Sustainable Agroforestry Potentials and Climate Change Mitigation

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ABSTRACT

Agroforestry is a land-use system that integrates trees (woody perennials), crops, people, and/or animals on the same piece of land in order to get higher productivity, greater economic returns, and more social benefits on a sustained basis. It remains the only prospective solution to address many forestry-related challenges in the world. It involves the application of woody perennials trees on the same management land unit with agricultural crops and or animals, either in some form of spatial arrangement or temporal sequence in which there are both ecological and economical interactions between different components. These interactions have been discovered to be so significant in environmental management, as it helps in solving numerous environmental degradation and climate change related problems. This paper presents the potentials Agroforestry practices beginning from its capacity to earn sustainable productions of food and wood products to the protective and environmentally-endowed potential in mitigating recurrent Climate changes in the world. The prospects of agroforestry systems in curbing the global greenhouse effect and much other environmental degradation were discussed while practical approaches for sustainable environmental management were highlighted.

Key words: Agroforestry, Global climate change, Greenhouse effect, Mitigation

Introduction

Agroforestry is a collective name for a land use systems and practices where woody perennials (trees, shrubs, palms, bamboo etc) are deliberately used on the same land management unit with agricultural crops and or animals, either in some form of spatial arrangement or temporal sequence in which there are both ecological and economical interactions between different components [8]. It encompasses principle of some ancient practices, including the shifting cultivation and the bush fallow systems. Agroforestry practices emphasize sustainable production of food and wood products among its numerous benefits. It offers both productive (of basic needs), and protective (of the environment) benefits to man. Agroforestry as a land use system of farming offers a more viable option as it appears to be more environmentally friendly in maintaining and improving soil fertility status particularly in the third world countries, where poor resources farmers exist. It is a major shift from the tradition land use or farming system often referred to as shifting cultivation found in the topics. Nair and Fernandes [10] criticized the traditional system for being wasteful and inefficient and for causing soil degradation and decline in soil fertility.

Forests and tree resources are becoming severely diminished by farming, animal husbandry, and fuelwood consumption, all of which are essential

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activities to the well-being of many communities. Farmers are mandatory to cultivate the same lands year after year, exhausting lands to the point where they can no longer support the families who depend on them. Similarly, charcoal demands in the cities have resulted in unrelenting pressure being placed on forest resources. Livestock are overgrazing lands and inhibiting the regeneration of forests. Agroforestry is one prospective solution to address these forestry-related challenges. By planting the agroforestry trees species on their lands, farmers can considerably increase local forestry resources, improve the quality of their farmlands, directly support new income generating opportunities, and they can establish sustainable supplies of high-protein animal forage, fuelwood, berries, beans, organic fertilizer, etc.

Agroforestry is important for all climatic zones, from the arid lowlands to the humid uplands, and every zone in between. Not only does agroforestry provide useful and marketable products, but it diversifies the timing of production - so that farmers do not receive their entire year's income at one time. Because ‘green manure trees’ are involved, the trees constantly recycle valuable nutrients from deep in the earth while they stabilize lands from hurricanes, floods, mudslides, and storms. Ultimately, the use of agroforestry leads to food security, water conservation, and sustainable agriculture.

Soil Fertility Problems in the Tropics:

The tropical soil has been reported by several authors to be fragile and requires considerable care in its management. The sustainable management of humid and sub-humid tropical soils is of deep seated concern, not only to soil scientist but to all practicing agriculturist. Deckers [5] reported that soil in the humid and sub-humid tropics are covered by Alfisols, ultisols and oxisols. These soils have been classified as low activity clay soils which are fragile. The characteristics of these soils groups are: oxisols are deep, highly weathered, acid, low base status soils and have excellent structure and good drainage with no significant increases in clay with depth; Ultisols are similar to oxisols except for clay increase with depth, while Alfisols have higher base status than ultisols but are similar otherwise.

The main constraint to plant production on these soils are chemical in nature which consist of low exchangeable base contents, low nutrient reserves, high Aluminum toxicity, low Phosphorus availability and mild acidity [12]. Despite these constraints, the total nutrients in circulation including those in the soil and in the associated vegetation constitute the nutrient capital available for possible use by agricultural plants. However, sustainable land use requires not only the conservation of soil but whole range of resources on which production depends.

According to Oke and Kadeba [11] there is a close link between soil productivity and plant production; and thus, the need to check the decline in soil fertility experienced in the tropics as a result of shortened fallow period. Although, this have been attributed to pressure due to increasing human population. The developments of alternative land use system of soil management found in Agroforestry practices seem promising and timely in checking nutrient depletion.

Multipurpose Woody Species for Agroforestry System:

Traditional formers have for long incorporated multipurpose woody species in their production systems. Preferences depend on the farming systems and socio-economic needs [6,8]. In a study by Ladipo and Okafor [9], they found that farmers in the southeastern part of Nigeria, within the high population density areas, have incorporated a more productive and useful fallow species purported to have soil enriching properties into their farming systems. Such indigenous species selected include Dacyteldenia barterii Alchornea cordifolia Anthonanta macrophylha, Baphia nitida Baphia pubescence Cnetis feruginea, dalium guineense Harunanga madagascariensis, Milletia aboensis, Napoleaonia imperalis and Nulea Latifolia. Recent works have shown that some of these traditionally selected species and have soil enriching properties and thus a suitable fallow species in the managed agroforestry system [1,2,3,4].

The Importance of the World’s Forests:

Forests are critically important carbon warehouses that filter massive quantities of carbon from the atmosphere, trapping it in their biomass. The Food and Agriculture Organization of the United Nations estimates that the world’s forests store 283 gigatonnes (Gt) of carbon in their trunks and roots. Additionally, there is more carbon stored in the deadwood, leaves, and soil of forests than there is in the earth’s entire atmosphere! The increased use of fossil fuels is only one part of the threat of Global Climate Change. With it, the earth is losing its forests at a rate of 13 million hectares every year! In the process, the land is burned over releasing this carbon into the atmosphere - more carbon but fewer trees to remove it! Introducing all this formerly-stored carbon into the atmosphere, with no corresponding mechanism to take it back out, has also contributed to the current high levels of CO₂ in the atmosphere. This deforestation has also caused the deaths of thousands upon thousands of people. Mudslides and floods that result from the loss of tree cover are happening more and more frequently.
Trees and Global Changes:

The earth is now heating up. The earth has been going through heating and cooling cycles forever. Each cycle took place over hundreds, often thousands, of years. Then, starting in the early years of the 19th Century, and continuing until now, the warming has increased rapidly. The change began to accelerate when the Industrial Revolution started; a time during the 1800’s when new technology enabled industries to replace animal and human labor with machines driven by fossil fuels. These new machines revolutionized production and transportation, but this has occurred at a significant cost to the environment. Like wood and other organic fuels, fossil fuels - such as coal, gas and oil are composed mostly of carbon. When burned, the carbon unites with oxygen and forms Carbon dioxide (CO2). It is therefore pertinent to emphasis that as these industries grew, and the use of fossil fuels increased, so did levels of carbon in the global atmosphere. The use of fossil fuels has continued to increase for almost 200 years. Currently, the atmosphere is filled with dangerously high levels of carbon-dioxide. It is colorless and odorless, so we can’t see or smell it, but it spreads itself evenly throughout the world; air pollution does not respect international boundaries and is becoming a big threat in many part of the world with divers and various levels of environmental degradations resulting in strange environmental disasters.

The Greenhouse Effect:

Solar radiation from the sun, which we see as light and feel as heat, constantly shines on the earth. Some of the heat is absorbed and some is reflected. Carbon dioxide (CO2) works like an invisible blanket that wraps around the earth, trapping the heat inside (Figure 1). A greenhouse is a structure that is used in colder climates to grow plants, flowers, and vegetables. Even when outside temperatures drop below freezing, greenhouses are still warm enough inside to grow plants. Greenhouses work like this: the roof and walls are made of glass so that light from the sun (solar radiation) can enter into the room. The heat is trapped inside the greenhouse, allowing plants to grow all year around in the trapped heat. Because the high concentrations of carbon dioxide in the earth’s atmosphere insulate it like a greenhouse, we call it the greenhouse effect. Carbon dioxide is the major greenhouse gas, but there are others as well, including methane and nitrous oxide.

Over the last 120 years, beginning around the time when the use of fossil fuels rapidly increased, the average global temperature has increased by about 1.3 degrees F (It has further been determined that the rate of increase is accelerating and that over this new century, the average temperature will increase by about two (2) additional degrees Centigrade. In recent years, we have seen record temperatures on every continent. Animals and insects are changing their migratory patterns. Invasive species and insects such as malaria-carrying mosquitoes are spreading into new territories. Glaciers in the arctic regions, on many Mountains of the world, including Europe, Asia, and the Americas are melting. This is causing the world’s oceans to rise and people in small island nations in the Pacific Ocean have already been forced to abandon their homes. With this, ocean temperatures are increasing, bleaching and killing coral reefs. Hurricanes are increasing in frequency and strength. Weather patterns are changing and farmers are confused by fluctuations in rainy seasons. Droughts and floods are more common than ever before and in many parts of the world global climate change is seriously threatening series of abnormalities in weather forecast and climatic predictions.

Forests potential in reducing the Atmospheric Levels of Carbon:

Through a natural process called photosynthesis (Figure 2), plants remove carbon dioxide from the atmosphere for plant growth. Plants take in carbon dioxide and release oxygen. They store this carbon in their leaves, branches, trunks, and roots. The rate of photosynthesis is higher in areas that are warm throughout the year, such as the tropics and subtropics. Because trees grow faster in the tropics, they absorb more carbon than trees in temperate regions. An average tree in our program can annually remove about 50-53 lbs (23 kg) of carbon dioxide from the atmosphere. In agroforestry trees encourage the growth of other vegetation in their understory, and thus increasing the amount of carbon sequestration in the atmosphere more than ever before.

Soil Management in an Agroforestry System:

Virgin soils have a natural fertility determined by such factors as climate and the parent materials from which they were formed. Changes occur so slowly that for soil under natural vegetation there is a virtual equilibrium. However, as soon as land is altered through clearing of the natural forest or savannah, this equilibrium is broken. Soil fertility declines at a rate dependent on the intensity of subsequent cropping and the way the land is managed. If cultivated for one or two years, and left fallow for seven to fifteen years, most cleared land will recuperate reasonably well.

Nonetheless, this is not the practices in the tropics where population pressure have resulted in
reduced fallow period with its attendant negative effects on soil fertility status. The extent of soil productivity improvement in agroforestry systems depends on many factors, including site characteristics, plant species and cultivar, cropping pattern and management factors. Kang [8] reported that many of the quantitative data on effect of trees on soil properties are based on natural systems.

Oke and Kadeba [11] in a study to determine the effects of four land use systems; natural fallow, Cajanus fallow, alley cropping and continue cropping on the Nitrate content of an Alfisol. They observed that Cajanus fallow and alley cropping had positive effect on soil Nitrate. The long term effect of alley cropping with various hedgerows species have also been reported by Hulugalle and Kang [7] to show a favourable effect on the soil physical and chemical properties as compared to the control (no tree) treatment.

Further studies by Adejuyigbe et al, [3] based on earlier reported finding by other scientist on enhanced biological activity in agroforestry systems, shows that higher microarthropod population was found under planted fallows than under cropping with maize/cassava intercrop. This was attributed to presence of trees, which guarantee perennial supply of organic nutrient via litter falls and root shedding.

Despite, the beneficial effect of agroforestry practices in soil management, its adverse effects on soil properties and associated crops has been reported. Woody species compete with crops for nutrient in an acid and low fertility soils due to their shallow root development [8]. Sustainable land use is that which maintains an acceptable level of production and at the same time conserves the basic resources on which production depends, so enabling production to be maintained [14].

Climate change Mitigating potentials of Agroforestry:

Agroforestry has the potential to conserve soil fertility. Appropriate agroforestry systems have the potential to control erosion, maintain soil organic matter and physical properties, augment nitrogen fixation and promote efficient nutrient cycling. Many of these potentials are plausible climate change mitigating abilities of agroforestry systems and are pragmatically considered in the highlights below:

Agroforestry System Can Control Erosion Thereby Reducing Losses of Soil Organic Matter and Nutrient:

Tree components of any agroforestry species perform two major functions in controlling erosion; the supplementary and direct roles. In the supplementary role, erosion control is achieved by conventional means, such as earth banks and ditches, terrace rises or grass strips. The trees serve as stabilizer for the conservation structures in the forest thus enhancing productivity use of the land they occupy (Figure 3).

In their direct role, the trees may act as barriers or as cover. The barrier function is the conventional approach to erosion control by checking runoff of water and suspended sediment. The cover function involves reducing raindrop impact and runoff by increasing soil cover, with living or dead plant materials. Evidence abounds from both theoretical and practical viewpoint that the potential to control erosion through soil cover is a least equal to, and probable greater than, that of the barrier approach.

Agroforestry Systems Maintain Soil Organic Matter at Levels Satisfactory for Soil Fertility:

The strongest indirect evidence in the capacity of Agroforestry systems to maintain soil organic matter is the high organic matter content of most soils under natural forests. In all the three major environmental zones of the tropics- humid (Rain forest), Sub-humid (Savannah) and Semi-arid (Sahel) – biomass from known multipurpose tree is adequate to maintain soil organic matter at 60% or more of that under natural vegetation, a level generally held to be adequate for soil fertility. However, this effect is greatly reduced if pruning are removed for livestock feed, although the tree-root residues continue to contribute to soil organic matter.

Agroforestry Systems Maintain More Favorable Soil Physical Properties than Agricultural Activities:

It is an established scientific finding that soil physical properties can be as important as nutrient levels in fertility and crop production. Given a satisfactory level of organic matter, the added benefits from tree root systems will ensure conservation of physical properties. According to Hulugalle and Kang [7], the direct evidence of agroforestry shows that soil physical properties are maintained under hedgerow intercropping.

The Cycling of Bases in Tree Litter Can Help Reduce Soil Acidity or Check Acidification:

Strong acid soils- with a PH less than 5.0- are widespread in the humid tropics and a problem in some part of the sub-humid zones. This acidity leads to phosphorus deficiency and supposedly aluminum toxicity. The mass of calcium and magnesium derived from tree litter is too small in order of magnitude to modify natural soil acidity but could however; exert a buffering effect, helping to check acidification.
Fig. 1: Greenhouse Effect showing increasing average global temperatures
Source: www.wikipedia.org

Fig. 2: Through photosynthesis, trees remove CO2 from the global atmosphere
Source: www.wikipedia.org/wiki/leaf

Fig. 3: A typical agroforestry tree species enhancing productivity of the land

Agroforestry Systems Offer Opportunity to Argument Soil Water Availability to Crops:

In the semi-arid and dry savanna zones, water availability is often more important for crop production than nutrient supplies. Proven evidence shows that one agroforestry system can reduce evaporation in order of 20 to 30% as recorded for wind breaks.

Agroforestry Can Be a Useful Component of Systems for the Reclamation of Degraded Soils:

Trees have been successfully used in the reclamation of saline and alkaline soils, notably in India, and attempts have been made to combine this with progressive introduction of cereal intercropping [12].

Effect of Shade in Soil Fertility Enhancement:

The shade influence of tree canopy alters soil conditions to promote microbial activity and the rate of soil mineralization [13]. This influence is important in agricultural areas where the soil nitrogen level is a limitation to crops or pasture growth.
Concluding Remarks:

The foregoing analysis of the potentials and the climate change mitigating roles of agroforestry lend support to the general conclusion about agroforestry option for the different ecological regions. It is the only viable alternative to the traditional shifting cultivation and bush fallowing system found in the tropics. Though, a modification of the traditional farming system, it offers great potential in soil fertility enhancement.

Agroforestry practices, if fully supported by governmental agencies and NGO’S offers way out for poor resource farmers in the tropics. The Agroforestry systems and approaches hold a great future for global food production as well as remaining the only traditional forest-based technology to solving the global environmental degradations and it’s destroying effects on the socio-economic livelihood of vast population of many countries of the world.

References