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THE ROLE OF TREES AND PLANTATION AGRICULTURE IN MITIGATING GLOBAL CLIMATE CHANGE

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ABSTRACT

Climate change refers to a paradigm shift in the climatic pattern of a location, region or planet which is linked with average weather components, such as temperature, wind patterns and precipitations. Climate change results in erratic events such as rising global temperature, intensified drought, flooding, cyclones, low or poor agricultural productivity, loss of biodiversity and shifting of seasons. Natural processes such as variations in the intensity of the sun, eruptions from volcanoes, very slow changes in ocean circulations and land surfaces can cause this global climate change but human activities are by far the major causes through the continuous release of greenhouse gases and aerosols into the atmosphere, by altering land surfaces, and or depleting the ozone layer. The most environmentally conservative response to climate change mitigation would be to stop the consumption of fossil fuels and production of methane and chlorofluorocarbons; but these options may not be feasible until alternative technologies emanate. Considering the large amounts of carbon accumulated as biomass in plantations, extensive planting of trees, which posses large canopies that are able to capture carbon dioxide (CO_2) from the atmosphere, could help mitigate the rising atmospheric CO_2 levels. The roles of plantations in mitigating global climate change are related, but not limited to the following: the influence of trees on the hydrologic cycle, the barrier against destructive windstorm and desertification, conservation of the soil surface against erosion and intense heat, binding action of the dense root system, sustainable biodiversity, provision of renewable and bioenergy, nutritious food, employment, and rural income, and the reservoir of sequestered carbon. There is an urgent need to properly integrate trees and plantations in our agricultural systems, homes, institutions, markets, parks and other public places. This would not only help to reduce the build-up of carbondioxide and other atmospheric impurities but also increase the produce from plantation crops in a locality thereby mitigating against food insecurity and poverty.

Key words: Climate-change, trees, mitigation, adaptation, carbon sequestration, food security, sustainable agriculture

INTRODUCTION

Global warming and the consequent climate change, and weather instability are among the key environmental issues facing the world today. Climate change refers to a change in the climatic pattern of a location, region or planet which is linked with average weather components, such as temperature, wind patterns and precipitations [1, 2, 3]; the effects of which are erratic behavior of nature, such as rising global temperature, intensified drought, flooding, cyclones, low or poor agricultural productivity, loss of biodiversities and shifting of seasons. These changes, according to the United Nations' Intergovernmental Panel on Climate Change [4] can be caused by natural processes like eruptions from volcanoes, variations in the intensity of the sun, or very slow changes in the circulation of the ocean or land surfaces which occur over decades, centuries or even longer. Human activities are, however, the major cause of climate change through the continuous release of greenhouse gases and aerosols into the atmosphere, the alteration of land surfaces, and depletion of the stratospheric ozone layer.

Climate change is progressively emerging as one of the most serious global problems affecting many segments of economic growth in the world [5, 6, 7]. Climate change effects have been experienced in many countries of the world in form of widespread flooding, incessant drought, disruption of weather patterns, increased global temperature, devastating windstorms, and forest fire devastations. Sectors widely affected by the impacts of climate-related hazards and calamities include agriculture, freshwater sources, fisheries, forestry and other land-use; others are wildlife, energy sources, industrial processes and product use, waste management, human health, and the sustainable livelihood of rural and urban communities [4].

It has become more challenging in the recent years to grow enough food in the developing nations due to the erratic changes in the world climate. Existing crop varieties and animal breeds are exposed to unpredictable changes that affect their biochemistry and physiological functions; the consequences are malfunctions of their genetic codes [8, 9], which may lead to death or extremely poor performance (productivity). Furthermore, explosive growth of the population worldwide and the need for ethanol (bio-fuel) blended gasoline has put more pressure on the demand for an increase in agricultural production [10]. Food shortages in recent times have ignited riots in some countries and sharp price hikes in markets around the globe causing lots of miseries and death due to starvation [11]. It, therefore, makes sense to adopt climate smart farming practices which would enhance productivity and provide workable adaptation and mitigation strategies on climate change.

Climate change has obvious effects on economic, social and human health [12]. According to FAO [12] the impacts of climate change can generally be divided into two groups namely:

Biophysical impacts:

- Effects on the physiological processes of crops, pasture, forests and livestock (quantity, quality);
- Increase in pest and weed challenges;
- Changes in land forms, soil and water resources (quantity, quality);
- Sea level rise and changes to ocean salinity;
- Sea temperature rise which disrupts marine life causing fish to inhabit different ranges;
- Shifts in spatial and temporal distribution of impacts.

Socio-economic impacts:

- General decline in agricultural production;
- Reduced marginal gross domestic products from agriculture;
- Instabilities in world market prices;
- Changes in geographical distribution of trade regimes;
- Increased food insecurity and hunger;
- High migration rate and civil unrest.

The biophysical effects of climate change on agriculture cause changes in production and market prices, which play out through the economic system as farmers and other market participants adjust autonomously by altering crop mix, input use, production chain, food demand, food consumption and trade regimes [13]. On the other hand, socio-economic impacts are concerned with the rising threats of climate change to the current income and consumption patterns of many households and individuals that earn their livelihoods from those sectors threatened by climate calamities [14], which are measured by changes in the level of poverty, food security, value of farm assets (such as land), income, consumption and health outcomes.

Adaptation Strategies to Climate Change

There are two main types of adaptation strategies, which are *autonomous* and *planned* adaptation [12]. Autonomous adaptation is the response of a farmer to changing precipitation patterns by changing the crop types/species grown or adjusting the planting/sowing and harvesting dates. Whereas, planned adaptation measures are conscious policy options or response strategies, often multi-sectoral in nature, aimed at altering the adaptive capacity of the agricultural system or facilitating specific adaptations to climate change. For example, deliberate crop selection and distribution strategies across different agro-climatic zones, substitution of new crops for old ones, and resource substitution induced by scarcity of agricultural resources [15].

Mitigation of greenhouse emissions in agriculture has several approaches, according to FAO [16], namely, (i) emissions can be reduced; (ii) emissions can be avoided or displaced; or (iii) sinks can be created to remove emissions.

Climate systems include all interactive systems, which determine and regulate climate regimes in different parts of the globe. The global climate system is made up of the atmosphere, the oceans, the ice sheets (cryosphere), living organisms (biosphere), soil

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sediments and rocks (geosphere), which all affect to a greater or lesser extent, the movement of heat around the earth's surface [17].

There is no doubt that the concentration of CO_2 in the atmosphere has risen. Carbon dioxide (CO_2) and other greenhouse gases are relatively transparent to visible radiation, but they absorb long wavelength infrared radiation emitted (reradiated) from the earth, hence they trap heat within the atmosphere causing the temperature at the earth's surface to rise [17].

Carbon dioxide concentration in the upper atmosphere is the main cause of greenhouse effect and rise in the atmospheric temperature. Bioremediation strategies have been employed to reduce the atmospheric CO_2 content at two levels which include:

(a) Phytoremediation, where fast-growing plant species use atmospheric CO_2 during photosynthesis thereby reducing the CO_2 concentrations of the atmosphere.

(b) Storage of CO_2 by certain deep sea organisms like corals and green/red algae through a process of biological calcification. More and more atmospheric CO_2 is absorbed for calcification as the $CaCO_3$ gets precipitated [18].

Recent estimates [19] indicate that emissions of CO_2 caused by deforestation could range between 1.1 to 3.9 billion tonnes by 2020. Similarly, methane emission from managed livestock (including their waste) and rice paddies will increase to 135 million tonnes, whereas nitrous oxide emissions from inorganic fertilizer use will probably increase up to 3.5 million tonnes [19].

The most environmentally conservative response would be to halt or slow global warming by cutting down on the consumption of fossil fuels (coal, petroleum products, limestone, and natural gas), and the production of methane and chlorofluorocarbons (CFCs). Besides greenhouse effect and global warming, CFCs released in aerosols, refrigerators and other industrial coolants attack the protective ozone layer (they liberate chlorine atoms which facilitate the destruction of the stratosphere), creating channels through which harmful ultra-violet rays reach the earth's surface [20, 21]. The stratospheric ozone layer acts as a protective shield, preventing much of the sun's UV radiation from hitting the earth.

Apart from the shading and cooling effect provided by tree canopies, extensive planting of trees to capture CO_2 from the atmosphere could help mitigate the rise in atmospheric CO_2 concentration considering the large amounts of carbon accumulated per hectare in most plantations. The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) [22] reported that the forest sector has a biophysical mitigation potential of 5,380 Mt CO_2 per year on the average. Any changes that result in increased forest biomass would contribute immensely to a sequestration of at least a portion of the 'excess carbon' released into the atmosphere. Possible expansion of the forested area by the establishment of new plantations could be effective in mitigating the buildup of atmospheric CO_2 [16]. The United Nations had identified that

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conservation of tropical forests is of vital importance for global climate stability (particularly for the important contributions of tropical forests destruction to global warming, atmospheric CO_2 concentration, methane (CH_4) and other trace gases), biodiversity conservation, economic and social development, and for local or regional climatic and environmental reasons.

The biomass above- and below-ground, debris of dead wood, the leaf litter fraction, and the accumulated soil organic matter from tree crop species constitute five important carbon pools needed to be considered for the carbon sequestration potential of tree crop species.

Causes of Climate Change

Factors that lead to change in climate are classified into natural factors and artificial or man-made factors. Natural factors are independent of human activities, and man has little or no control over them. These include:

1. **Volcanic eruption,** which is associated with the release of large volumes of sulphur (IV) oxide (SO_2), water vapour, dust, CO_2, heat and ashes into the atmosphere. These particles when released into the atmosphere could influence climatic pattern for several years. For instance, SO_2 may combine with water vapour to form tiny droplets of sulphuric acid which could remain in the upper atmosphere for years causing acid rain.

2. **Ocean effect** as the ocean is a major component of the climatic system. Oceans cover about 71% of the earth and absorb about twice as much of the sun's radiation compared to the atmosphere or the land surface [23]. Heat escapes from the ocean in the form of water vapour which is the most abundant greenhouse gas. Ironically, water vapour contributes to the formation of clouds which shade the earth's surface producing a cooling effect. Besides, without vaporization and condensation of water molecules in the upper atmosphere, the hydrologic cycle would not be complete, and life on earth would have been very difficult.

3. **Human activities** are still contributing significantly to the global climate change [4, 19, 24]. Some of the human activities that contribute to climate change include:

   I. **Consumption of fossil fuels** in automobiles and generators, industrial wastes, and effluents from the mining and oil drilling activities [25].

   II. **Deforestation:** This is the indiscriminate cutting of forest trees to satisfy man's immediate needs. The main causes of forest destruction include:

      - Clearing for agriculture, particularly shifting cultivation at the forest fringes.
      - Intensive logging for timber.
      - Exploitation for charcoal, firewood, poles and other domestic uses.

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- Urban and industrial expansion including mining and hydroelectric schemes.
- Overgrazing and harvest of fodder for livestock, especially in arid savannah regions.
- Accidental or deliberate burning of forests, that is, seasonal forest fire.
- Ravages of war.

III. **Agricultural activities:** Agricultural activities currently produce approximately 14 % of the total greenhouse gases (GHGs) emitted globally [16, 26]. The major GHGs emitted by agricultural production sources include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) [26]. These sources include emissions from rice paddies, decaying vegetation (peat and swamp), ruminant animals, fertilizer application, and loss of soil organic matter, biomass burning, sewage disposal and land conversion.

Ruminant animals produce CH_4 during the process of their food digestion. Total CH_4 emission from domestic ruminants have been estimated between 65-100 million tonnes annually, and animal waste from anaerobic waste management systems are likely to yield up to 15 million tonnes globally [27]. Also flooded rice fields produce CH_4 due to microbial decay of organic matter.

The World Meteorological Organization reports that the burning of biomass for land-use as well as agricultural wastes are estimated to account for more than half of all biomass lost annually [16]. In fact, if not for human activities, the composition of the atmosphere would have been stable; a balance would exist between natural emissions, natural sinks (plants, soil and ocean life forms) and atmospheric processes.

IV. **Discharge from aerosols:** The use of perfumes and body sprays contributes to the release of noxious chlorofluorocarbons (aerosol spray propellants) into the atmosphere, which depletes the protective ozone layer. These chlorofluorocarbons are also released from refrigerators and other coolants causing further harm to the stratospheric ozone layer.

Effects of Global Climatic Change

If the buildup of greenhouse gases continues at the current rates, a significant climatic warming is expected in a few decades [25]. Human activities are changing the composition of the atmosphere at an unprecedented rate.

1. **Effect on water resources**: Global warming is certain to have major impacts on both water availability and water quality. Temperature, precipitation pattern, rates of evapotranspiration, timing and the magnitude of runoff, the frequency and intensity of storms will be affected by increasing concentration of CO_2 and other GHGs. A rise in sea levels which is associated with global warming could

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threaten the freshwater supplies of coastal communities [28], and changes in temperature and rainfall level would affect the demand for water especially for irrigation.

Climate modelers have recently agreed that global warming will increase global precipitation with an accelerated melting of ice sheets in the Polar Regions and mountain glaciers resulting in rise in sea level and flooding of the coastal areas [25].

2. **Effects on agriculture:** Climate change affects agriculture in several ways:
   - Increased weed growth.
   - Increased pest and disease infestation; emergence of new pests and diseases.
   - Reduction in soil nutrients.
   - Decreased agricultural yields.
   - Loss of agricultural land due to flooding and erosion.
   - Vegetation loss and land degradation following deforestation.
   - Reduction in soil moisture.
   - Uncertainty in weather variability.

3. **Weather-related disasters**: If global temperatures continue to rise with the current predictions, increase in number and severity of storms, flood, drought, and other short-term weather extremes may escalate in many regions.

   Wind arises from the usual heating of the earth's surface by solar energy. The severity of windstorms could increase with increased solar radiation as typified in tropical cyclones, typhoons, hurricanes and tornadoes [28]. Recent hurricanes and cyclones happening around the world are indications of the effects of climate change. There are suggestions that these catastrophes would not only increase in severity but also extend to new areas, if efforts are not made to mitigate global climate change [13, 23].

4. **Effect on health**: There are both direct and indirect effects of climate change on human health. High temperature causes dehydration, spread of infectious disease, and heat related ailments like Meningitis. Exposure to UV radiation has been associated with damage to the cornea, lens and retina of the eyes, as well as, skin cancer. Changes in weather patterns can lead to disturbances in the ecology, changes in the levels of food production, increased distribution of malaria and other vector-borne diseases, rise in sea levels with the concomitant flooding and other hazards.

Mitigation Roles of Plantation Crops

Mitigation denotes all activities geared towards reducing GHG emissions and or removal of CO_2 from the atmosphere which aims at stabilizing CO_2 concentrations around the globe [29, 30]. The roles of trees and plantation crops in the mitigation of climate change are related to the following:

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Carbon sequestration: Forests and trees serve as important carbon sinks [30]. Their leaves absorb CO_2 from the atmosphere and store it as carbon in the accumulated biomass. Carbon sequestration by forests has attracted much interest as a mitigation approach, as it has been considered a relatively inexpensive means of combating climate change challenges [30]. Expansion of the forest area through the establishment of new plantations has been suggested to mitigate the buildup of atmospheric CO_2 via carbon sequestration [16]. The ability of forests to store large amounts of carbon, as well as their importance in global carbon cycle has led to the suggestion of massive afforestation programs to provide additional carbon sink. The ability of forests to sequester carbon is related very directly to the biomass accumulation. The most environmentally conservative response to global climate change would be to halt or slow global warming by cutting back on the combustion of fossil fuels, and production of methane and chlorofluorocarbons, but at present this may not be feasible unless alternative technologies emanate. Extensive planting of trees to capture CO_2 could merely help to slow the rise in atmospheric CO_2 concentrations. Afforestation is, therefore, vital for a continuous purification of the atmosphere by mere absorption of CO_2 and the release of oxygen during photosynthesis. When a forest or plantation is cleared, particularly with forest fire, much of the stored carbon is rapidly converted to CO_2, and it takes decades to fix again the carbon released through deforestation. The Intergovernmental Panel for Climate Change (IPCC) estimated that about 65% of the total mitigation potential in the forest sector is located in the tropics and about 50% of this lot could be achieved by reducing deforestation [31]. The IPCC opined that the most cost effective way of reducing atmospheric carbon concentrations is to reduce deforestation of tropical forests and encourage forest cover expansion [29].

Forest and plantation mitigation options include reducing emissions from deforestation and forest degradation, enhancing carbon sequestration rate in existing and new plantations, providing fuel from wood as a substitute for fossil fuels, and providing wood products (as renewable energy) for more energy-intensive materials [32]. When properly designed and implemented, plantation mitigation options will have substantial co-benefits with respect to employment and income generation prospects, biodiversity and watershed conservation, provision of timber and fibre, as well as aesthetic and recreational services [32].

Hydrologic cycle: Trees influence rainfall through evapotranspiration. About 10-20% of the rain falling onto the forest never reaches the ground; the rain drops are intercepted by the tree canopy and evaporated back into the atmosphere [33]. This is experienced in most tropical forests. Forest canopy and the understory vegetation protect the soil surface against the abrasive action of rain drops, thereby minimizing erosion and surface runoff. The roots of trees grow deeper in the soil than arable crops. These roots absorb water at a deeper soil depth which is transpired to the atmosphere, forming clouds that in turn release water in the form of rainfall.

Windbreak: Tree crops are often used in shelterbelts, particularly in arid regions to minimize wind speed, and combat desert encroachment. Trees provide a barrier against the destructive action of heavy windstorm; acting as windbreak for annual crops [34, 35, 36]. Similarly, Puri *et al*. [37] reported that a tree belt was able to reduce the wind speed by 15 to 45% depending upon the season and wind intensity. The authors also observed that the plant growth of cotton (with respect to plant height, leaf number, leaf area) and seed cotton yield were higher in sheltered belts than in open fields.

Binding action of the roots: If left undisturbed, the ground beneath tree crops becomes covered with a layer of debris called forest litter (comprising dead leaves, twigs, branches, and logs at various stages of decomposition). The litter and humus layers that accumulate in the long run absorb moisture and further modulate the infiltration rate of the underlying soil. The heavy canopy of plantations is effective in maintaining ideal humidity and microclimate in the immediate and adjoining environments, while the dense root volume explores the soil for nutrients and water thereby minimizing leaching and runoff losses; thus, reducing pollution of underground and surface water.

Roots increase the strength of soils [38]. The rate of soil strength support varies according to species, root size, and the activities of decay organisms. Roots become stronger as they get larger; the logarithm of root shear strength is closely related to the logarithm of the diameter of the root. The roots of trees are estimated to be 1.5-3 times stronger than the roots of grassy plants of the same diameter [38], and a tree possesses thousands of leaves and hundreds of kilometers of roots with hundreds of thousands of root tips; all contributing to the binding action on soil particles.

When land is devoid of vegetation, the organic matter which decomposes gradually will be exposed to high temperature which leads to rapid depletion and resultant CO_2 emission that increase global warming [30]. Because plantation crops are heavy feeders, they are capable of absorbing large amounts of substances introduced to the soil either through fertilizer application and waste management or atmospheric impurities washed down with torrential rainstorms. Trees and other plantation crops take up nutrients from the soil and incorporate them in their biomass. These nutrients are only released back to the soil when the leaves of the trees fall or when the plants die and decay. Part of the tree biomass is eaten by various soil animals (including insects and earthworms), and their excreta return nutrients to the soil. In the soil, a huge number of soil microorganisms are involved in the decomposition of organic materials which makes nutrients available to plant roots. The dense root system of tree crop species with the thick litter conserves and holds the soil together and collects the released nutrients almost completely, thereby minimizing eutrophication (pollution) of both surface and underground water. Due to their deep taproot system, tree crops are able to recycle nutrients leached beyond the rooting zone of most field crops.

Provision of natural shelter: In general, agroforestry provides shade and shelter; improving microclimate of the immediate and surrounding environment [39, 40]. Tree crops modulate the microclimate protecting the environment against intense tropical heat and high temperatures, and as windbreak, reduce wind speed. This provides some relief against climate change vagaries. Unlike most field crops, plantation crop species provide permanent fallow protecting the soil against perennial bush fire (seasonal bush burning), thereby preventing CO_2 release to the atmosphere. When the trunks of trees are logged, they are used in construction, roofing and in furniture; thus, keeping a reservoir of sequestered carbon for several years. Tree crops help in the reclamation of degraded and marginal lands and also actively ameliorate the soils against erosion, compaction, surface crusting and floods. At maturity, an orchard would keep roughly constant biomass according to the adopted pruning and husbandry intensity, and would colonize an environmental space far larger than most field crops and in a more permanent way.

Sustainable biodiversity: Agroforestry, which is an intentional management of shade tree with agricultural crops, has the potential for providing habitat outside formally protected land, connecting nature reserves and alleviating resource-use pressure; and contributing to soil resource conservation [41]. Trees provide natural abode for most arboreal animals. Forests sustain the wild animal species without which these animals would go extinct. Establishment of large expanse of tree crop species could harbor the activities of bees and other insect pollinators, as well as, the growth and productivity of wood climbers. Some crop species grow better as understory plants as typified in *Theobroma cacao*, *Dennettia tripetala*, and *Kola* spp. Massive establishment of plantations would provide, in no small measure, the harmonious biodiversity required in nature to mitigate global climate change and sustain our cooperate existence – trees sustain life. Moreover, tree crops are more amenable to carbon friendly and climate smart agricultural practices including zero tillage, mulching, and use of organic sources of plant nutrients/slow release fertilizers and the likes. Conservation agriculture plays an important role in climate friendly practices, as well as, organic techniques and bioenergy production.

Source of renewable and bioenergy: Bioenergy refers to products of biomass that have been converted into liquid, solid or gaseous form, depending on the source of energy generation, such as the raw material base and technology employed. [42,43]. Biomass, on the other hand, encompasses a wide range of plant materials comprising agricultural, forestry and municipal wastes as well as crops which are grown specifically to make biofuels, such as bioethanol and biodiesel [42, 44]. Bioenergy is energy generated through biofuels [45]. Hence, biofuels are fuels made by the conversion of biomass [42]. When biofuel is combusted, CO_2 is released back into the atmosphere, without a net increase in the atmospheric CO_2 [29, 46]. Biodiesel could be made from sunflower, oil palm, coconut, soybean, Jatropha, rapeseed and animal fats. [42]. When bioenergy is adopted with other products, the approach will be more effective for GHG mitigation that is, by utilising biomass that has already served other functions [43].

Modern bioenergy contributes substantially to climate change mitigation by providing alternative sources of renewable energy [29]. The author stated that using fuels such as bio-diesel originating from wood products is carbon neutral since trees harvested for use as fuel are continually replanted. It is no news that biodiesel is produced commercially from trees such as *Jatropha curca* [46, 47]. Large plantations of Jatropha are now being grown in most of the tropics to supply the industrialized nations for processing. Investments in Jatropha plantations have provided for additional carbon sink, alternative fuel, employment and income in most rural communities.

In the face of a continual global escalation of climate related calamities and food shortage, conventional crop species would need to be complemented by shifting to more resilient food sources provided by tree crops. Bread fruit, banana and plantains, moringa, avocado, paw-paw and soursop are some of such alternatives. The fact that tree crops contain significantly higher carbon stocks than row crops or pastures [48] suggests that the integration and proper management of trees on croplands has a greater potential for carbon sequestration, in addition to rehabilitating degraded land. Reports on soil carbon dynamics [49, 50] have specified that soil organic matter increases after a few seasons of tree planting especially on degraded soils.

Source of complementary medicine for humans and animals. Since the dawn of history, man has depended on medicinal plants for his health and food needs. Trees like *Warburgia ugandensis*, *Azadirachita indica*, *Moringa oleifera*, *Prunus africana*, *Khaya senegalensis*, *Garcinia kola*, among others, some of which are at risk of extinction due to over-exploitation [51], are powerful sources of medicine for man and his animals [52]. Extracts from common fruit trees like *Carica papaya* (paw paw), *Citrus aurantifolia* (lime), *Citrus paradise* (grape fruit), *Psidium guajava* (guava), *Anarcadium occidentale* (cashew), *Mangifera indica* (mango), *Dennettia tripetala* (pepper fruit), *Dacryodes edulis* (butter fruit), *Vitellaria paradoxa* (shea butter) and *Dalium guineense* (velvet tamarind) serve a plethora of medicinal functions [52, 53]. These tree species can be grown as carbon sinks and for other uses, such as timber, natural fallow species for soil fertility restoration and conservation, for aesthetic and horticultural appeal, source of renewable energy, food and fodder. When properly integrated into crop or range lands, homes, schools, and other public places, these trees will serve as a source of good nutritious food and fodder, medicine, renewable energy (in form of fuel wood and charcoal), additional income, as well as provide such services as shade, soil improvement, windbreak, erosion control; and as such, support sustainable land care.

CONCLUSION

Trees and plantation crops have great potential to sequester atmospheric carbon and mitigate global climate change. There is an urgent need to properly integrate trees and plantations in our agricultural systems, homes, institutions, markets, parks and other public places. This is in corroboration with the FAO [30] reports that the contribution of trees to the reduction of climate change could be enhanced by promoting agroforestry systems and planting trees in the urban areas. This would help reduce the buildup of CO_2 and other atmospheric impurities. Trees modulate our environment, and can thrive on marginal lands (even without supplemental fertilizer application) providing succor to the devastating effects of climate change. Integrating trees or plantation crops on croplands would also increase the produce from farmland, thereby mitigating against food insecurity and poverty.

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REFERENCES

1. **Warrick RA and EM Barrow** Climate change scenarios for the UK. *Transactions of the Institute of British Geographers*. 1991; **16**: 387-399.

2. **Ngaira JKW** Impact of climate change on agriculture in Africa by 2030. *Scientific Research and Essays*, 2007; **2 (7):** 238-243.

3. **Ifeanyi-obi CC, Etuk UR and O Jike-wai** Climate Change, Effects and Adaptation Strategies; Implication for agricultural extension system in Nigeria, *Greener Journal of Agricultural Sciences*. 2012; **2 (2):** 053-060.

4. **IPCC.** The United Nations Intergovernmental Panel on Climate Change. The science of climate change. Cambridge University Press. 2001a.

5. **Lema MA and AE Majule** Impacts of climate change variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. *African Journal of Environmental Science and Technology*. 2009; **3(8):** 206-218.

6. **Bates BC, Kundzewicz ZW, Wu S and JP Palutikof** Climate change and water. IPCC Technical Paper VI, Geneva. 2008: 210.

7. **Kangalawe RYM and JG Lyimo** Climate Change, Adaptive Strategies and Rural Livelihoods in Semiarid Tanzania. *Natural Resources*, 2013; **(4)**: 266-278. Available at http://dx.doi.org/10.4236/nr.2013.43034. Accessed on 23rd October, 2014.

8. **Nwosu CC and CC Ogbu** Climate change and livestock production in Nigeria: issues and concerns. *Agro-Science*, 2011; **10 (1):** 41-60.

9. **Sunil Kumar BV, Kumar A and M Kataria** Effect of heat stress in tropical livestock and different strategies for its amelioration. *Journal of Stress Physiology and Biochemistry*, 2011; **7 (1):** 45-54.

10. **Adelekan BA** Investigation of ethanol productivity of cassava crop as a sustainable source of biofuel in tropical countries. *African Journal of Biotechnology*, 2010; **9 (35):** 5643-5650.

11. **Griffiths S** The world faces widespread food shortages due to global warming: crops will become scarce as droughts ravage Africa and Asia. *Mailonline*, 24th December, 2015. Available at www.dailymail.co.uk/sciencetech/article-3373018.Accessed on 4th Jan.2016.

12. **FAO.** Adaptation to climate change in agriculture, forestry and fisheries: Perspective, framework and priorities, Food and Agriculture Organization of the United Nations, Rome, Italy. 2007; 32.

13. **Nelson GC, Rosegrant MW, Koo J, Robertson R, Sulser T, Zhu T, Ringler C, Msangi S, Palazzo A, Batka M, Magalhaes M, Valmonte-Santos R, Ewing M and D Lee** Climate Change Impact on Agriculture and Costs of Adaptation, International Food Policy Research Institute. 2009; 30.

14. **Karfakis P, Lipper L and M Smulders** The assessment of the socio-economic impacts of climate change at household level and policy implications. **In:** Meybeck A, Lankoski J, Redfern S, Azzu N and V Gitz (eds.). Building Resilience for Adaptation to Climate Change in the Agriculture Sector. (Proceedings of a joint FAO/OECD workshop 23-24 April, 2012, Food and Agriculture Organization of the United Nations and the Organization for Economic Co-operation and Development, Rome, 2012: 133-150.

15. **Easterling WE** Adapting North American Agriculture to Climate Change in Review. *Agricultural and Forest Meteorology*, 1996; **80 (1):** 1-54.

16. **FAO.** Global Survey of agricultural mitigation projects. Mitigation of Climate Change in Agriculture (MICCA) Series I. Food and Agriculture Organization of the United Nations, Rome, Italy. 2010a. Available online at www.fao.org/climatechange/micca/en. Accessed on 5th June, 2012.

17. **Buchdahl JM** Global climate change student information guide. Atmosphheric Research and Information Centre, Manchester Metropolitan University. 1999; 98.

18. **Riebesell U, Schulz KG, Bellerby RGJ, Botros M, Fritsche P, Meyerhofer M, Neill C, Nondal G, Oschlies A, Wohlers J and E Zöllner** Enhanced biological carbon consumption in high CO_2 ocean. *Nature*, 2007; **450:** 545-548.

19. **IPCC.** Agriculture: In Climate Change Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, U.S.A. Cambridge University Press. 2007a.

20. **Molina MJ and FS Rowland** Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone. *Nature,* 1974; **249:** 810-812.

21. **Prather MJ and RT Watson** Stratospheric ozone depletion and future levels of atmospheric chlorine and bromine. *Nature*, 1990; **344:** 729-734.

22. **Kauppi P, Sedjo RJ, Apps M, Cerri C, Fujimori T, Janzen H, Krankina O, Makundi W, Marland G, Masera O, Nabuurs GJ, Razali W and NH Ravindranath** Technical and economic potential of options to enhance, maintain and manage biological carbon reservoirs and geo-engineering. **In**: Metz B, Davidson O, Swart R, Pan J (eds.) Climate change 2001: Mitigation. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge. 2001.

23. **Pidwirny M** Energy balance of earth; 2013. Available at http://www.eoearth.org/view/article/152458.Accessed on 22nd February, 2014.

24. **World Meterological Organization (WMO)** A WMO information note: A summary of current climate change findings and figures, November, 2013: 9.

25. **IPCC.** "Comparison between modelled and observations of temperature rise since the year 1860." **In:** *Climate Change 2001: Synthesis Report*, Contribution of Working Groups I, II, and III to the Third Assessment Report. Robert T. Watson and the Core Writing Team, (eds.). Cambridge University Press, Cambridge, UK. 2001b.

26. **LaSalle TJ and P Hepperly** Regenerative Organic Farming: A Solution to Global Warming. Rodale Institute 2008. Available at http://www.rodaleinstitute.org/files/Rodale_Research_Paper-07_30_08.pdf Accessed on 5th June, 2009.

27. **Kupfer D and R Karimanzira** Agriculture, forestry, and other human activities. **In:** Climate Change – The IPCC Response Strategies. The report of the Response Strategies Working Group (RSWG) III Plenary Session held in Geneva, Switzerland, June 9, 1990: pp. 73-127. Available online at. www.ipcc.ch/ipccreports/far/wg-III/ipcc_far_wg_III_chapter_04.pdf.Accessed on 15th January, 2010.

28. **Nicholls RJ and A Cazenave** Sea-level rise and its impact on coastal zones, *Science (New York, N.Y)*. 2010; **328 (5985):** 1517-1520.

29. **Patosaari P** Forests and Climate Change: Mitigation and Adaptation through Sustainable Forest Management. Remarks presented at UN Forum on Forests Secretariat during the 60th Annual DPI/NGO Conference "Climate Change: How it Impacts Us All" Roundtable on Coping with Climate Change: Best Land Use Practices United Nations, New York, 6 September 2007. 2007; 6.

30. **FAO.** Managing forest for climate. Food and Agriculture Organisation of the United Nations, Rome, Italy. 2010b; 20.

31. **IPCC.** Climate change 2007: Mitigation. Contribution of Working group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, L. A. Meyer (eds).], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2007b.

32. **Nabuurs GJ, Masera O, Andrasko K, Benitez-Ponce P, Boer R, Dutschke M, Elsiddig JF, Ford-Robertson F, Frumhoff P, Karjalainen T, Krankina O, Kurz WA, Matsumoto M, Oyhantcabal W, Ravindranath NH, Sanz Sanchez MJ and X Zhang** Forestry. **In:** Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2007: 542-584.

33. **Critchley WRS and LA Bruijnzeel** Environmental impacts on converting moist tropical forest to agriculture and plantations. UNESCO 1996: 50.

34. **Verheij E** Agrodok 16. Agroforestry. Agromisa Foundation, Wageningen. 2003; 85.

35. **Rahman S, Paras F, Khan SR, Imtiaj A, Farhana M, Toy M, Akhand M and T Sunderland** Initiative of tropical agroforestry to sustainable agriculture: a case of Capasia Village, Northern Bangladesh. *J Hortic For*. 2011; **3**:115-121.

36. **Waha K, Muller C, Bondeau A, Dietrich J, Kurukulasuriya P, Heinke J and H Lotze-Campen** Adaptation to climate change through the choice of cropping system and sowing date in sub-Saharan Africa. *Global Environ Change*, 2013; **22**:130-143.

37. **Puri S, Singh S and A Khara** Effect of windbreak on the yield of cotton crop in semiarid regions of Haryana. *Agroforestry Systems*, 1992; **18 (3):** 183-195.

38. **Perry TO** Tree Roots: Facts and Fallacies. *Journal of Arboriculture*, 1982; **8 (8):**197-211.

39. **Ajayi OC, Akinnifesi FK, Sileshi G, Chakeredza S, Mn'gomba S, Nyoka I and T Chineke** Local solutions to global problems: the potential of agroforestry for climate change adaptation and mitigation in southern Africa. Paper presented at the Tropical Forests and Climate Change Adaptation (TroFCCA) Regional meeting "Knowledge and Action on Forests for Climate Change Adaptation in Africa", November 18–20, Accra, Ghana: 2009:1-17.

40. **Syampungani S, Chirwa PW, Akkinifesi FK and OC Ayayi** The potential of using agroforestry as a win-win solution to climate change mitigation and adaptation and meeting food security challenges in Southern Africa. *Agric J*. 2010; **5**:80-88.

41. **Bhagwat S, Willis KJ, Birks HJB and RJ Whittaker** Agroforestry: a refuge for tropical biodiversity? *Trends Ecol. Evol*. 2008; **23**:261-267. Available at http://dx.doi.org/10.1016/j.tree Accessed on 5th January, 2008.

42. **International Assessment of Agricultural knowledge, Science and Technology for Development (IAASTD).** Bioenergy and Biofuels: Opportunities and Constraints. 2008 Issues in Brief, Island Press.

43. **Bauen A, Berndes G, Junginger M, Londo M and F Vuille** Bioenergy – A sustainable and reliable energy source; A review of status and prospects. IEA Bioenergy, 2009:108.

44. **Nicholls D, Monserud RA and DP Dykstra** A synthesis of biomass utilization for bioenergy in the Western United States. Gen. Tech. Rep. PNWGTR-753. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 2008; 48.

45. **Hazell P and RK Pachauri** Bioenergy and Agriculture: Promises and challenges, 2020 vision for food, agriculture, and the environment, Focus 14, Brief 1 of 12, December 2006; 28.

46. **Olaniyi A** Biofuels opportunities and development of renewable energies markets in Africa: A case of Nigeria. A paper presented during the Biofuels Market Africa, 2007 Conference, in Cape Town South Africa on November 5-7, 2007.

47. **Henning RK** Jatropha curcas L. **In:** van der Vossen, HAM. and Mkamilo GS. (Eds.). Prota 11(1): Medicinal plants/Plantes médicinales 1. [CD-Rom]. PROTA, Wageningen, Netherlands. 2007.

48. **Winjum JK, Dixon RK and PE Schroeder** Estimating the global potential of forest and agroforestry management practices to sequester carbon. *Water, Air and Soil Pollution*, 1992; **64**: 213–228.

49. **Ong CK, Wilson J, Deans JD, Mulatya J, Raussen T and N Wajja-Musukwe** Tree-crop interactions: manipulation of water use and root function. *Agricultural Water Management*, 2002; **53**: 171–186.

50. **Albrecht A and ST Kandji** Carbon sequestration in tropical agroforestry systems. *Agriculture, Ecosytems and Environment*, 2003; **99**: 15–27.

51. **The IUCN** Red List of Threatened Species. Version 2015-4. International Union for Conservation of Nature and Natural Resources. Available at www.iucnredlist.org Retrieved on 19 February, 2016.

52. **Nwachukwu CU, Umeh CN, Kalu IG, Okere S and MC Nwoko** Identification and traditional uses of some common medicinal plants in Ezinihitte Mbaise L.G.A. of Imo State, Nigeria. *Report and Opinion.* 2010; **2 (6):** 1-8.

53. **National Research Council.** Lost Crops of Africa. Volume III: Fruits. The National Academies Press, Washington DC. 2008.