf.
3. Li Z (2018) Health risk characterization of maximum legal exposures for persistent organic pollutant (POP) pesticides in residential soil: an analysis. J Environ Manage 1: 163-173.
4. Andualem TG, Hagos YG, Kefale A, Zelalem B (2020) Soil erosion-prone area identification using multi-criteria decision analysis in Ethiopian highlands. Modeling Earth Systems and Environment 6: 1407-1418.
5. Aslam B, Maqsoom A, Alaloul WS, Musarat MA, Jabbar T, et al. (2021) Soil erosion susceptibility mapping using a GIS-based multi-criteria decision approach: case of district Chitral, Pakistan. Ain Shams 12: 1637-1649.
6. Robinson DA, Panagos P, Borrelli P, Jones A, Montanarella L, et al. (2017) Soil natural capital in Europe; a framework for state and change assessment. Sci Rep 7 :1–14.
7. Shareef H, Hasan N (2019) Integrating of GIS and fuzzy multi-criteria method to evaluate land degradation and their impact on the urban growth of Kirkuk city. Iraq Inter J Adv Sci Tech 28: 800-815.
8. Arabameri A, Pradhan B, Pourghasemi HR, Rezaei K (2018) Identification of erosion-prone areas using different multi-criteria decision-making techniques and GIS. Geom Nat Haz Risk 9: 1129-1155.
9. Chitsaz N, Malekian A (2016) Development of a risk-based multi-criteria approach for watershed prioritization with consideration of soil erosion alleviation (case study of Iran) springer 75: 1448.
10. De Laurentiis V, Secchi M, Bos U, Horn R, Laurent A, et al. (2019) Soil quality index: exploring options for a comprehensive assessment of land use impacts in LCA. J Cleaner Prod 215 :63-74.
11. Ewunetu A, Simane B, Teferi E, Zaitchik BF (2021) Mapping

and quantifying comprehensive land degradation status using spatial multicriteria evaluation technique in the headwaters area of upper Blue Nile River. Sustainability 13: 2244.

12. (2018) Institut National de la Statistique du Cameroun, INS Deuxième Recensement Général des Entreprises (RGE) 2016, Rapport final. Yaoundé. Cameroun.
13. Imbrenda V, Quaranta G, Salvia R, Egidi G, Salvati L, et al. (2021) Land degradation and metropolitan expansion in a peri-urban environment tandfonline 12: 1797-1818.
14. Vulević T, Dragović N (2017) Multi-criteria decision analysis for sub-watersheds ranking via the Promethee method. Int Soil Water Conserv Res 5: 50-55.
15. Yang Q, Liu G, Casazza M, Campbell ET, Giannetti BF, Brown MT (2018) Development of a new framework for non-monetary accounting on ecosystem services valuation. Ecosyst Serv 34: 37-54.