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AGRISILVICULTURE: A REFUGE FOR ABOVE AND BELOWGROUND BIODIVERSITY

***Uleh, A. M. and Usman, A. I.**

Department of Forest Production and Products, Federal University of Agriculture Makurdi Nigeria
***Corresponding Author:** *mauleh@ucdavis.edu*

ABSTRACT

Agrisilviculture is a land use system that involves the integration of trees and other large woody perennials into farming systems through the conservation of existing trees, their active planting and tending operations. Biodiversity comprises of the variety of different form of life on earth such as plants, animals, microorganisms, the gene they contain and the ecosystem they form. It can be divided into belowground and aboveground biodiversity. This paper discussed agroforestry and biodiversity conservation, deforestation and its implication on biodiversity, agrisilviculture and mitigation of biodiversity loss. The benefits of agrisilviculture as revealed in this paper include provision of habitats for animals, preservation of germ plasm and other ecosystem services. The paper further revealed the relationship between agrislviculture and pollination service, agrisilviculture and belowground biodiversity with agrisilviculture and aboveground biodiversity. Despite the importance of agrsilviculture practices, it is reported not to always have positive effect on biodiversity and ecosystem services which is why there are needs to take some precautions into consideration. It was concluded that agrisilviculture will not only help to conserve biodiversity but also will increase yield and provide other ecosystem services. Hence, it was recommended that governments and non-governmental organizations involved in crop production should incorporate agrisilviculture in their extension services so as to encourage more farmers on the need to introduce trees in their farming activities.

Keywords: biodiversity, agrisiviculture, conservation, aboveground, belowground

INTRODUCTION

Globally, forest covers about one third of the land area and serves as habitat to about 80 % of terrestrial biodiversity (Aerts and Honnay, 2011). However, due to increase in human population and the need to provide food for the increasing population, there has been a decrease in the extent and quality of forest habitat in the world over (Tilman *et al*., 2017). Forest lands are being cleared for agriculture and other activities without any viable solution to curb the trend. The extent of the decline is at an alarming rate especially in developing nations (Okeke, 2018). It has been reported that some countries in developing nations, the forest cover is extremely low due to high rate of deforestation (McDermott, 2009). Many trees, shrubs, herbs and assorted animals have been depleted while some are endangered, leading to biodiversity loss (Donkersley, 2019).

Agrisilviculture is a land-use system where woody perennials (trees, shrubs, palms, bamboos among others) are deliberately used on the same land-management units as agricultural crops (Carne, 2008). It intentionally combines agriculture and forestry to create integrated and sustainable land-use systems. It serves as a realistic alternative in balancing food production and biodiversity conservation. Agrisilviculture has the potential to maintain higher levels of biodiversity, and also enhance soil quality by increasing litter inputs and soil organic matter accumulation. As tree cover increases in agricultural landscape, it reduces the pressure of pests on crops and greatly improves pollination services (Barrios *et al*., 2017). Agricultural lands can support biodiversity provided better management plans are implemented to support their survival (Kleijn and Sutherland, 2003; Opermmann *et al.*, 2012). In Europe ~50% of plant and animal species depend on agricultural habitats

(Kristensen, 2003). Therefore, agricultural practices that favour biodiversity can be used to conserve and improve biodiversity.

Agroforestry and biodiversity conservation

Agroforestry has been identified as a tool to preserve rich species diversity around the world (Mendez *et al.,* 2001; Borkhataria *et al.,* 2012). The roles it plays in biodiversity conservation cannot be overemphasized. These include providing habitat for species that can tolerate a certain level of disturbance, helps preserve sensitive species germplasm, helps to provide a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats; and 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. Agroforestry practices have 50–80% of the diversity of comparable natural forests and this can contribute to further preservation of biodiversity. Agroforestry induced biodiversity improvements have been reported in both temperate and tropical regions (Huang *et al.,* 2002; Noble and Dirzo, 1997; Dollinger and Jose, 2018). Some studies have indicated significantly greater diversity in Agroforestry compared to forests and tree monoculture management (Steffan *et al.,* 2007; Sistla *et al*., 2016; Huang *et al.,* 2002).

The services provided by agroforestry practices to rural livelihoods and conservation of biodiversity have attracted wide attention among agroforestry and conservation scientists (Mcneely and Schroth, 2006). Agroforestry technologies focus on the role of trees on farms and agricultural landscapes to meet economic, social and ecological needs (Garrity, 2006). Traditional agroforestry practices have a huge potential in supporting biodiversity conservation.

The use of agroforestry technologies mitigates biodiversity loss and provides opportunities for improving diversification and range of livelihood options for rural households (Akinnifesi *et al.*, 2008).

Deforestation and its implication on biodiversity

Deforestation is regarded as the permanent removal of trees (Derouin, 2019) without correct replacement, leading to loss of biodiversity due to habitat destruction (Trucksess, 2003). Biodiversity is the variety of different forms of life on earth, including the different plants, animals, micro-organisms, the genes they contain, and the ecosystem they form (Rawat and Agarwal, 2015). It is also regarded as the variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and ecological complexes. Biodiversity is essential in so many ways. It serves as source of food, fodder, fuel, timber, medicine, and much more. Biodiversity in agricultural landscapes can be divide into visible aboveground biodiversity, such as shade trees, insects with bio-control and pollination functions (parasitoid wasps, bees) which can be managed by farmers and invisible belowground biodiversity and mostly unmanaged soil biodiversity contributing to soil health (Swift *et al.,* 2004; Wall *et al.,* 2010).

Habitat loss due to deforestation is seen as the major threat to biodiversity (Rinkesh, 2020) and this is more alarming in developing nations. This is due to the high rate of unemployment in developing nations making the populace to harvest trees in an uncontrolled manner from natural forests. As population density increases in and near forested areas, the rate of deforestation also increases. Peasants continue to clear trees for subsistence farming to provide food for their families and when they experience low yield due to reduction in soil quality, they clear other land dominated by trees thereby increasing the rate of deforestation. Many of the trees removed are habitats of many pollinators. As their habitat and source of food is lost, they are compelled to migrate to other locations and some are even killed leading to loss of biodiversity (Anonymous, 2013).

The reduction in quality and quantity of the forest has led to massive extinction of many fauna species inhabiting the forest habitats (Aerts and Honnay, 2011). Forests are being degraded from primary forest to plantation forests resulting in the sharp decline of several fauna such as birds, fruit-feeding butterflies, leaf-litter amphibians, large mammals, arachnids, lizards, dung beetles and bats. Biodiversity loss typically affects a variety of benefits flow to people, often called ecosystem services. Trees help in providing habitats for

wildlife, absorbing carbon from the atmosphere (Marinelli, 2019), fiber production, food, and many other products to generations of mankind and are invaluable genetic resources gained from the forest. Removal of forest leads to loss of biodiversity and jeopardizes many ecological services it provides. Many agricultural crops depend on birds for pollination, so removal of trees destroys their habitats and thus leads to their extinction. As natural forest declines, the population of pollinators and their activities also decline. It should be noted that forest regeneration for indigenous tree species and habitat features suitable for pollinators such as nesting sites and flora resources takes decades (Ricketts and Lonsdorf, 2013).

Case studies: Agrisilviculture and mitigation of Biodiversity loss

Tree cover preserves not only the aboveground biodiversity but also the less-studied, largely invisible and mostly unmanaged belowground biodiversity. Trees in agricultural landscapes provide favorable habitats for soil biodiversity, through microclimate buffering and continuous supply of organic matter inputs. Barrios *et al*. (2017), investigated the impact of changing tree cover on biodiversity and ecosystem services in different agricultural landscape. The experiments focused partly on the role of agroforestry as a biodiversity-based intervention for ecological intensification of agriculture. Land uses evaluated included dominant land-cover scenarios useful to comparatively assess the effects of trees on both below-ground and above-ground biodiversity. Results obtained from the six experimental sites suggest that increasing tree cover in agricultural landscapes can support plant and invertebrate biodiversity and significantly improve ecosystem functions that underpin ecosystem services.

i. Agrislviculture and Pollination Service

As forest conversion from natural forest to agricultural system increases, pollination services are expected to decline, which is very critical for many crops. Forest remnants can help beneficial organisms to migrate into adjacent annual and perennial agroecosystems. Klein *et al*. (2003) carried out a research in Indonesia to investigate how decline in pollinators negatively affect the fruit of wild and cultivated plants. Twenty-four agroforestry systems, differing in shade and distance to the nearest forest were compared. To estimate the resources available for bees, the fields were characterized according to the shade level and percentage cover of coffee plants in flower, and percentage cover of all non-coffee plants in flower. Flower-visiting bees were observed for 28 days. It was noted that coffee flowers attracted flower visiting bees for only one day. All flower visitors were counted, and sweep net was also used to catch bees for identification purpose. Some coffee plants were then selected to investigate pollen transfer efficiency for the different bees caught. They found that the diversity of social bees decreased with increasing forest distance. When foraging distances into the adjacent land-use systems were too long, coffee had a reduced fruit set. The forest offers suitable nesting site for bees and the shorter the distance the better for the bees. In their conclusion they pointed out that enhancement of bee diversity from three to 20 species may increase fruit set from 60 % to 90 %; therefore, farmers should conserve bee diversity to improve their coffee production. Their result agrees with Ricketts and Lonsdorf (2013) where they compared marginal values of tropical forest remnants for pollination service. Ricketts and Lonsdorf, though in a different region (Costa Rica), found that pollinator richness, visitation rate and pollen deposition rates all decline significantly with increasing distance from natural forest. This goes a long way to further buttress the need for policy makers to encourage agrisilviculture. Open farms are not likely to have rich diversity of pollinators as there will be no nesting sites for birds and other pollinators that live on trees.

Agrisilviculture will not only conserve plants, arthropods and vertebrates, they can also help in creating nests for pollinators and help in pest control. In comparing monoculture with agroforests, farm scale coffee trees conserve lower diversity than forests at the landscape scale. Also, transition from forests to habitats with lower tree cover significantly affected the species richness, abundance and functionality of insect pollinators (Barrios *et al*., 2017). In

Indonesia, a total of 453 insect pollinator individuals from 21 families were collected in pan traps that included eight species of bees, seven of wasps, seven of beetles, four of moths/butterflies and four of flies. Of them, all eight bee species, three wasps, five beetles, one butterfly and all four flies are known as efficient insect crop pollinators. Species richness and abundance were significantly different among landscape elements. Richness of total insect pollinators declined in monocrops (rice paddy fields) by 14% compared to natural forests, while it remained unchanged under mixed-tree (MT) agroforestry. A decrease in richness of efficient insect pollinators close to 40% was observed under monocrops, but this decrease was only about 15% under MT agroforestry. This richness of pollinators in agroforestry system compared to monoculture has been reported by many authors. Increased vegetation cover has been identified as an essential factor encouraging greater species diversity of insect pollinators in tropical landscapes.

A field survey of birds and trees diversity was carried out in three communities surrounding Calakmul Biosphere Reserve in Campeche, Mexico, by Bohn, *et al*., (2014). Their objective was to evaluate how different management practices affect forest biodiversity. They found that bird species richness was higher in areas surrounding communities that generated more forest products. It was noted from their research that people living around forest lands could take care of the forest if they were given the right orientation and the relevance of trees to them. Krishna (2006) carried out a study on farm management in two villages in western middle hills, Nepal. The findings indicated that farmers who plant trees in their farms do not interfere with government owned forest. The trees they have in their farms provide the needed services and as such takes away pressure from natural forest and government owned forest. This again points to the fact that agrisilviculture can serve as a strategy to decongest the pressure on federal and state forest reserves. The result also pointed out that some of the farmers are willing to plant trees in their farms.

ii. Agrislviculture and belowground biodiversity

Mujeeb *et al*., (2012) investigated the effects of land use intensification on the distribution and abundance of soil invertebrate communities in India. Soil invertebrates were sampled in 15 different land use practices involving simple and intensively managed annual crop fields, monoculture tree plantation, and an agroforestry system. The study area (having 15 different land uses) was divided into 72 grid points of 200 m by 200 m per grid. In each of the 15 different land use systems, four plots were chosen, and soil monoliths were randomly taken from each plot. Soil monoliths of 25 cm × 25 cm × 30 cm were dug, and soil micro fauna were hand-sorted and preserved in alcohol for identification. The–findings revealed that the highest taxonomic richness in moist-deciduous and semi-evergreen forests and the lowest in annual crops and monoculture plantation. Earthworms and millipedes were significantly higher in the agroforestry systems than in annual crop field. Ants, termites, beetles, centipedes, crickets and spiders were more abundant in forest ecosystems than in any other system. They concluded that annual cropping systems have lower diversity of invertebrates than agroforestry system. This result further encourages the need to strengthen agrisilviculture to conserve biodiversity.

A forested area was converted to monoculture coffee to evaluate the effects of the clearing on soil health (Barrios *et al*., 2017). It was reported that four large-bodied native earthworms were lost upon conversion. The native earthworms were completely replaced by small bodied exotic earthworms. The conversion lowered the soil macro porosity by about 76%, annual litterfall reduced by 71%. These reductions can cause reduction in infiltration, increase in run-off and soil erosion, and pollinators that feed primarily on the native earthworms will migrate to other locations. The findings of this research further show that soil biotic diversity is linked to plant communities through the activities of herbivory and the decomposition of dead organic plant materials. Soil biota responds in different ways when the plant communities are altered. As the intensity of disturbance from tree

harvesting increases, the abundance of belowground biodiversity decreases (Sylvian and Wall, 2011; Tajik *et al.,* 2020).

In another location in Thailand where cassava farm was replaced with a rubber plantation, there was an initial sharp reduction in density and biomass of soil micro fauna. However, as the tree canopy began to expand and tree habitat function became prevalent, there was an overall increase in biomass, which was accompanied by a decrease in ant and increase in earthworms and termites. The species richness was higher in the rubber plantation compared to the one from the cassava farm.

iii. **Agrisilviculture and aboveground biodiversity**

Agroforestry systems conserve plants, arthropods and vertebrates that have been linked to the delivery of habitat as well as important regulating services, such as pollination and pest control (Perfecto *et al.,* 2004; Klein *et al.,* 2008; Tscharntke *et al.,* 2011). The contributions of agroforestry trees to the nitrogen budget on the farm is substantial and can lead to greater increase in yield when managed efficiently, e,g 200kg/ha from *leucaena leucocephala*(Vanlauwe *et al.,* 2012), 110kg/ha from *S. rostala* (Giller, 2001) 120kg/ha from *Tephrosia vophii* (Gathumbi *et al.,* 2002) were investigated as contributions of trees to nutrient enrichment.

Potential tradeoffs of Agrisilviculture

It is of uttermost importance to recognize that the effects of agrsilviculture practices are not always positive and their effects on biodiversity and ecosystem services needs taking some things into consideration. Organic input from certain agroforestry tree species may have negative effects on soil animals and functions (Barrios *et al.,* 2017). Hence, a rich knowledge of different tree species and their functions will help to influence choice of the right species. In Thailand, there was an early reduction in soil macrofauna abundance and biomass before it eventually picked up. Farmers who are involved in annual crops may not want to experience reduction in micro fauna at the start of farming, as it can impact yield. There are cases where the farmer does not want trees in his or her farm as they believe it will hinder growth and there are foresters who believe the land for forest should not be used for any form of farming. All these issues need to be considered when designing the pattern of agrisilviculture systems that will minimize trade-offs and maximize synergies and complementarities that aim at biodiversity conservation and the delivery of multiple ecosystem service.

CONCLUSION

Agrisilviculture will not only help to conserve biodiversity but also will increase yield and provide other ecosystem services. Trees in the farm will serve as nest and pollen for pollinators and will minimize the rate of dependence on natural forest by man. Although agrisilviculture is a centuries-old form of ecosystem management in many parts of the world, its relevance in biodiversity management has not received the needed advocacy. The results obtained by the different authors cited in this paper and much other literature suggests very strongly that agrisilviculture will help to conserve above and belowground biodiversity. The need for farmers to continue to plant native trees in their farms is very essential.

Recommendations

Based on the importance of agrisilviculture, the following recommendations were drawn to encourage its practices.

i. Non-Governmental Organizations (NGOs), Universities and other agencies involved in crop production should incorporate agrisilvicultural system in their extension work so that rural dwellers can help in conserving biodiversity and at the same time enhance food production.
ii. Governments in developing nations should as a matter of priority sensitize farmers on the need to introduce trees in their farms.
iii. There is need to further research on the effect of trees on yam productivity since some farms believe trees negatively affect yields of yam.
iv. Farmers should be guided on the type of trees to introduce into their farms to avoid toxicity of trees' chemicals to their crops.

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