



## Adoption of Silvopastoral Agroforestry System for a Sustainable Cattle Production in Nigeria

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**ABSTRACT:** Silvopastoral systems are agroforestry systems that involves a combination of tree growing with the production of livestock. This type of agroforestry system has the potential to improve hydric balance, enhances biodiversity conservation, increases organic livestock proximity index, allows cleaner cattle production, improves cattle production per hectare, improves carbon sequestration, reduce greenhouse gases and significantly reduce /eliminate herder -farmer conflicts in Nigeria . Hence, this paper reviews and introduces the adoption of silvopastoral agroforestry system for a sustainable cattle production in Nigeria using literatures. Types of silvopastoral systems includes Fodder bank systems, live fence or boundary systems, hedgerow intercropping systems and tree plantation with animal grazing systems. There is limited information on silvopastoral system in Nigeria, hence the need to carry out more research and studies on its acceptability and sustainability in the future.

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While there is no clear, and universally accepted definition of agroforestry, it can be defined as any practice of purposeful growing of trees together with crops, and/or animals with the aim of increasing crop production, conserving biodiversity and enhancing soil fertility and water quality while preventing soil deterioration (Murgueitio *et al.*, 2011, Kim *et al.*, 2016; and Solorio *et al.*, 2016). Agroforestry is one of the options to reduce greenhouse gas emission from agriculture. Agroforestry has been defined by Alao and Shuaibu, (2013) as a dynamic ecologically based natural resources management system that integrates trees on farms and landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. Agroforestry practices offer practical ways of applying various specialized knowledge and skills to the development of sustainable rural production systems. Roese *et al.*, (2018) submitted that Agroforestry can provide new and useful solutions to many of the consequences of human land use.

Agroforestry involves tree crop options while silvopastoral incorporates animals to provide important opportunities for enhancing agricultural productivity and environmental sustainability (Devendra, 2012). These systems are underestimated, but are being increasingly recognized. Although tree crops are widely grown in the uplands, they are also as is common in oil palm cultivation, increasingly using up valuable arable land in lowland environment.

### *Concept of Agroforestry and Typology*

*Agropastoral Systems:* Agropastoral systems integrate crops, and animals (Devendra, 2012). In agropastoral systems, farmers engage in growing crops and raising livestock. They keep mainly indigenous breeds, with herd size ranging from 20 to 100 heads. Family labor is mainly used and animals rely on grazing on demarcated rangelands and supplementary feeds.

*Silvopastoral System:* This system involves trees (e.g. coconuts, rubber and oil palm) and animals or pasture

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(Devendra, 2012). Silvopastoral systems (SPS) according to Chará *et al.*, (2019) are agroforestry arrangements that deliberately combine fodder plants, such as grasses and leguminous herbs, with shrubs and trees for animal nutrition and complementary uses. Silvopastoral systems are the least studied types of agroforestry, even though many such systems exist. An agroforestry practice where trees, animals and or pastures are deliberately combined to maximize benefits and services is called a silvopastoral system. The integration of these components can vary both in time and in space. Marginal lands which have poor productivity for food or grain crops can be put under silvopastoral system to deliberately enhance soil fertility through their droppings. However tree species for this system must be chosen depending upon the farmers' needs and marketability of fruits, barks or leaves

Silvopastoral system primarily provides forage for ruminants, enhances soil conservation/improvement and biodiversity (McAdam *et al.*, 2007, Van- Wieren and Bakker, 2008). The system also provides shade for cattle (Shi *et al.*, 2010) and provides humidity in dry periods (Van - Wieren and Bakker, 2008). Silvopastoral system has been shown to improve soil quality and enhance soil conservation and maintain environmental sustainability (Plienige *et al.*, 2011) while Shi *et al.*, (2010) have demonstrated that silvopastoral system improves soil organic carbon and soil macro nutrients when compared to non silvopastoral lands. Some authors noted that forage production increased by 7 times over the initial situation (Aayush *et al.*, 2019). The improved quality of forage is verified in higher digestibility and more energy, protein and other nutrients available. This according to the study allowed increasing five-fold the number of animals. Aayush *et al.*, (2019) submitted that traditional livestock production systems based on grass monoculture tend to exhaust natural resources in a process of continuous degradation. They however concluded that alternatively, silvopastoral systems are a prototype of agroforestry with a livestock component and are characterized as cleaner production that provides four major environmental benefits: carbon sequestration and reduction in greenhouse gas emissions, biodiversity conservation, soil enrichment and improved air and water quality. Incorporation of a silvopastoral system will therefore increase the quantity and quality of wildlife habitat, provides wide range of versatility in potential outputs from the land base and yields economic returns that are comparable to other land uses. In comparison to the traditional pastoralist system where herders go in search of pasture and water during dry seasons, sedentary agropastoralists face additional challenges from land

pressure and limited pastures for their cattle; agropastoralists are relatively more commercialized than the pastoralists (Nwigwe *et al.*, 2016). Although, Olafadehan and Adewumi, (2009) noted that pastoralists rarely supplemented their animals with concentrate diets Olafadehan and Adewumi, (2010) confirmed that majority of agropastoralists depended on grazing plus browsing and crop residues for feeding their animals, with very few reported as using concentrate as supplement to grazing and browsing. Silvopastoral system and more importantly, intensive silvopastoral livestock production is higher than that of conventional systems Montagnini *et al.*, (2013). Biomass production throughout the year, even in the dry season, allows a greater transformation of cattle feed into beef and milk with cattle stocking densities almost four times higher than those in conventional, extensive system.

*Types of Silvopastoral Systems:* Different systems exist depending on the system objectives, client preferences and management practices. Likewise, tree species, animals, pastures, soil, climate, other vegetation, land-use patterns and planting configurations also contribute to the development of a variety of systems. Some common types and examples of silvopastoral systems are as follows:

*Fodder Bank Systems:* Woody perennial vegetation judiciously used helps to supply forage during dry seasons or years of low Rainfall. A protein bank is a type of fodder bank which intentionally chooses trees, shrubs and pasture legumes with high protein-containing leaf biomass. Commonly used species include ipil-ipil (*Leucaena leucocephala*), kakawate (*Gliricidia sepium*), desmodium (*Desmodium rensonii*), centro (*Centrosema pubescens*) and kudzu (*Pueraria phaseoloides*). Protein banks according to Aayush *et al.*, (2019) are fodder banks where trees, shrubs and pasture legumes with high protein-containing leaf biomass are combined. Trees are planted as close as 1m x 1m and cut regularly to induce maximum herbage production. The three-strata forage system is another type of fodder bank developed in Indonesia. It involves the planting of forages, shrubs and trees to form three canopy layers or strata in a unit of land. Pasture grasses, vines and herbs occupy the lower strata; shrubs occupy the middle strata and trees occupy the upper strata. The combination of grasses and trees can ensure year-round supply of fodder. A protein bank is a form of silvopastoral practice, including two plant species spatially separated (pasture and woody perennial) along with the animal component (Somarriba 1992) in which trees are planted in and around the farm land and rangelands.

*Live Fence or Boundary Systems:* Live fences consist of on-line plantings of trees and/or shrubs in order to fence off crops, pastures or boundaries between properties. Such fences do not only contribute to the existing vegetation and wild animal conservation; they offer wood, firewood, fruit and livestock fodder too, (Aayush *et al.*, 2019). Single or double rows of fodder trees are planted along farm boundaries. The trees have the dual purpose of providing fodder and serving as live fence posts. If intended to enclose animals, the trees are usually planted densely, as in hedges, to prevent animals from getting out. In Palawan, Philippines some farmers use the thorny camachile (*Pithecellobium dulce*) to confine goats and prevent them from straying into crop plots. In some parts of Africa, thorny species are planted as thick hedges to fence off livestock from wild animals.

*Hedgerow Intercropping Systems:* Fodder trees, mostly ipil-ipil, are planted as hedges in single, double or triple rows. The spaces in between hedgerows are planted with pasture grasses. Such systems are found on some private farms in Queensland. As it is common in fodder banks, herbage may be cut and carried to animal feeding stalls. The more common practice is to let the animals forage on the cut tree branches and pasture grasses. On sloping lands, hedgerows can be planted along contours for the added benefit of controlling soil erosion. This is exemplified by SALT II (simple agro-livestock technology) which is being promoted in Mindanao, Philippines.

*Tree Plantation with Animal Grazing Systems:* The understory of tree plantations is utilized as grazing area for cattle, sheep and goats. The plantation may be of forest trees, fruit trees, coconuts, oil palms or rubber. The Nasipit Lumber Company in Agusan, Mindanao, Philippines allows cattle to graze freely on improved pasture grasses planted under trees of lumbang (*Aleuritis molucana*). In parts of Sri Lanka, as well as in Bicol, Quezon and Batangas, Philippines cattle and goats graze on indigenous forages growing under coconut plantations. In Malaysia, sheep, goats and poultry are found grazing under oil palm and rubber plantations. Some authors include bee keeping in citrus orchards as another form of silvopastoral system.

*Indigenous Cut-and-Carry Systems:* As the name implies, the fodder is cut and carried to animal stalls. Farmers of Batangas, a traditional livestock-growing province in the Philippines, have long been practicing this. Ipil-ipil and kakawate are the most preferred fodder tree species. However, after the psyllid infestation on ipil-ipil, farmers shifted back to their traditional practice of using indigenous fodder trees

and shrubs (IFTS). The more important IFTS include anabiong (*Trema orientalis*), binunga (*Macaranga tanarius*), kalios (*Streblus asper*) and dalunot (*Pipturus arbrescens*). In Nepal, *Artocarpus* and *Ficus* species are commonly used.

#### *Benefits of Silvopastoral System*

*Silvopasture Improves Hydric Balance:* An important aspect of silvopastoral system is that they improve the hydric balance because, when woody plants and grasses share the same space, the lesser temperature of the herbaceous strata under the tree crown leads to a diminished transpiration rate and less evaporation (Wilson and Ludlow 1991). This may retard or prevent hydric stress during the dry period. Perennial woody plants according to Rios *et al.*, (2007) affect the water dynamic by:

1. Acting as barriers which reduce runoff.
2. Reducing the impact of rain drops, and
3. Improving the soil by increasing water infiltration and retention. These impacts depend on tree size, principally height and crown cover.

*Silvopasture Ensures Soil Enrichment:* Non Nitrogen-fixing trees can also enhance soil physical, chemical and biological properties by adding significant amount of above and belowground organic matter and releasing and recycling nutrients in agroforestry systems (Roese *et al.*, 2018 and Aayush *et al.*, 2019).

*Silvopasture Enhances Biodiversity Conservation:* In general, Silvopasture plays five major roles in conserving biodiversity:

- i. Silvopasture provides habitat for species that can tolerate a certain level of disturbance.
- ii. Silvopasture helps preserve germplasm of sensitive species.
- iii. Silvopasture helps reduce the rates of conversion of natural habitat by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats.
- iv. Silvopasture provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and
- v. Silvopasture helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat. Vegetation complexity might attract beneficial insect eating birds that could reduce insect damage, but complexity was also associated with greater prevalence of fungal leaf symptoms (Jose 2009, Nair *et al.*, 2010, Giraldo *et al.*, 2011, Montoya-Molina *et al.*, 2016).

*Silvopasture Improves Air and Water Quality:* Silvopasture practices such as windbreaks and shelterbelts as reported by Aayush *et al.*, (2019) are touted as having numerous benefits. These benefits include savings in livestock production by reducing wind chills, protecting crops, providing wildlife habitat, removing atmospheric carbon dioxide and producing oxygen, reducing wind velocity and thereby limiting wind erosion and particulate matter in the air, reducing noise pollution, and mitigating odour from concentrated livestock operations.

*Silvopasture Increases Organic Livestock Proximity Index:* The rate of the Organic Livestock Proximity Index (OLPI) increases when pastures are managed to have a greater tree density. This index is an indicator of:

1. The level of use of agro-ecological technologies, which are environmentally friendly,
2. The extent to which producers respect the list of permitted, prohibited, and restricted substances stipulated by organic production standards, and
3. The quality of animal products obtained in the cattle raising units (Nahed-Toral *et al.*, (2013).
4. Organic meat production systems, due to their integrated nature and low reliance on external inputs (Nahed-Toral *et al.*, 2013).

*Silvopasture Allows Cleaner Cattle Production:* The quantity of fixed nitrogen provides a valuable contribution to cleaner cattle production as its presence allows for avoiding use of chemically synthesized fertilizers. Another advantage is that the efficiency of use of N fixed to the soil by leguminous trees is close to 100 per cent, as compared to 50-60 per cent for soil application of nitrogen fertilizers (Urzua *et al.*, 2000).

*Silvopasture Improves Carbon Sequestration and Reduces Greenhouse Gases:* Silvopastoral systems (SPS) are agroforestry arrangements that purposely combine fodder plants, such as grasses and leguminous herbs, with shrubs and trees for animal nutrition and complementary uses. They allow the intensification of cattle production based on natural processes and are recognized as an integrated approach to sustainable land use. SPS promote beneficial ecological interactions that manifest themselves as increased yield per unit area, improved resource use efficiency and enhanced provision of environmental services (Chará *et al.*, 2019).

*Silvopasture Improves Animal Welfare:* Animal welfare is favored by the fact that cattle are managed in pastures with a high tree density and the trees protect the animals from inclement weather (Souza *et*

*al.*, 2004). This according to Nahed-Toral *et al.*, (2013) leads to improvement of environmental conditions required by the animals to develop their productive and reproductive functions and in general satisfy their physiological needs. Similarly, production of weaned calves per year increased when animals were managed in pastures with a greater tree density. Moreover the beneficial effects of shade are substantial in hot weather with cattle skin temperatures up to 4 °C lower than in pasture only systems. High temperature increases water and energy loss and reduces foraging times in paddocks fully exposed to the sun. Less sun exposure results in less sun-burn, less cancer, and less photosensitization. Silvopastoral thus improves animal welfare (Broom *et al.*, 2013).

*Silvopasture Improves Cattle Production per Hectare:* Reports have earlier shown that the introduction of cattle to silvopastoral system has no negative effect on timber growth if introduction occurs after trees reach a height of 18 inches. Introduction of cattle to the system in year two allows time for forage and tree establishment as this results in increased efficiency of cattle production per ha (up to 4-fold) with improved animal welfare (Broom *et al.*, 2013 and Reyes *et al.*, 2017).

*Silvopasture Improves Soil Properties:* There is improvement of soil properties due to greater uptake of nutrients from deeper soil layers (Nair *et al.*, 2007, Vallejo *et al.*, 2010, Cubillos *et al.*, 2016) and cycling of nutrients, enhanced availability of nutrients from leaf-litter and enhanced resilience of the soil to degradation, nutrient loss, and climate change was reported by Nair *et al.*, (2007) and Reyes *et al.*, (2017).

*Silvopasture for Species Richness:* Ant richness was 60-62 percent higher in intensive silvopastoral system and dung beetle abundance and diversity were more than two times higher in relation to pasture monocultures (Giraldo *et al.*, 2011 and Rivera *et al.*, 2013). Higher diversity in farm production increases the family incomes after the stabilization period of 5-6 years.

*Silvopasture Provides Payment on International Level for Environmental Services:* The producers have the possibility of receiving payment on international level for environmental services, due to the fact that these systems allow for:

1. Mitigating effects of climate change through carbon capture and storage, principally by planting trees and increasing organic soil matter.

2. Reducing CO<sub>2</sub> emissions by avoiding slash and burn and deforestation due to reduced pressure on forests and jungles.
3. Reducing nitrous oxide emissions by reducing nitrogen fertilizer use.
4. Reducing methane gas emissions by offering animals a variety of fodders with greater nutritional quality, greater digestibility, and a better pattern of ruminal fermentation; and
5. Reducing the impact of rain on the soil, thus increasing the soil's capacity for water infiltration and retention and diminishing surface run off (Rios *et al.*, 2007).

*Adoption of Agrosilvopastoral System of Cattle Rearing in Nigeria:* Investigations on cattle rearing systems in the south-western region of Nigeria (Akewusola *et al.*, 2017) show that agropastoral is well adopted in the region. Although it was convenient to conclude that sustainable cattle production through agropastoral is well adopted across the south west of Nigeria (Babayemi, 2020), it is however worth of note that agrosilvopastoral activity is not well researched into. Alao and Shuaibu (2013) in their earlier study on agroforestry practices and concepts in sustainable land use systems in Lafia Local Government Area, Nasarawa State, Nigeria, identified the inherent role of Agroforestry practices accruable to farmers which include: additional income, human nutrition, medicinal herbs, fuel, stakes and timber, shades for human and livestock, reduce weeding, wind break and soil improvement.

*Conclusion:* Agroforestry is an alternative farming system for agricultural production that increases the biomass yields with low external inputs, favoring the land conservation and improvement, and making the productive systems more bio-diverse. Silvopastoral system is a prototype of agroforestry with livestock component. Cattle industry can achieve much in satisfying domestic and export demand for beef if integrated into agroforestry systems with great potential to drastically reduced conflict between herders and farmers in Nigeria.

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