# A Review of Sustainable Agroforestry Practices as Climate Change Adaption and Mitigation Strategy in Nigeria

OKONKWO, MC
Federal College of Forestry Mechanization, Kaduna, Nigeria
GBADEBO, JO AND SALAUDEEN, AB
Plantation Establishment Unit, Sustainable Forest Management,
Forestry Research Institute of Nigeria, Ibadan
waheed.salawu@yahoo.com

**Abstract**
Agroforestry is one of the most conspicuous land use systems across landscapes and agroecological zones in Nigeria. With food shortages and increased threats of climate change, interest in agroforestry is gathering for its potential to address various on-farm adaptation needs, and fulfill many roles in mitigation pathways. Agroforestry provides assets and income from carbon, wood energy, improved soil fertility and enhancement of local climate conditions; it provides ecosystem services and reduces human impacts on natural forests. Most of these benefits have direct benefits for local adaptation while contributing to global efforts to control atmospheric greenhouse gas concentrations. This paper presents recent findings on how agroforestry as a sustainable practice helps to achieve both mitigation and adaptation objectives while remaining relevant to the livelihoods of the poor smallholder farmers in Nigeria.
**Keywords:** Review, sustainable, Mitigation, adaptation, climate change, strategy, Nigeria
**DOI:** 10.7176/JEES/12-12-01
**Publication date:** December 31st 2022

## INTRODUCTION

Despite the fact that most developing countries like Nigeria rely on agriculture for rural livelihoods development and advancement in the committee of nations, agricultural systems are still adversely affected by land pressure and climate change with consequential impact on food production. Most developing countries are experiencing food deficit as a result of land degradation despite their relative success in agricultural systems hence resulting in adverse feedbacks on climate, food security and low on-farm income scale (Krausmann *et al.,* 2013). Mueller *et al*., (2012) also asserts that even the 'green revolution' model as experimented by some developing nations via subsidies and other inputs have been costly and of course unsustainable because the roles of trees cannot be substituted by technologies. Studies (Lott *et al.*, 2009; Gockowski and Asten, 2012) have underscore the importance of diversification as a means to achieving improved crop and land management through the integration of trees in land use systems. To achieve this fit requires low external inputs (pro-poor), a high recycling rate, and good integration of trees, crops and animals to achieve sustainable livelihood and climate changes objectives (Nguyen *et al.,* 2013). Agroforestry is a two-edged sword that proffers solution to reforestation through forest protection and agricultural land use via increase in carbon sequestration and enhanced agricultural productivity [Koohafkan *et al*., 2012; Garnett *et al*., 2013). Scientific reports (Verchot *et al*., 2007; Mbow *et al.,* 2012) have proved that smallholder farmers address the problem of climate change through natural production systems which provide improved ecological and social functions, meet adaptation needs and building resilient agro-ecological systems that actively sequester carbon. This has built the interest of the peasant farmers in investing in agroforestry systems for multiple benefits (Pandey**,** 2002; Bayala *et al*., 2008), and innovative practices to cope with climate change impacts (Verchot *et al*., 2007). Although the benefits of agroforestry-based mitigation are still in the public domain but common ground is found in the areas of high production and economic values financial capital that aid capital accumulation and re-investment at the farm level (Tschakert, 2004). Although the capacity of agroforestry to raise carbon stocks and produce livelihood benefits has been well demonstrated, the research community needs to better understand the emerging challenge of assessing benefits from other ecosystem services beyond the symbolic value of carbon sequestration (Smith and Wollenberg, 2012).

### Synergizing Agroforestry Systems with Agricultural Performance

Soil fertility has been a serious constraint for sustainable agriculture in most third world nations (Duguma and Hager, 2011) with the erosion of topsoil resulting in soil degradation and aggravation of surface litter and crop residues. This couple with poor performance of current agricultural policies made way for food security via sustainable agroforestry practices [Muchena 2005; Kiptot and Franzel 2012) because of its potential to improve soil fertility. Leguminous agroforestry systems increase soil organic matter, fix nitrogen, facilitate nutrient cycling as well enrich the soil with nutrients and organic matter (Molua, 2005), while improving soil structural properties. Trees on farmland tap water, prevent nutrient leaching and help recover nutrients, conserve soil moisture. Several works (Van der Ent *et al.,* 2010; Garnett *et a*l., 2013; Du-Toit *et al*., 20014) posit that, there are a number of successful agroforestry technologies meant to reduce yield gap, such as trees that improve soil, fast-growing trees for fuel wood, indigenous fruit trees to provide added nutrition and income, and trees that can provide medicinal plant products. Majority of these can be achieved in practice, simple and complex agroforestry systems that are integrated into agricultural management systems (Oke and Odebiyi, 2007). The interest of investigating agroforestry in a changing climate comes from the potential of agroforestry practices to produce assets for farmers, combined with opportunities for climate change mitigation and potential to promote sustainable production that enhances agroecosystem diversity and resilience.

**Agroforestry as Climate Mitigation Strategy**

Increased numbers of trees on farmlands coupled with improved cropping systems contribute significantly to climate change mitigation. (Garrity *et al*., 2010) affirmed estimated the global greenhouse gas potential(GHG) sequestration in agriculture ranges to be between 1500  and 4300 Mt CO2e yr _n  1, with 90% of this potential in soil carbon restoration and avoided net soil carbon emission (Luedeling *et al.,*2012). Tree densities in farming landscapes range from 5% (in the Sahel) to around 45% (in humid tropics) where cocoa, coffee and palm oil agroforestry systems prevail (Kimaro *et al.,* 2012). Performance of mitigation options in agroforestry is a factor of many factors like tree species selection and management, soil characteristics, topography, rainfall, agricultural practices, priorities for food security, economic development options, among others. (Takimoto *et al*., 2008) established that agroforestry systems have 3–4 times more biomass than traditional treeless cropping systems and constitute the third largest carbon sink after primary forests and long term fallows in most developing countries. Sood and Mitchell (2011) further affirmed that area suitable for agroforestry globally is much larger with substantially greater potential than prevailing existing agroforestry systems with many methods of estimating carbon sequestration like the in situ measurements. Available literature has it that C stocks and C sequestration vary across agroforestry systems and integrated land use practices like agro-silvo-pastoral systems, combine high C stocks with high C sequestration potentials. Besides, agroforestry systems can reduce the pressure on natural forests for energy needs significantly as higher consumption of tree products would motivate farmers to adopt agroforestry (Ellison *et al*., 2012). Garnett *et al*., (2013) assert that development of agroforestry for sustainable fuel wood contributes to energy substitution with important carbon offset option. However, a combination of adaptation and mitigation strategies has been recognized as a necessity in the AFOLU (agriculture, forestry and other land use) sector of most developing countries. Agroforestry increase farm profitability through improvement and diversification of output per unit area of tree/crop/livestock, through protection against damaging effects of wind or water flow, and through new products added to the financial diversity and flexibility of the farming enterprise (Nguyen *et al*., 2013) and as well contribute substantially to climate change mitigation especially through the use of integrated multipurpose trees approaches profitability (Takimoto *et al.,* 2008; Koohafkan *et al.,* 2012). Trees on farms can provide wild edible fruits and non-timber forest products (NTFP) as alternative food during deficit of primary sources of income for the peasant farmers (Matocha *et al*., 2012). By inference, agroforestry improves the economic and resource sustainability of agriculture not at the detriment of Green House Gas (GHG) sequestration. To optimize agroforestry for climate change adaptation and mitigation there is a need for more integrated management to increase benefits and reduce negative impacts on climate.

**Agroforestry and Biodiversity Resilience**

From the research of Luedeling *et al.,* (2014) consolidating an earlier report by Ellison *et al*., (2012), land management practices offered by agroforestry systems include crop diversification, long rotation systems for soil conservation, home gardens, perimeter plantings, perennial crops, hedgerow intercrop- ping, live fences, mixed strata agro-forestry amongst others. A well-managed agroforestry outfit plays a crucial role in improving resilience to uncertain climates through microclimate buffering and regulation of water flow (Kimaro *et al*., 2012). Management options in agroforestry include tree pruning, to reduce below-ground competition for water with attention on microclimate control and others. Agroforestry system conserve and protect natural resources through mitigating non-point source pollution, soil  erosion control, protect wildlife habitat facilitates flexible ecological conditions and restore soil and water resources (Du-Toit *et al*., 2014). Sustainable agroforestry systems through the shading effects of trees that buffer temperature and saturation deficit improve the microclimate hence improving effective crop performance. Arguably, scattered trees system of agroforestry practice enhances the understory growth as it reduces air, soil temperature and incident solar radiation and many more. Agroforestry contributes to water recycling as reported by Luedeling *et al*., (2014) that, about 25% of the water transpired by trees is used during the dry season, indicating that they are able to utilize off-season rainfall (comprising 15–20% of the total annual rainfall) and residual soil water after the cropping period, with the rest being lost by evaporation (40%) or deep drainage (33–40%) with efficient soil utilization (Spracklen *et al*., 2012).

**Conclusion**

This paper addresses agroforestry systems as mitigation and adaptation strategies for food security particularly for peasant farmers. This underscores the need for much more attention on Agroforestry in global agendas considering its socio-environmental benefits. The work of Matocha *et al*., (2012) posited that, adding trees to cropping systems and/or animal production requires advanced cultivation methods and support for swift adoption. He further concluded that, the inability of extension service experts limits the expected progress in agroforestry innovations along with the limited investment in agroforestry practices as experienced by smallholder farmers willing to adopt the practice. Agroforestry for mitigation and adaptation at farm level should be scrutinized to increase social and economic benefits through agriculture with multifaceted analysis that focuses on basic local needs (Jackson *et al*., 2000). On the basis of this as a win-win approach for optimal land management practices, equal importance should be alluded to mitigation with clear adaptation strategic benefits. In Nigeria therefore, carbon sequestration should be considered a co-benefit of strategies to support sustainable livelihoods and adapt to climate change where progress towards adapted and sustainable livelihoods are measured by accumulation of asset and mapped out against these assets.

**References**

Bayala J, Heng LK, Noordwijk MV, Ouedraogo SJ (2008): Hydraulic redistribution study in two native tree species of agroforestry parklands of West African dry savanna. Acta Oecolo 2008. doi:10.1016/j.actao.

Duguma LA, Hager H (2011): Farmers' assessment of the social and ecological values of land uses in central highland Ethiopia. Environ Manage, 47:969-982.

Du-Toit JT, Walker BH, Campbell BM (20014): Conserving tropical nature: current challenges for ecologists. Trends Ecol Evol, 19:12-17.

Ellison D, Futter MN, Bishop K (2012): On the forest cover-water yield debate: from demand- to supply-side thinking. Global Change Biol, 18:806-820.

Garnett T, Appleby CM, Balmford A, Bateman JI, Benton GT (2013): Sustainable intensification in agriculture: premises and policies. Science, 341:33-34.

Garrity DP, Akinnifesi FK, Ajayi OC, Weldesemayat SG, Mowo JG, Kalinganire A, Larwanou M, Bayala J(2010): Evergreen agriculture: a robust approach to sustainable food security in Africa. Food Security, 2:1970-2214.

Gockowski J, Asten PV (2012): Agricultural intensification as a climate change and food security strategy for sub-Saharan Africa. In: Climate Change Mitigation and Agriculture. (Eds) Wollenberg E, Nihart A, Tapio-Bostro¨m M-L, Grieg-Gran M. London-New York: ICRAF-CIAT; 382-390.

Jackson NA, Wallace JS, Ong CK (2000): Tree pruning as a means of controlling water use in an agroforestry system in Kenya. Forest Ecol Manage, 126:133-148.

Kimaro AA, Isaac ME, Chamshama SAO (2012): Carbon pools in tree biomass and soils under rotational woodlot systems in eastern Tanzania. In: Carbon Sequestration Potential of Agroforestry Systems. (Eds) Kumar BM. Nair PKR: Springer; 2012:142-156.

Koohafkan P, Altieri AM, Gimenez HE (2012): Green Agriculture: foundations for biodiverse, resilient and productive agricultural systems. Int J Agric Sustain, 10:61-75.

Krausmann F, Erb HK, Gingrich S, Haberl H, Bondeau A (2013).: Global human appropriation of net primary production doubled in the 20th century. Proc Natl Acad Sci USA, 110:10324-10329

Kiptot E, Franzel S (2012): Gender and agroforestry in Africa: a review of women's participation. Agroforest Syst 2012, 84:35-58.

Lott JE, Ong CK, Black CR (2009): Understorey microclimate and crop performance in a Grevillea robusta-based agroforestry system in semi-arid Kenya. Agric Forest Meteor 2009, 149:1140-1151.

Luedeling E, Sileshi G, Beedy T, Dietz J (2012): Carbon sequestration potential of agroforestry systems in Africa. In Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges vol. Advances in Agroforestry 8. (Eds) Kumar BM, Nair PKR. Springer; 2012:23.

Luedeling E, Kindt R, Huth NI, Koenig K (2014): Agroforestry systems in a changing climate — challenges in projecting future performance. Curr Opin Environ Sustain, 6: 1-7.

Matocha J, Schroth G, Hills T, Hole D (2012): Integrating climate change adaptation and mitigation through agroforestry and ecosystem conservation. In: Agroforestry-The future of Land Use, vol Advances in Agroforestry 9. (Eds) Nair PKR, Garrity D. Springer; 2012:105-126.

Mbow C, Skole D, Dieng M, Justice C, Kwesha D (2012): Challenges and Prospects for REDD+ in Africa: Desk Review Of REDD+ Implementation in Africa. Copenhagen: GLP-IPO .

Muchena FN, Onduru DD, Gachini GN, Jager DA (2005): Turning the tides of soil degradation in Africa: capturing the reality and exploring opportunities. Land Use Policy, 22:23-31.

Molua EL (2005): The economics of tropical agroforestry systems: the case of agroforestry farms in Cameroon. Forest Policy Econ, 7:199-211.

 

Mueller DN, Gerber SJ, Johnston M, Ra KD, Ramankutty N(2012): Closing yield gaps through nutrient and water management. Nature, 490:254-257

Nguyen Q, Hoang MH, O¨born I, Noordwijk MV (2013): Multipurpose agroforestry as a climate change resiliency option for farmers: an example of local adaptation in Vietnam. Climatic Change, 117:241-257.

Oke DO, Odebiyi KA (2007): Traditional cocoa-based agroforestry and forest species conservation in Ondo State, Nigeria. Agric Ecosyst Environ, 122:305-311.

Pandey DN (2002): Carbon sequestration in agroforestry systems. Climate Policy, 2:367-377.

Smith P, Wollenberg E (2012): Achieving mitigation through synergies with adaptation. In Climate Change Mitigation and Agriculture. (Eds) Wollenberg E, Nihart A, Tapio- Bostro¨m M-L, Grieg-Gran M. London-New York: ICRAF-CIAT:50-57.

Sood KK, Mitchell CP (2011): Household level domestic fuel consumption and forest resource in relation to agroforestry adoption: evidence against need-based approach. Biomass Bioenergy 2011, 35:337-345.

Spracklen DV, Arnold SR, Taylor CM (2012): Observations of increased tropical rainfall preceded by air passage over forests. Nat Res Lett, 000:5 pp.

Takimoto A, Nair PKR, Nair VD(2008): Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel. Agric Ecosyst Environ:159-166.

Tschakert P, Tappan G (2004): The social context of carbon sequestration: considerations from a multi-scale environmental history of the Old Peanut Basin of Senegal. J Arid Environ:535-564.

Van der Ent RJ, Savenije HHG, Schaefli B, Steele-Dunne SC (2010): Origin and fate of atmospheric moisture over continents. Water Resour Res, 46 W 50952.

Verchot LV, Noordwijk MV, Kandji S, Tomich T, Ong C, Albrecht A, Mackensen J, Bantilan C, Anupama KV, Palm C (2007): Climate change: linking adaptation and mitigation through agroforestry. Mitigation Adapt Strat Global Change, 12:901-918.