CLIMATE SMART ACTIONS (CSA) AQUACULTURE, AGROFORESTRY AND RESOURCES MANAGEMENT

GLOBAL ISSUES & LOCAL PERSPECTIVES

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Global Issues & Local Perspectives

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous **Climate smart actions (CSA) aquaculture, agroforestry and resources management** issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which **Climate smart actions (CSA) aquaculture, agroforestry and resources management** issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue **Climate smart actions (CSA) aquaculture, agroforestry and resources management** necessary in policy making process that will stimulate increase in food production and environmental sustainability. **Climate smart actions (CSA) aquaculture, agroforestry and resources management :** *Global Issues & Local Perspectives* is organized in three parts. Part One deals with The Concept of **Climate smart actions (CSA)**, Part Two is concerned with The Concept of **aquaculture,** and Part Three deals with the Concept of **agroforestry and resources management**

Eteyen Nyong; March 2026

Chapter 18:

Enhancement of Soil Fertility and Nutrients Sustainability on Arable Crops Production in Agroforestry Ecosystem

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INTRODUCTION

Soil fertility refers to the ability of soil to sustain agricultural plant growth; fertile soil provides a habitat with essential nutrients and favourable chemical, physical and biological characteristics to sustain plant growth (Tang, 2025 and Tudi *et al.*, 2022). Peasant farmers used several approaches to managed soil fertility in their locality based on it productivity nature. Productivity of the soil depends on the output, while output in turns depends on soil nutrient status. Macro and micro plant nutrients are critical for plant growth and reproduction, a deficiency of them causes the plant growth cycle to fail (Zhou *et al.*, 2021). Soil nutrient status anchored on natural phenomenon like nutrient cycling, nitrogen-fixing plants through nodulations, bush fallow system and also through soil amendments like organic manures, mineral fertilizers and leaf litters decomposition. Appropriate nutrient management is crucial to beneficial agronomic systems and environmentally safe crop production (Ghosh *et al.*, 2020). However, soil fertility could be maintained and sustained through: application of manures (organic and inorganic fertilizers), traditional bush fallow system, improved bush fallow, mixed cropping system, crops rotation, shifting cultivation and nitrogen-fixing plants. Ajah (2006) noted that transformation and movement of materials within soil organic matter pools is a process influenced by climate, soil type, vegetation and soil organisms. It is possible to trace the cyclic movement of these essential chemical elements through the biosphere and by so doing; much can be learned about the interdependencies that exist. The cycles involve both physical (dissolution, precipitation, volatization and fixation) and chemical (synthesis, degradation and oxidation-reduction). Forests improve the microclimate by reducing the change caused by wind, protection against soil erosion and restoring soil productivity. Tree crops result in significant improvement in soil fertility through the addition of plant litter, nutrient cycling, biological nitrogen fixation, permeability, and water holding capacity, aggregate stability and soil temperature regimes (Aluko, 2001). Deforestation results in changing the status of the forest soil. In tropical rain forests, certain tree species are found to exert considerable influence on soil properties (Lal *et al*., 1975).

Lal *et al*., (1975) stated that soil nutrient status could be improved through nutrient cycling in terms of litter fall, litter decomposition and mineralization. This phenomenon cannot occur without forest cover. Forests, especially protected, ensure environmental sustainability and conserve biological resources for future generations (Thies and Pfeil, 2004).

Increasing human population places greater demand on forests for wood and non- wood resources which consequently results to rapid decline in the existing forest estates (Ogbonna and Nzegbule, 2010). Otorokpo (2012) noted that due to increasing pressure, bush fallow periods are short and soil fertility is highly reduced. Low crops yields are obtained when food crops are planted on farmlands with reduced soil fertility, continuous cropping and low organic matter contents. The key component of shifting cultivation system is increases recycling of plant nutrients through the addition of above and below ground biomass of the fallow vegetation (Otorokpo, 2012). Bush fallow system in the tropics accumulates large biomass and enriches soil fertility. Nwoboshi, (1975) explained that for optimal growth, plant requires essential nutrient elements such as potassium (K), magnesium (Mg) calcium (Ca). The fertility and productivity of the soil depend partly on the soil's capacity to hold these cations on particles of soil and to exchange them from hydrogen and other ions obtained from the soil or plant roots. The property that enables the soil to perform this unique function is the cation exchange capacity (CEC) (Nwoboshi, 1975). Several studies have been carried out to quantify the rate of leaf litter decomposition is a major pathway for the transfer of organic matter and nutrients in the soil within the forest ecosystems.

According to Liebig`s law of the minimum, nutrient that can limit plant growth is an essential plant nutrient, especially if the plant cannot complete its full life cycle without it (Foster and Bahatti, 2006). There are two of groups of nutrient elements, namely: (a) major, essential or macro- nutrients and (b) minor, non- essential or micro-nutrients. This classification is due to their relative abundance in plants.

According to Otorokpo (2012) and Tisdale (2003) macro- nutrients can be broken into two more groups, namely: primary and secondary nutrients. The primary macro- nutrients are: nitrogen (N), phosphorus (P), potassium (K), whereas the secondary macro-nutrients are: calcium (Ca), sulphur (S) and magnesium (Mg) (Foster and Bhatti, 2006; Evans, 1992; Ken, 1986).

Tisdale, (2003) reported that macro-nutrients are consumed in large quantities and are present in plant tissues in quantities ranging from 0.2% to 4.0% on a dry weight content. These primary macro-nutrients are often lacking in the soil mainly because plants often utilized large quantities of these macronutrients for their growth and survival. Secondary macro nutrients which are always enough in the soil do not always require fertilizer application.

Micro-nutrients {chlorine (Cl), manganese (Mn), boron (Bo), iron (Fe), copper (Cu), molybdenum (Mo), and zinc (Zn)} are those essential elements that plants need for growth but in relatively small quantities. Organic matters are excellent ways of supplying micro-nutrients to the soil. According to Tisdale (2003), micronutrients are present in plant tissues in quantities that are measured in parts per million (ppm), and range from 5 to 200ppm or that are less than 0.02% of their dry weights. Evans (1992) observed that green plants obtain essential elements from the soil through their roots and from the air through their leaves.

Leaf litter is an important in forest ecology because it helps to return nutrients to the soil through nutrient recycling and consequently, maintains soil fertility (Nzegbule and Mbakwe, 2001). Decomposition of leaf litter is the major source of nutrients in forest ecosystems. Litterfall undergoes microbial decomposition; organically bound nutrients are released as free ions to the soil and are consequently made available for plant uptake (Okeke and Omaliko, 1992). The organic matter in decayed litter serves as nutrient source for the release of nutrient elements. Organic matter enhances the release of nutrients in the forest ecosystem, thus preventing loss of nutrients from the ecosystem. Naturally, leaf litter helps to improve the soil structure, increase the water holding capacity of the soil, conserve moisture content, and reduce leaching and water infiltration.

Efforts are, therefore, made to restore more sustainable and productive land-use systems, such as agroforestry, for increased crop and soil productivity per unit area on small farms and also to maintain ecological balance on the long - term basis through the inclusion of forest food species (Kang *et al*., 1981). Agroforestry is defined as a multiple land use system in which woody perennials are integrated with crops and animals simultaneously or sequentially on the same land unit area, using management systems that are compatible with the culture of the local people (Nair, 1989). Such woody perennials not only raise the protein requirements of the rural populace but also contribute to improving the physico-chemical conditions of the soil among other valuable services rendered (Prassed *et al.*, 1985). Goor (1985) and Nair (1989) noted that soils under trees (woody perennials) have high utilization capacity and infiltration rates and also enhance the soil productivity.

Hence, evaluation of agroforestry potentials of trees and shrubs with respect to: soil conservation and management, including soil fertility enhancement are essentials. This article focuses on management of soil fertility through natural mechanism like agroforestry, the leaf litter production, leaf litter decomposition, shifting cultivation/bush fallow, nutrient cycling and as well as integration of various forms of fertilizers.

CHANNELS FOR SUSTAINABLE ENHANCEMENT OF SOIL FERTILITY AND NUTRIENTS STATUS

The role of fertilizers in growth, development and quality of most crops has been a controversial issue. Responses have been obtained in locations of low nutrient status while negative effects have been reported in other areas, either due to species response or imbalance in nutrient application (Udounang, 2006). In the humid tropics of Africa, bush fallows have gradually grown shorter and shorter (Adeola, 2015a). Under such short bush fallows, full vegetation regeneration and soil fertility restoration are not possible, thereby rendering the traditional farming system in the humid tropics partially unproductive. This could lead to low productivity as crop yields are reduced, at times to below 10% (Adeola, 2015a).

The steady decline in food production in Nigeria due to reduced length of fallow on land prompt the farmers to amend the soil with different materials (organic or inorganic) in order to enhance plant growth and increase yield (Otorokpo, 2012). The sustainability of high crop yields through intensive cropping could only be achieved via the use of fertilizers. For healthy growth and optimal yield, nutrients must be available to plants in sufficient and balanced quantities and in a usable form at the right time (Ramesh *et al.*, 2011). It is necessary to add mineral fertilizers to the soil to compensate for the loss of natural fertilizers (Udounang, 2006). Ramesh *et al.* (2011) noted that fertilizers could be used to supplement the nutrients already in the soil.

According to SSSA (2011), fertilizer is any organic or inorganic material of natural or synthetic origin that is added to a soil to supply one or more plants nutrients essential to the growth of plants. Stewart *et al.* (2005) reported that recent assessment confirmed that about 40 to 60% of crop yield are attributable to commercial fertilizer use.

APPLICATION OF ORGANIC FERTILIZERS ON ARABLE CROP PRODUCTION IN AGROFORESTRY ECOSYSTEM

Due to imbalance of nutrients in the soil, the need to use renewable forms of energy has been stressed globally. Organic manures (compost) enhances soil fertility by increasing organic matter, improving soil structure, water retention, and nutrient cycling (Singh *et al.*, 2022). The organic matter in compost serves as a slow-release source of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as secondary macronutrients like calcium (Ca), magnesium (Mg), and sulfur (S) (Elshony *et al.*, 2019). The present of these nutrientss in the soil serves as a catalyst for plants growth and development. Organic fertilizer, for example, poultry manure, is essential for crop production as exhibited by the local farmers who use it regularly on their farms (Ibeawuchi, 2009). The use of poultry manure and dehydrated pig manure for the growth of maize crop production and vegetable crop production on dehydrated ultisols of Owerri, in Southeastern Nigeria has been recommended (Ibeawuchi *et al.*, 2006 and Onweremadu *et al.*, 2003). Organic fertilizers enhance and improve soil for a sustainable cultivation and food production in a variety of soils. *Telferia occidentalis* require soil with high organic matter content and adequate mineral reserve (Alabi *et al.*, 2005). However, for optimum yield, some species are tolerant to fairly wide range of soil conditions. Farmers are equally encouraged to use additional nutrients to increase the life span of their vegetable.

Organic fertilizer, apart from the particle size distribution resulting from the matter, contributes greatly to the water holding capacity of the soil (Udounang, 2006). In an experiment carried out in Ghana, Young (1976) reported that a reduction in organic matter content from 5% to 3% caused the water holding capacity to drop from 57% to 35%. Udounang, (2006) also noted that organic matter contains the clay-humus complexes which forms a good protection against wind and water erosion and helps to promote permeability while simultaneously improving water storage. Humus that results from organic matter decomposition tends to decrease soil bulk density and promote aggregate stability. Maerere *et al.* (2010) and Ugwu *et al.* (2010) reported that organic matter has higher values of soil-available N and P. The increase in the soil available N and P could be attributed to increase in microbial activities as a result of increased concentration of nutrients which could have resulted in enhanced decomposition of the organic forms of N and P. Ibeawuchi (2009) reported that increasing application of poultry manure to the soil improved the nutrient status of the soil which in turn enhanced the growth and yield of some arable crops. Fruit yield, leaf yield, leaf expansion and other yield components of the plant species increases in response to increasing rate of poultry manure application (Ibeawuchi, 2009).

The addition of organic amendments has been reported to have a suppressive effect on plant-parasitic nematodes (Walker, 2004). Preliminary attempt to control the nematodes in the nursery using poultry litter (Orisajo *et al*., 2008) had shown reduction in nematode infection and consistently stimulated growth of cacao seedlings in the nursery. Organic soil amendments offer an alternative or supplementing control tactic to chemicals of nematode pathogens on agricultural crops (Akhar and Malik, 2000). In addition to providing supplementary nutrients which in turn may have a positive effect on vegetative growth and yield, organic soil amendments is reputed to mitigate the impact of plant- parasitic nematodes on cacao (Orisajo and Fademi, 2005).

Similarly, wood ash has been reported as being used by farmers in South America to control bacterial wilt (Demo, 2004). Wood ash applied at the rate of 500 and 750kg/ha $^{-1}$ significantly ($P \leq 0.05$) improved yield and gave a higher gross margin compared with the control (Dung *et al.*, 2009).Wood ash is known to be rich in potassium and micro- elements needed for healthy plant growth. In addition to the reduction in the incidence of bacterial wilt, increased yield could be obtained with the application of 500 and 750kg/ha of wood ash (Dung *et al*., 2009). In Nigeria, the shortage and high cost of inorganic fertilizer has put the commodity out of reach of most peasant farmers, leaving them with no option than to look for cheaper alternatives of fertilizing their maize crop. The need for a cheaper alternative to mineral fertilizer culminated in the search (through this study) for an appropriate organic fertilizer such as the poultry manure. Organic fertilizers such as poultry manure are derived from farm manures and have high organic matter contents (Udounang, 2006)

Benefits of using organic matter: Organic manures or fertilisers have the unique ability to improve the physical, chemical and biological characteristics of soils or growing media (U.S composting council, 2001).

Physical benefits:

Improved soil structure: Organic matter/manure can greatly enhance the physical structure of soil. The soil binding properties of organic matter are due to its humus contents. Humus is a stable residue resulting from a high degree of organic mattered composition.

Improved moisture holding capacity**:** Humus is a dark brown or black soft spongy substance that holds water and plant nutrients. Organic manures application is one of the best "hidden" water harvesting methods available. Studies have shown that every 0.5% increase of organic matter in soil can conserve 80,000 litres of water over one hectare of farmland (Solomon, 2020). Globally water supply is the major challenged facing farming activities, hence this can be solved through organic manures or matters.

Chemical benefits:

Modifies and Stabilizes Soil pH**:** The addition of organic to soil may modify the pH of the final mix. Depending on the pH of the organic matter and the local soil, organic matter addition may raise or lower the pH of the soil/organic matter blend (Solomon, 2020).

Increases Cation Exchange Capacity: Organic matter improved the cation exchange capacity of soils, enabling them to retain nutrients longer. Naturally the soil fertility is normally with the availability of organic manures or matters in the areas or local soil.

Provides nutrients: Organic manures or matters provides both macro and micronutrients, therefore serves as a good source of plants nutrients. Macro and micronutrients derived from organic manures or matters are sustainable due to it gradual addition to the forest soil. The addition of organic matter can affect both fertilizer and pH adjustments (lime addition) (Solomon, 2020).

Biological benefits:

Provides soil biota: **S**oil micro-organisms like: bacteria (ozotobacter and nitrobacter), protozoa, fungi and actinomicetes play vital roles in healthy and fertile soils and for productive plants. Miro-organisms present in the soil facilitate the decomposition or conversion of organic matters or manures to humus that promotes and enhancing nutrients in the soil. **Table 1 below shows some micro-organisms and their associated influence in fixing nitrogen to the soil.**

Table **1: Different types of nitrogen fixing system**

Association Type	**Microorganism**	**Host plants**
Symbiotic	Bacteria (e.g. *Rhizobium*)	Legume
Actinomycetes (e.g. *Frankia*)	Actinorhiza	
Cyanobacteria (e.g. *Anabaena azollaea*)	Fern	
Non Symbiotic	Bacteria (e.g. *Azotobacter ,Azospirillum*)	Cereals
Free living	Bacteria (e.g.*Thiobacillus Clostridium*)	

Source:Solomon,2020.

Controls weeds and plant diseases: **Compost, green manure, farm yard manure (**organic matters / manures) play significant roles in suppressing weeds, which often competes nutrients with agricultural or plantation crops in the field. Organic manures/matters also reduced the weeds population that harbour pests and diseases in the farm, thereby encouraging better performance of plants.

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According to Solomon, (2020) raising and maintaining soil organic matter to desirable levels is crucial to sustainable land management, as it retains nutrients for plant use, reduces the runoff rate and the hazard of erosion, and improves the physical condition of the soil. He therefore recommended the practice for raising and maintaining soil organic matter as shown in Table 2 below, as a way of managing and sustaining soil fertility. The application of organic manure/matter is pre-requisite for sustaining soil fertility in any location of the farm.

Table 2: Recommended practices for raising and maintaining soil organic matter

Increasing inputs of organic materials	**Reducing organic matter losses**
***Apply organic materials to soil*:** apply manure, add plant residues, apply compost and vermi-compost, apply green manures, pruning's or mulch	***Minimize soil erosion*:** Erosion removes organic m\atter contained in topsoil. Maintaining good vegetative or ground cover to protect soil from erosion will ensure that valuable topsoil and organic matter are conserved.
***Retain crop residues*:** Crop residues such as straw and maize or sorghum stalks should be incorporated into the soil or left on the soil surface to decompose whenever possible.	***Avoid overgrazing*:** Overgrazing leads to reduction of biomass and therefore productivity. Overgrazing also increases the area of bare ground making the surface soil more prone to erosion. Lower biomass means low input of organic matter to the soil.
***Grow cover crops*:** Growing cover crops rather than leaving the land fallow during the dry season using residual moisture or belg rains increases organic matter and adds carbon to soil.	**Reduce tillage operations** when possible: **Because excessive tillage accelerates organic** **matter decomposition and makes soils** **susceptible to erosion, the adoption of minimum** **tillage becomes important in reducing organic** matter loss

Include a pasture phase in arable cropping: **Grasses and legumes are regarded as soil builders because their root residues add active organic matter to the soils. They will help return the paddock to either long-term or short-term pasture depending on the degree of soil degradations**	**Manage decomposition rates**: ***Encourage soil*** **organisms (e.g. worms, beetles) to enhance the burial and incorporation of plant litter into soil aggregates to protect organic matter from loss by decomposition. Living shelterbelts with deep roots will capture and sequester carbon at deeper soil layers.**

Source:Solomon,2020.

APPLICATION OF INORGANIC FERTILIZER ON CROP PRODUCTION IN AGROFORESTRY ECOSYSTEM

Marginal lands that are not productive have been converted to fertile farmlands because of effective soil fertility management through the use of manure, inorganic fertilizers and soil amendments (Udounang, 2006). Inorganic fertilizers are generally known to increase yields per hectare. Fertilizers are essential chemical nutrients (inorganic) desired by crops at different levels and time for good growth and yield. Nutrient elements in the fertilizers boost crop production. According to Ndaeyo *et al.* (2005), four types of fertilizers (nitrogen, phosphatic, potassic and compound fertilizers) are in common use. Micronutrient fertilizers are sometimes added to compound fertilizers.

Inorganic fertilizer is composed of synthetic chemicals and/or minerals (Otorokpo, 2012). Inorganic use has significantly supported global population growth. It has been estimated that almost half the people on earth are currently fed as a result of use of synthetic nitrogen fertilizers (Erisaman *et al.*, 2008). The positive effect of the application of inorganic fertilizers on crop yield and yield improvements has been reported (Carsky and Iwuafor, 1999; Otorokpo, 2012).

COMBINATION OF INORGANIC FERTILIZERS AND ORGANIC FERTILIZERS/MANURES IN AGROFORESTRY ECOSYSTEM

Integrated soil fertility management (ISFM) represents a set of soil fertility management practices that includes both the use of inorganic fertilisers and organic inputs as well as improved germplasm or seed (Solomon, 2020). These need to be combined with the knowledge of how to adapt these practices to local conditions aimed at maximising agronomic use efficiency of the nutrients as well as improving crop productivity. Nutrients supplied from organic materials can be complemented by enriching them with inorganic nutrients that will be released fast and utilized by crops to compensate for late start in nutrient release of organic manure (Ayoola and Makinde, 2007). Mixture of inorganic fertilizer and poultry manure (IFPM) has been noted to significantly improve the plant height, dry matter and grain yield of sorghum (150 cm, 72.3g and 3.55 ton/ha respectively) compared with maize (1.39 cm, 71.0g and 2.89 ton /ha) (Amujoyegbe *et al.*, 2007). This result indicated that IFPM is a better nutrient source compared to poultry manure (PM) or inorganic fertilizer (IF) only (Otorokpo, 2012). This may be due to the fact that inorganic fertilizer (IF) component of the mixture provided early nutrients to the growing crops during the early vegetative growth stage, while the organic component provided nutrients at the later stage of the crop development (Amujoyegbe *et al.*, 2007; Ramesh *et al.*, 2011).

The increased and uniform supply of nutrients at all stages of plant growth could be due to the combined effect of poultry manure and inorganic fertilizers that could have possibly contributed to an increase in growth attributes as well as early flowering (Amujoyebge *et al.*, 2007). Higher crop growth parameters in the presence of both organic and inorganic fertilizer nutrients could be ascribed to improved soil condition and supply of both macro and micro-nutrients through organic sources of nutrients and readily available major nutrients such as nitrogen, phosphorus and potassium in the early stages of growth (Otorokpo, 2012). The combined use of both organic and inorganic fertilizers in the right proportions seems to be necessary for sustaining good growth and enhancing productivity. The available NPK in soil after harvest is always high in organic fertilizers and its combination except in individual application of PM. This indicates that the combined use of organic manure and inorganic fertilizers helps to build up active pools of NPK and to maintain regular supply of nutrients for proper plant growth and yield. The combined use of both organic and inorganic fertilizers also helps to maintain soil structure, health and enhance the productivity of future crops (Ramesh *et al*., 2011).

The use of chemical fertilizer or organic fertilizer or bio-fertilizer has its advantages and disadvantages in the context of nutrient supply, crop growth and environmental quality. The advantages need to be integrated in order to make optimum use of each type of fertilizer and achieve balanced nutrients management for crop growth (Esawy *et al.,* 2009).

CROP ROTATION AS MECHANISM FOR SOIL FERTILITY MANAGEMENT

Crop rotation simply means changing the type of crop grown on a particular piece of land from time (year) to time (year).The rotation of the crops in the field could be cyclical rotations (same sequence of crops) or non cyclical rotations (sequence of crops) varies irregularly to meet up objectives of the farmer. Farmers worldwide have rotated different crops on their land for many centuries in other to maintain soil fertility. This agronomic practice was developed to produce higher yields by replenishing soil nutrients and breaking disease and pest cycles (Solomon, 2020). Its obvious crop rotations are not applicable to mono-cropping, examples plantation or tree crops such as oil palm (*Elaeis guinensis*), bitter kola (*Garcinia kola*), cocoa (*Theobroma cacao*) and bush mango (*Irvingia spp*) etc, annual and biennial crops are commonly adopted by this system. According to the EU Directorate General for the Environment (2012), it increases organic matter in the soil, improves soil structure, reduces soil degradation, and can result in higher yields and greater farm profitability in the long-term. Crop rotations increased levels of soil organic matter enhance water and nutrient retention and decreases synthetic fertilizer requirements.

Solomon, (2020) noted several factors to be adopted while planning crop rotations include:

1. Following a legume crop with a high-nitrogen-demanding crop such maize or vegetables to take advantage of the nitrogen.
2. Inoculating legumes with biofertilizers at planting in order to enhance biological nitrogenfixation.
3. Growing the same crop only once each year on the same piece of land to decrease the likelihood of insects, diseases, and nematodes becoming a problem.
4. Growing some crops that will leave a significant amount of crop residues like beans, to help maintain organic matter levels.

Generally effective utilization of this approach will add enormous nutrients to the soil through organic matters, like plant/crop residues and nutrients from root nodules of legumes crops, such as groundnut, beans and cover crops. Mulching is the covering of the soil with crop residues such as straw, weed biomass, leaf litter and dry grasses. Once they have rotten and decomposed, mulch forms humus and adds to the organic matter in the soil. Mulching is important for the prevention of soil erosion, addition of organic matter to the soil, regulating the soil temperature, increasing oil microorganism and biological activity, weed suppression, increasing water retention, and reducing evaporation from the surface of the land/soil (Solomon, 2020). He estimated crop residues produced by different crops as shown in table 3 below. Crop residue produced degrades over the fallow period at varying rates depending on the weed control methods used and climatic conditions within the geographical location.

Table 3: Estimated crop residues produced by cereals, legumes, and other crops

CROP	Residue produced (10_6 ton/yr)	
	1991	**2001**
Cereals	2563	2802
Legumes	238	305
Oil palm	163	108
Sugar cane	140	373
Tubers	154	170

Total	3448	3758

Source:Lal, R. 2005.

SHIFTING CULTIVATION/BUSH FALLOW

Shifting cultivation/bush fallow is an age-long practiced in tropical regions-Nigeria inclusive, especially in the former south-eastern state, now known as south-south and south-east geo- political zones. This system was dominant in these areas some decades ago, though most places in Akwa Ibom State (Esit Ekit LGA-Ntak Inyang, Afaha Ekpenedi, Odoro Nkit and Urua Okok etc communities and Abia State (Ikwano LGA-Ariam, Ndoro, Amawom and Amaoba etc communities are still practicing shifting cultivation/bush fallow system. Shifting cultivation/bush fallow can simply be explained as traditional, sustainable and low-cost agricultural method widely practiced in the tropics, where land is cultivated for a few years and then abandoned (fallowed) for a longer period to allow recycling of nutrients and to recover soil fertility. However, there is no standard/uniformity in the length or fallow period, rather it does depend on agreement between individual communities, and some can leave their land fallowed (abandoned) for periods of 5 -7 year, 8-13year and10-15 year. For the villages earlier mentioned, their length/ fallow periods are within 5-7year (Nsien, 2026). The system requires or needs large area of land, for it to be effective. Most of the communities mentioned above, their farm sizes have been reduced to due the law of inheritance and ever-increasing population. Generally peasant farmers practiced this system agriculture realized mostly on crude implements and hardly do they used modern technology such as fertilizers (NPK-fertilizers) and chemicals (herbicides and fungicides). Most people still hold on to the system, because they believed that natural mechanism of soil replenishments are eco-system friendly and economical for them, couple with numerous benefits (non-timber forest products-NTFPs) accrued from such practice.

Reasons for maintaining or adopting shifting cultivation/bush fallow system despite land scarcity

Despite paucity of land due urbanization and population increased, some communities in Abia and Akwa Ibom states are still practicing shifting cultivation/bush fallow system due to reasons as summarized below:

Soil Fertility Enhancement: some forest tree species like *Anthonotha. Macrophylla*, a member family Caeselpiniodeae and other leguminous trees, shrubs, and weeds, such as *Acacia* species or *Tephrosia* tree species that are known to aid in fixing nitrogen to the soil. The leaf litter of nitrogen fixing tree species decomposes faster as compared to non-nitrogen fixing tree and crop species.

Nutrient Cycling: Deep-rooted plants and trees during the fallow period bring nutrients from deeper soil layers to the surface, making them available for subsequent crops. *Anthonotha macrophylla* is a prominent tree species in terms of biomass formation (both above and below ground level biomass).

Organic Matter Accumulation: Greater accumulation of organic materials and nutrient storage in biomass increase root density and greater vertical extension of tree roots help maintain nutrients stock by reducing leaching loses or by taking up nutrient from deep layers (Nsien *et al.*, 2016).

Fuelwood/Energy Source and Revenue Generation: UNDP (2000) reported that over 2 billion people depend on wood for cooking, heating and food preservation.

. It functions as a natural mechanism to replenish soil nutrients removed by crops, improve soil structure, and control pests.

Climate Amelioration: tree species abandoned in bush fallow and shifting cultivation has the capacity to suppress air pollutants due to the number of foliages and biomass it can accumulates within it habitat. It is now crystal clear that global warming and its concomitant climate change have profound adverse effects on our environment, and also on health.

Improvement of Soil Structure and Moisture content: Shifting cultivation/ bush fallow ensured vegetation covers of the soil, protecting it from intense rain and sunlight, which reduces erosion and leaching. Roots penetration increases porosity, improves infiltration and aeration of the soil. *Regeneration and encouragement of coppices:* Restores soil productivity without the need for expensive synthetic fertilizers.

Conservation and protection of Biological diversity: shifting cultivation/bush fallow encourages the return of various classes of plants (flora) and animals (fauna).

In view of the above mentioned facts, shifting cultivation/ bush fallow has some challenges and limitations, namely:

paucity and scarcity of land- due to ever-increasing population that lead to infrastructural development and urbanization, bush fallow and shifting cultivation periods has been reduced, hence period of land fallow (abandonment) for fertility or nutrients restoration become shorting and lead to poor or low yield.

a. **Deforestation rate:** The process of clearing new land can contribute to deforestation and loss of biological diversity.
b. **Low of soil fertility:** If the shifting cultivation/bush fallow period is not long enough, the soil cannot recover, leading to soil exhaustion.

AGROFORESTRY AS PATHWAY TO NUTRIENTS ACCRETION TO THE SOIL

Land area, which is fixed, needs to be conserved and protected to sustain our ever-increasing population. This could be achieved effectively through agroforestry as multiple lands –use systems in which agricultural crops and woody perennials are grown on the same land management unit (Nsien *et al.,* 2011). Agroforestry has been defined as a dynamic, ecologically based natural resources management system that through the integration of trees on farms and in agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits (Nsien *et al.,* 2011 and Leakey, 1996). Agroforestry system have the potential to address a number of land-use problems such as low soil fertility, fodder, fuelwood and small timber shortages and soil water erosion, if designed appropriately (Nsien *et al.,* 2011and Singh,1991). Work done at the International Institute of Tropical Agriculture (IITA) Ibadan has shown that crop yield increases when the pruned trees were well incorporated into soil. Incorporation of oil bean (*Pentaclethra macorphylla*) in farming system in the Southern Eastern states has increased soil fertility and enhances better crops yields through accretion of nutrients by nitrogen-fixing bacteria. Nsien *et al.., (*2011) noted that the presence of trees on farmlands reduces the drying effect of prevailing wind on the soil, and so conserves oil moisture required for good crop growth and development. Preliminary investigation to assess the effects of Scattered Farm Trees on the yield of agricultural crops, showed that food crops like yam (*Discorea rotudata*) planted under light shade of trees such as *Mangifera indica* (mango) or *Acacia auriculiformis* gave as much 30% higher yield than those in the open (Nsien *et al..,* 2011 and Adegbehin, *et.al..,* 1990). According to Nsien *et al.,* (2011) and Merem (2005) agroforestry techniques (integrated farming) was established along Niger Delta area of Uroboland to maintain fertility of the soil. The farmers in Uroboland area of the Niger Delta practiced integrated farming that uses palm trees along side other crops to maintain soil fertility (Aweto, 2000).

The adoption of various types of agroforestry syetem (agrisilvicultural, silvopastoral and agrosilvipastoral systems) across the globe has proved its efficacy in organic matter accumulations, nutrients restoration, nutrient cycling and soil fertility enhancement. This depends on pathways (precipitations- rainfall, throughfall, stemflow, litterfall- leaf litters, dead bark, flowers, twigs) in which nutrients are flow into forest ecosystem. Rainfall ie direct rainfall added nutrients to forest floor/soils, throughfall-nutrients accretion from plant leaves to soil and stemflow-nutrients that flow from bole (stem) to the forest floor. Nutrients accrued from leaf litters are through decomposition of its contents. Generally leaf litters decomposition rates of tropical forest species varied significantly irrespective of the decomposition modes (surface placement or soil incorporation placement methods). Table 4 below shows decomposition of some tropical forest species.

Table 4: Decomposition of some tropical forest species

S/N	Species	Time (Week After Litter Placement-WALP)
1.	*Diospyros crassiflora*	12
2.	*Irvingia wombulu*	39
3.	*Entandrophragma cylindricum*	32
4.	*Hura crepitans*	28
5.	*Bauhinia monandra*	28
6.	*Hildegardia barteri*	28
7.	*Acioa barteri*	40
8.	*Centrosema pubescens*	48
9.	*Mimosa inversa*	12
10	*Brachystegia Nigeria*	12
11	*Hymenostigia afzelii*	12

Source: Field Experimentation

Various studies have confirmed that the stemflow and throughfall are major channels which nutrients accrued to the forest floor or soil (Nsien et al., 2021 and Otorokpo, 2012). Stemflow along with throughfall are responsible for the transfer of precipitation and nutrients from the plant cover to the soil (Nsien *et al.*, 2021). The quality of precipitation falling on forests is affected during rainfall are brief but significant interaction with the surfaces of plants, resulting in the transfer of additional minerals to the soil (Nsien *et al.*, 2021 and Parker, 1983). Wet and dry canopy interception through throughfall and stemflow play a significant role in the water and nutrient cycles in forest ecosystems (Johnson and Lehmann, 2006). No matter the agroforestry system practices in an area, it contributions to environmental management and soil fertility enhancement has been recorded by many agriculturalists, agroforesters as well as environmentalists.

CONCLUSION

Soil fertility and nutrients status anchored on natural phenomenon like nutrient cycling, nitrogen-fixing plants through nodulations, bush fallow system and also through soil amendments like organic manures, mineral fertilizers and leaf litters decomposition. The paper highlighted precipitation pathways in which nutrients accrued to the soil through agroforestry ecosystem. Soil fertility enhancement and nutrients status could be maintained and sustained through application of manures (organic and inorganic fertilizers); practiced of traditional bush fallow system, improved bush fallow, mixed cropping system, crops rotation, shifting cultivation and nitrogen-fixing plants. The paper also emphasized that agroforestry system have the potential to address a number of land-use problems such as low soil fertility, fodder, fuelwood and small timber shortages and soil water erosion, if designed appropriately. Restoration, sustainability and productive land-use systems via agroforestry system have been proven to enhanced soil fertility, increased crops performance and yields; and also maintained ecological balance.

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