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*Review*

# PARAMOUNT ROLES OF AGROFORESTRY SYSTEMS AS HABITAT FOR BIRD SPECIES

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## Abstract

*In addressing global sustainability and warming challenges, agroforestry approaches has a very good prospect in combating both challenges, using the benefits derived from agroforestry as criteria for assessment. Deliberate integration of tree crops into agronomic crops with the main aim of promoting sustainable land management could be referred to as agroforestry. The three main types of agroforestry systems are agrisilvicultural, silvopastoral and agrisilvopastoral. However, the roles of agroforestry as habitat for bird species are provision food, provision of nesting site and resources, provision of nectar, reduction of bioaccumulation of heavy metals and pesticide residue, provision of shade which serves as relaxation spot and protection for bird species, coupled with provision of improved microclimate. Foraging items for bird species can be categorized into plants, seeds, or vertebrates and invertebrates. These food source are in high supply in agroforestry system. Apart from that, nectar serves as a good source of nourishment to nectarivorous birds and agroforestry makes healthy food available to bird species by minimizing bioaccumulation of heavy metal and pesticide residue in their vital organs. Birds are safeguarded from predators by crops and crops serves as recreational centres, where birds relax. Shade provided by agroforestry tree species may alleviate temperatures and precipitation excesses coupled with wind and storm proceedings, thereby preventing prospective habitat loss by bird species. Similarly, avian survival rates, reproductive success, breeding time, species distribution, and habitat choices are all influenced by microclimate and habitat architecture. In order to widen the agro-ecological emphasis of agroforestry systems and bird diversity, more study is needed, including suitable measurement, modelling, and testing to categorize the essential components of agroforestry systems that are most imperative for supporting avian species in the landscape.*

**Keywords:** agroforestry; bird species; climate change; agriculture; habitat; environment

## INTRODUCTION

Agroforestry systems and practices cover about 1,023 m ha across the world, ranging from modest sustenance rearing of cattle and pastoral systems to shifting cultivation, home gardens, and alley cropping. (Kumar *et al*., 2020). Series of benefits may be provided by agroforestry methods to combat the deteriorating ecological resources and climate predicaments based on research findings (Schwab *et al*., 2015; Siminski *et al*., 2016). In addressing global sustainability and warming challenges, agroforestry approaches has a very good prospect in combating both challenges, using the benefits derived from agroforestry as criteria for assessment (Abbas *et al*., 2017; Elevitch *et al*., 2018; Toensmeier, 2016). Deliberate integration of tree crops into agronomic crops with the main aim of promoting sustainable land management could be referred to as agroforestry (Santiago-Freijanes *et al*., 2021). However, forest farming, silvopastoral, home gardens, silvoarable, hedge, windbreak, riparian buffer strip systems and others are inclusive. Numerous agriculturalists who adopted agroforestry as a form of land management practice on the other hand, do not recognize it as a separate and specialized land use, nor do they embrace it

as such (Mosquera-Losada *et al*., 2020). Diverse practices of land-use that incorporate animal husbandry with cultivation of tree crops or arable crops is known as agroforestry according to FAO (2019). Agroforestry is gaining popularity because it is capable of combating worldwide climate change crisis, while also providing additional environmental, economic, and social advantages as a form of land-use approach (Waldron *et al*., 2017).

With intensive agriculture, hundreds of flora and fauna are endangered and others are threatened. Similarly, more than 37,400 species are endangered with some at the verge of extinction, based on IUCN Red List (2021). In order to conserve different plants and animals some ecological proceedings are taken to safeguard biodiversity. This involves adopting sustainable use of natural resources coupled with rational and justifiable delivery obtained from the advantages of utilizing such genetic assets (Mosquera-Losada *et al*., 2020). A blueprint for a sustainable economy could be considered as part of the Green Deal, this was developed by the European Union with the main aim of becoming the first continent that is climate-neutral (EU 2021). One of the utmost essential strategies for addressing the aforementioned global problem is by adopting agroforestry. In addition, agroforestry could be adopted in terms of addressing international objective to conserving biodiversity, which can easily be achieved (Rankoth *et al*., 2019; Mosquera-Losada *et al*., 2020).

A practical description of agroforestry could be viewed from the angle of a calculated mixture of woody vegetation of which trees and shrubs are inclusive, with arable crops and/ or farm animals on a land supervised as an entity, whichever simultaneously or consecutively. Through complimentary interactions between system components, this integration aims at branching out agricultural assemblage to produce environmental, monetary, and collective returns (Atangana *et al*., 2014). The integration of arable crops or rearing of farm animals within forested zones is known as forest farming. Home-gardens could be described as metropolitan agroforestry, which involves incorporating trees with crops close to the estate. Other categories of agroforestry are agrosilviculture, silvopasture and agrosilvipasture. However, agrosilviculture can be well defined as a farming arrangement where trees are incorporated into crops. It is also known as silvoarable. Silvopasture can be defined as a farming arrangement where trees are incorporated into farm animals. Agrosilvipasture is a farming arrangement where trees are incorporated together into crops and farm animals (Atangana *et al*., 2014). The aforementioned systems are considered to be excellent methods of land management, because it involves incorporating agronomic crop and livestock husbandry with production of forest crops such as trees and shrubs deliberately. This paper aims to discuss the roles of agroforestry systems as habitat for bird species using theoretical and empirical evidence provided in different literature and its influence on the survival and conservation of bird species.

**Birds and Human**

Humans have been linked to birds in many ways among the fauna groups because they are found practically in all habitats, excellent richness coupled with the simplicity of connecting with them (Vásquez–Dávila e*t al*., 2014). These animals have been utilized for a variety of purpose due to the collaborations among evolutions of man and avian species. Foraging items and drugs are the most shared between man and bird species. This arrangement replicates human demands in places where birds are employed and the information can be adopted in regulating the impact of avian species that fared in their natural habitat or produced from game farming (Cruz *et al*., 2014; Jiménez–Daz *et al*., 2014).

In severely cultivated zones, biodiversity is at jeopardy due to great loss according to scientific reports (Beckmann *et al*., 2019; Homburg *et al*., 2019). Agroforestry systems, as opposed to monocultures, promote landscape variety and may contribute to greater biodiversity (Maskell *et al*., 2019; Fagerholm *et al*., 2016). Demonstrating a practical benefit for biodiversity might help agroforestry systems develop prospective adoptions from the common agricultural policy or successor programs (Mosquera-Losada *et al*., 2018; Santiago-Freijanes *et al*., 2018). The basic advantages of agroforestry systems with respect to biodiversity conservation have been studied especially in the tropics, with results suggesting that agroforestry can boost biodiversity in degraded and severely cultivated zones, but in divergence to prime (primary) and subordinate (secondary) forests it remains lower (Santos *et al*., 2019; Martin *et al*., 2020).

**Types of Agroforestry Systems**

A range of living things, including trees, crops, and livestock are provided with home range by Agroforestry systems. All the aforementioned living things are

integrated and help to sustain biodiversity, which is important for maintaining structure and diversity. In addition, soil stores a variety of organisms such as beneficial micro-organisms, bacteria, fungi, protozoans, earthworms, and other macro-organisms that not only aid in the decomposition of organic matter and other residues but also help to maintain biodiversity. Similarly, the organisms nurture plants and animals, and maintain a healthy ecosystem and environment especially in climate condition that is experiencing variation and global warming (Vallejo-Ramos *et a*l., 2016). Understanding habitat preferences is important for species conservation because birds choose foraging sites depending on the abundance and distribution of key prey items accessible to the species (Egwumah *et al*., 2014). Food availability and diversity play a vital influence as well (Tiwonge, and ABC Malawi Representative 2011; Egwumah and Iboyi, 2017).

A comparison of flora between regions where certain bird species utilizes and eat during day time and the preserve area improves knowledge of the significance of food in the sustenance of any natural community of birds, because without food, the population would eventually die out and go extinct. Foraging items are made available to wildlife species through agroforestry systems. Despite the fact that agroforestry systems have a lower floristic diversity compared to forested areas, several tree species that are product of agroforestry, yield more fresh fruits or nectar. Fresh fruits or nectar are capable of fascinating birds and bats to farmland where agroforestry practices are integrated because of the essential and floristic richness of such home range (Gonza lez 1999; Carlo *et al*., 2004). In addition, the presence of lower concentration of heavy metals and pesticides residue could be responsible, because the system does not utilize pesticides or inorganic fertilizers to improve crop productivity. In addition, large distribution and abundance of insects are associated with agroforestry systems which tends to support the presence of insectivorous birds (Wun-derle and Latta 1998; Johnson 2000; Hole *et al*., 2005). The three main types of agroforestry systems are;

a. Agrisilvicultural,
b. Silvopastoral,
c. Agrisilvopastoral

**Agrisilvicultural Systems**

One-third of the earth surface is occupy by forests, and it makes available immeasurable resources. In addition, more than 80 percent of global land-dwelling biodiversity are accommodated by the forest (Chao, 2012). However, human population is increasing globally with corresponding increase in demand for food resulting to rapid increase in demand for forestland for agricultural production. As a result, the size and quality of forest home range available to bird species everywhere in the world has shrunk (Tilman *et al*., 2017). Destruction of forest habitat for farming and other forms of land-use is a very common phenomena without remedy to reverse the tendency. The degree of deterioration is worrisome and developing nations are the worst hit. Numerous plants species including trees, shrubs, plants, and animals are currently at risk due to dwindling in population, and several species are endangered in recent time, resulting to biodiversity loss (Donkersley, 2019).

More bird species are associated with farmland based on research findings (Sekerciolu *et al*., 2007), and bird species utilizes essential short-lived crops such as sugarcane (Alexandrino *et al*., 2019) and rice. The aforementioned crops are well reported based on research findings (Elphick *et al*., 2010; Masero *et al*., 2011; Elphick, 2015). Foraging items for bird species can be categorized into plants, seeds, or vertebrates and invertebrates. These food source are in high supply in agroforestry system (Stafford *et al*., 2010). Birds are safeguarded from predators by crops and crops serves as recreational centers where birds relaxes (Linscott and Senner, 2021). Sparrows and Finches, including Juncos and Redpolls, Grouse, Quail, Pheasants, Partridges, Doves and Pigeons, smaller Parrot and Parakeet species, and many others are among the birds that benefit from agrisilviculture systems. Agrisilviculture is a land-use system in which woody perennials (trees, shrubs, palms, and bamboos, among others) are deliberately established together with agricultural crops on the same land-management entities (Carne, 2008). Birds uses the plants parts such are palm fronts to make nest during their breeding season thereby influencing the breeding performance. For example Orioles, Cassin's Kingbirds, Starlings, Egrets, and Herons.

Agriculture and forestry are purposefully combined to generate integrated and sustainable land-use systems. It is a viable option for balancing food production with biodiversity preservation. By increasing litter inputs and soil organic matter buildup, agrisilviculture has the ability to maintain higher levels of biodiversity while simultaneously improving soil quality. As the amount of tree cover in the agricultural environment grows, pest

burden on crops decreases and pollination services improve dramatically (Barrios *et al.*, 2017). Hedgerow intercropping/alley cropping (e.g. maize between rows of nitrogen-fixing trees such as Sesbania sp. or Gliricidia sp.) is an example of a simultaneous practice, whereas improved fallows are an example of a sequential activity (for instance, legume trees such as Calliandra sp in rotation with maize). Enhanced soil fertility, shade for understory crops, trees functioning as stakes for climbing plants, soil erosion control, improved microclimate, and increased yield stability are some of the benefits sought by farmers. In the course of seeking improved yield by the farmer provision of shade for understory crops improves the microclimate which could be beneficial to birds. Lovebird's population increases in time and space in response to increased rainfall, which promotes the availability of food sources, and drop in time and space in response to decreased rainfall, which directly affects food supplies (Egwumah *et al*., 2014). Because the tree blossoms, flowers, and bears fruit during the late rainy season (August-October), the distribution and quantity of lovebirds is strongly linked to rainfall and high relative humidity (Egwumah *et al*., 2014).

Agrisilviculture is used in a range of cropping systems and climate zones, but it is particularly essential in small-scale and low-input agricultural systems, mainly those with partial accessibility to mineral fertilizers. This is correct for numerous agriculturalists in Sub-Saharan Africa, Southeast Asia, and Latin America, where agroforestry plays a vital role in augmenting partial fertilizer inputs with nitrogen-fixing trees and preventing soil erosion in hilly places (Zomer *et al*., 2014). Birds are particularly vulnerable to unselective felling of trees, which occurs as a result of transformation of forestland into cropland, firewood collecting, tree chopping for lumber, charcoal production, and wildfires. All the aforementioned factors renders bird species homeless (Egwumah *et al*., 2014). Surface runoff can introduce contaminated substance such as pesticides, herbicides, and fertilizer remainder into water that is not flowing, owing to the vulnerability of naked land to excessive runoff due to intensive cultivation of crops. This discharge contains contaminants such as salts, nutrients such as phosphate and nitrogen, and pesticide residue (Gohary 2015) Pesticides can pollute soil, water, and air. Increased pesticide usage, reduces arthropod prey and weed availability (Ratcliffe and Crowe 2001; Egwumah, 2015) for bird species. Agroforestry helps to prevent all this from happening by providing sufficient trees in degraded areas. These trees helps to prevent excessive runoff which could introduce pollutants into natural water bodies.

Not only would agrisilviculture help to conserve plants, arthropods, and vertebrates, but it will also aid in the creation of pollinator nests and pest regulator. If agroforestry is compared with plantation agriculture, farm scale coffee trees maintain less variety compared to landscape scale forests. Insect pollinator species richness, abundance, and functionality were all altered by the transition from forests to areas with less tree cover (Barrios *et al*., 2017). Improved 'fallow' in shifting cultivation; Alley cropping (Hedgerow intercropping); and other agroforestry practices are used in agrisilvicultural systems. Plantation and other crops; mixture of plantation crops; biomass transfer; reduces the rate of solar penetration on commercial plantation crops; trees for firewood making; shelterbelt, windbreak, soil conservation hedges, etc.; multispecies tree garden, Taungya; Scattered trees on farmland (Parklands); woodlots that rotate; markings of the boundaries. Coffee may be cultivated in a broad variety of shade concentrations especially from rural farmland that is yet to be tempered with in terms of removal of trees species that provides shade from natural woody areas to low shade circumstances that mimic sun coffee plantations. This is simply suggesting that adoption of shade trees gives minimal direction for agriculturalists (Moguel and Toledo 1999). Structured habitat elements, such as shadow cover, canopy height, and tree density, impact on how bird species utilizes trees in agroforestry systems (Parrish and Petit 1996; Greenberg *et al*., 1997b; Reitsma *et al*., 2001; Gordon *et al*., 2007; Harvey and Villalobos 2007; Florian *et al*., 2008). Examples of some birds found in this system include the Cuckoos (*Cuculidae*), Shrikes (*Laniidae*) and others.

### *Benefits of Agrisilvicultural Systems as Habitat for Bird Species*

Birds are unquestionably vital members of a variety of ecosystems (Sekercioglu 2006). They are essential components of food chains and webs (Holmes and Sturges 1975; Holmes 1990). Some birds, for example, feed mostly on vegetation in an agrisilvicultural setting. Others prefer to consume insects or earthworms, which are small animals. In an agrisilvicultural system where wooden perennials are combined with agricultural crops, there is availability of insects and pests that disturb the crops which could reduce yield. Birds eat these insects, they're a natural technique to keep pests at bay.

Hundreds of insects can be consumed each day by a flock of birds gliding through the air. Birds that consume insects include warblers, bluebirds, and woodpeckers. When nectarivore birds travel, the agrisilvicultural system provides food for them, and they are key pollinators, which means they transport pollen from flower to flower to help fertilize sex cells and form new plants. Bananaquits, Chickadees, Finches, Flowerpeckers, Hummingbirds, Honeyeaters, Lorikeets, Orioles, and other birds are known to consume nectar to varied degrees. Fruit-eating birds like Mockingbirds, Orioles, Finches and Robins, also find their food from this system.

Bohn *et al*. (2014) conducted a field investigation of bird and tree variety in three towns near the Calakmul Biosphere Reserve in Campeche, Mexico. Their goal was to see how different forest management strategies affected biodiversity. Bird species richness was shown to be higher in locations proximate to group of people that generate additional forest products. With adequate orientation coupled with proper appreciation of the significance of trees in avian species, people living in proximity to forestland could manage the forest very well. Therefore, forests is important in the life of birds because it provides habitat, nesting site, shelter, and numerous type of food (insects, nectar, fruits, etc.) for both local and indigenous birds.

**Silvopastoral Systems**

The Silvopastoral system, a more environmentally approachable substitute to normal cow grazing. It is a relatively new kind of agroforestry that is gaining international interest (Murgueitio *et al*., 2011). This approach entails rearing animals on better meadows that have been planted beside trees. Silvopastoral systems can be defined as any agroforestry structures that integrates foraging items such as grasses, shrubs and leguminous plants and trees for feeding livestock and any other commitments (Murgueitio *et al*., 2011). Some examples of grassland birds are common waxbill, seed cracker, sparrow weaver, pin-tailed whydah, village weaver, red-vented malimbe and many others. Silvopastoral systems encourage favorable ecological interactions, which can result in higher yield per unit area, more efficient resource utilization, and better supply of ecological services. Large sales of timber, livestock and farm animal products may generate more agricultural proceeds as nonstop profits, whereas indirect benefits are safeguarding of soil against excessive runoff and heat generated from solar radiation, livestock accommodation, and improved habitat for relaxation of livestock and wildlife. The prospect of these systems with respect to production is higher. In addition, the system is money-spinning, and long-standing compared to high-quality forestry or livestock farming as a single entity (Peri *et al*. 2016). Murgueitio *et al.* (2015) and Chará *et al*. (2017) describe the primary silvopastoral systems as distributed tree species in pasturelands, woody agricultural estate with zones set aside for farm animals to browse, pastures between tree alleys, windbreaks, live fences, fodder banks with shrubs, and extensive silvopastoral systems. Deliberate incorporation of woody species coupled with browsing cattle processes on a similar piece of land could be described as silvopasture. Both forest products and fodder are extensively maintained in these systems, providing both short- and long-term income sources.

Excellent examples of agroforestry practices associated with silvopastoral systems are; protein banks (fodder tree banks), trees and shrubs on rangeland or pastures, live fences of fodder trees and shrubs (living fences), Plantation crops with pastures and animals, Integrated production of animals and wood products. In terms of biological diversity, silvopasture is very essential because it contributes to safeguarding of biological diversity through provision of other ecological benefits for example regulation of excessive runoff and restoration of water, minimizing dreadful conditions of habitat and loss. Silvopasture systems are established by planting trees in a pasture or introducing fodder into a woodland or tree plantation. When utilizing silvopasture, rotational grazing is a critical management practice for minimizing tree damage. For long-term tree regeneration, special concerns and planning must be taken into account. Although vegetation complexity may attract helpful insect-eating birds, which may help to minimize insect damage, it was also linked to a higher incidence of fungal leaf symptoms.

***Benefits of Silvopastoral Systems as Habitat for Bird Species***

Diverse bird species found in Africa utilizes the body of farm animals by perching on it to forage on insects' pest using the big herbivorous bodies as host or forage on the insects left behind during grazing (Mikula *et al*., 2018). The integration of livestock such as cattle into the production of trees on the same area allows for the formation of a commensalistic relationship in this system. This indicates that avian species can coexist with

livestock without causing harm to them. Numerous African birds use livestock with bigger-bodied as hosts to perched on and forage on insects as feeding materials, gathering parasites and insect flesh from the host to advance feeding effectiveness. They collect more food while expending less energy, or gain additional protection from predators (Ndlovu & Combrink, 2015; Goodale *et al*., 2017).

Although certain bird species engage mutualistically with farm animals that eat grasses (herbivores), large population of bird species found in Africa establishes commensalistic sitting relationships with farm animals (Kioko *et al*., 2016. Mammals that are big in size including those in larger herds are more obvious to birds (Kioko *et al*., 2016). Birds may interrupt more insects that are attracted to farm animals because various community of birds may hunt for insects as source of food. There is a commensalistic connection between trees and birds because birds build their nest on location where the trees are growing and the presence of avian species on the tree could safeguard the tree species from logging. The red-eyed vireo (*Vireo olivaceus*) is a common and beautiful bird that builds its nest in the forks of broadleaf tree branches. It consumes caterpillars and aphids from the tree canopy, as well as berries on occasion. The black-throated green warbler (*Setophaga virens*) feeds on insects and larvae found on leaves and branches, and builds its nest in tree forks near the ground. Cattle egrets escort browsing grazing cows. They also forage on the flies and bugs associated with the cows. However, the presence of these insects could be irritation to cow. Most insects that are remove from the grazing field are consumed by cattle egrets.

**Agrosilvopastoral Systems**

Many measures have been taken to combat the detrimental consequences of deforestation and other human interferences, which have resulted in biodiversity loss and climate change. For grasslands in dry regions that are primarily utilized for grazing, the agrosilvopastoral system has been employed successfully for generations. (Horrillo 2018, Den Herder *et al*. 2017). According to Abdul (2017), on the same piece of land, an agrosilvopastoral system includes tree crops (forest), agricultural crops, fodder crops, and/or cattle. Using the farmer's goal and ecological circumstances as a criteria, incorporating the various parts of agrosilvopastoral system might take different patterns. In agrosilvopastoral ecosystems, the basic functions of trees are provision of shade and foraging items coupled with safeguarding of farm animals. The shade given by trees is beneficial to crops, pastures and birds.

The leaves of the plants serves as litter and when the drop from the branches of the tree to the forest floor. They serve as organic matter to improve the level of soil fertility. This may promote the growth of the plants. Manure is also added to the soil through animal dung and urine. Animal excrement enhances crop growth by increasing soil fertility. It's a win-win situation since certain crops serves as sources of food to cattle (Oliveira *et al*., 2018). In agrosilvopastoral systems, the leaves of the plants serves as litter and when the drop from the branches of the tree to the forest floor, they undergo decomposition thereby promoting improve soil fertility, while also lowering bulk density (Issac and Borden, 2019). Aside from direct benefits, farmers may also profit financially from fuelwood, lumber, poles, and feed, all are ultimately employed on the farm for livestock management. When the edible sections of legume bushes are used as fodder, they give protein supplement to farm animals. Diversification of goods and services can be obtained from tree species, thereby reducing the risk of economic calamities through crop failure and improving climate change resilience and adaptation (Palsaniya and Ghosh, 2016). Agroforestry practices under the agrosilvopastoral systems are; Homegardens (Homestead gardens), Woody hedgerows serves as foraging items for farm herbivores to browse. Apart from that, it serves as green manure to promote safeguarding of soil, coupled with integrated production of crops, animals and wood (fuelwood, poles, timber etc).

***Benefits of Agrosilvopastoral Systems as Habitat for Birds***

Habitat destruction through agricultural practices resulting from conversion of forestland to farmland is considered to be a serious threat to existing bird species (Peh *et al*., 2006). Avian survival rates, reproductive success, breeding time, species distribution, and habitat choices are all influenced by microclimate and habitat architecture (Rajpar and Zakaria, 2011). The presence of shade in coffee plantation covering the forest floor, approximate 50 percent may stimulate good coffee output in terms of quantity and quality. The reason for the output might be due to control of temperature and insects (Jha *et al*., 2014, Jonsson *et al*., 2015, Atallah *et al*. 2016, Meylan *et al*., 2017). Shade does not only decreases coffee pests by dropping temperatures below

their thermal optimum, but it also aids in pest control by increasing bird predation (Mäntylä *et al*., 2011, Kariuki Ndang'ang'a *et al*., 2013, Classen *et al*., 2014, Karp *et al*., 2014, Railsback and Johnson 2014, Nesper *et al*., 2017). Shade trees' influence on local climatic conditions may help to moderate present and prospective temperature and relative humidity excesses, resulting to sustenance of coffee and habitat for bird species (Pearson and Dawson 2003, Buechley *et al*., 2015). So many factors may be responsible for increased focus on heat stress regulation in cattle rearing, but it is not restricted to these factors. Some of these factors are; increase in number of farm animals utilizing a feedlots, variation in climate conditions, rise in excessive weather events, livestock population increase coupled with increase in demand to cutting down wastage and promote growth, changes in livestock population and animal well-being due to societal pressure (Brown-Brandl *et al*., 2003).

The need to cut down heat stress is one of the international issues of discuss in livestock well-being in recent time, due to variation in environmental temperature. In different research work on cattle based on heat stress or the effects of shade on cow well-being, there is more emphasis on the necessity to fine a lasting solution to impacts of rising global temperatures (Foust and Headlee, 2017; Polsky and von Keyserlingk, 2017; Herbut *et al*., 2019; Lees *et al*., 2019). In terms of addressing global temperature increase, shade supply could be adopted as one of the mitigation actions, if and only if proper planning is put into consideration. It can also help to reduce heat buildup from planetary radiation emitted by sunlight, hence lowering overall heat burden. Although shade provides direct protection from planetary radiation emitted by sunlight, reflected shortwave radiation may still have a negative effects on animals in the shade, which is energy redirected on neighboring exteriors such as hot soil surface or ground, even though to a lesser extent in the shade (Binns *et al*., 2002). Oaks, plane trees, willows, birches, beeches, maples, ashes, lindens, and elms are some of the most common shade trees in temperate climates. In Australia and India where fig trees are prevalently planted basically for provision of shed in such subtropical zones, whereas in tropical zone such as Africa, tree species that provides shed are *Vitellaria paradoxa, Mangifera indica, Parkia biglobosa, Azadirachta indica, Afzelia africana, Detarium microcarpum* and *Vitex doniana (*Ibrahim *et al.,* 2019). Other tree species associated with agroforestry are; *Borassus aetheopium, Balanites aegyptiaca, Annona senegelensis, Parkia biglobosa, Mangifera indica, Moringa oleifera, Tamirandus indica, Vitex doniana* and *Zizipus species* (Gideon and Verinumbe, 2013). Birds as little as hummingbirds and as huge as herons, as well as hawks, owls, and crows, build their nests on tree branches. From the crown to the understory, the nests may be found at all levels of the tree. They can be found in the crotch, between the branch and the trunk, or at the branch's end. Nesting trees include Maples *Acer platanoides*, pine Pinus sylvestris, Juniper Juniperus communis, White oak *Quercus alba*, Sycamore Platanus occidentalis, Palm tree *Elaeis guineensis*, African locust bean *Parkia biglobosa*, Neem *Azadirachta indica* and Mango *Mangifera indica*.

**Roles of Agroforestry as Habitat for Bird Species**

The impact of organic and conservative management practices on the amount of insects (pest and profitable species inclusive) cannot be over emphasized in terms of defining the function of agroforestry in enhancing biodiversity (Akesse-Ransford *et al*., 2021). The roles of Agroforestry in providing habitat for bird species are;

i. provision food
ii. provision of nesting site and resources
iii. provision of nectar
iv. reduction of bioaccumulation of heavy metals and pesticide residue
v. provision of shade which serves as relaxation spot and protection
vi. provision of improved microclimate

***Provision of Food for Bird Species***

In cocoa, the quantity of insect pests was found to be greater in conventional farms, but organic farming methods upholds numerous species of insects that are destructive and might operate as natural enemies. This highlighted the relevance of adopting a management methodology that are capable of sustaining large percentage of biodiversity in order to continue to keep the environment healthy (Lopes *et al*., 2016). However, some of the predatory insect pest serves as food for insectivorous birds thereby promoting their survival. Insectivorous birds are described as any bird species that consumes an important fraction of arthropods such as precise insects and spiders at least temporarily (Lopes *et al*., 2016). Insects governs the biota with respect to their population, biomass, and diversity, serving as the largest source of feeding items to land-dwelling flesh-eating wild animals. This might elucidate the predominance of insectivore as a mode of feeding in avian species. For

example, more than 700 million tons of global upended biomass are associated with insect species that are social based on assumption (Hölldobler and Wilson 1994; Sanderson 1996). True insectivores, such as warblers and robins, have short bills specialized for capturing these small invertebrates, but Thrushes have more powerful beaks. Bluebirds, Cardinals, Chickadees, Grosbeaks, Nuthatches, Orioles, Swallows, Titmice, Warblers, Woodpeckers, and others are examples of insect-eating birds.

More bird species are associated with farmland based on research findings (Sekerciolu *et al*., 2007), and bird species utilizes essential short-lived crops such as sugarcane (Alexandrino *et al*., 2019) and rice. The aforementioned crops are well reported based on research findings (Elphick *et al*., 2010; Masero *et al*., 2011; Elphick, 2015). Foraging items for bird species can be categorized into plants, seeds, or vertebrates and invertebrates. These food source are in high supply in agroforestry system (Stafford *et al*., 2010).

In an agrisilvicultural system where wooden perennials are combined with agricultural crops, there is availability of insects and pests that disturb the crops which could reduce yield. Birds eat these insects, they are natural technique to keep pests at bay. Hundreds of insects can be consumed each day by a flock of birds gliding through the air. Birds that consume insects include warblers, bluebirds, and woodpeckers. When nectarivore birds travel, the agrisilvicultural system provides food for them, and they are key pollinators, which means they transport pollen from flower to flower to help fertilize sex cells and form new plants for example Bananaquits, Chickadees, Finches and Flowerpeckers. Therefore, food is very essential for survival of bird species.

***Provision of Nesting Site and Resources***

According to Kay *et al*. (2020), apart from foraging items agroforestry provides significant nesting resources for wild bees and birds. In order to protect their eggs and nestlings, most birds construct a building nest. A bird's nest can be as basic as a nighthawk or Killdeer's depression on the ground, a woodpecker's hole in a tree, or an Oriole's ornate pouch-like nest. The most common sort of nest is a cup constructed of plants and occasionally mud. The exterior layers are frequently made of coarse material, whereas the inside layers are made of softer or finer material. Cup-nesters may hide their nests in trees or bushes, build them on the ground, or install them in nest boxes or tree cavities, depending on the species. Scrape nest is the meekest nest build by birds. It is made up of ordinary superficial depression in topsoil or plant materials (Campbell and Lack 1985) and the rim are adequately deep to safeguard eggs from rolling away. In some cases they are decorated with some small stones, feathers, shell fragments or vegetation (Ehrlich *et al*., 1994). Safeguarding the eggs inform of camouflaging and insulation are provided by these materials. Apart from that, the materials reduces the incidence of the eggs falling into an environment that is mud-covered or coarse soil, if the nest becomes wet coincidentally. Scrape nests are built by Ostriches, most Tinamous, many Ducks, most Shorebirds, most Terns, some Falcons, Pheasants, Quail, Partridges, Bustards, and Sandgrouse.

Nesting chances provided by agroforestry trees may benefit mostly cavity nesting species. The cavity nest can be defined as a tree hole or chamber established on a living or lifeless log of wood (Collar 2001). Only a few species, such as woodpeckers, trogons, many nuthatches, and a variety of Barbets, are capable of digging cavities in tree species on their own. Parrots, Tits, Bluebirds, most Hornbills, specific Kingfishers, specific Owls, specific Ducks, and specific Flycatchers utilizes cavities existing naturally on tree species for nesting. In some cases, nest cavities uninhibited by avian species with such skilful ability to dig them could be adopted and utilize for nesting purpose. Some avian species that are nest cavity holders, could be robbed of their nest hollows by other unskillful bird species. For example, primary hollow nesters species are capable of digging their personal cavities on tree species, whereas secondary cavity nesters cannot dig their own hollow for nesting, but utilizes natural or non-natural hollows made by other bird species. Another name for bird houses is nest box. Nest box might captivate prime and subordinate hollows nesters to breed. They emulate regular cavities nesters and this could be a serious risk in zones where natural hollows are restricted (Phillips and Tina, 2005; Fred, 2013).

Agrisilviculture is a land-use system in which woody perennials (trees, shrubs, palms, and bamboos, among others) are deliberately established together with agricultural crops on the same land-management entities (Carne, 2008). Different bird species such Orioles, Cassin's Kingbirds, Starlings, Egrets, and Herons uses various plants parts such are palm fronts to make nest during their breeding season thereby influencing the breeding performance.

***Provision of Nectar***

Improved pollination services could be obtained from agroforestry lands with a greater proportion of cherry trees. Kay *et al*. (2020) observed that an integration of ordinary tree species that produces flowers and fruits into agroforestry are very essential in the course of supporting wild bee populations to promote pollination services delivery in agricultural environments. Agroforestry's pollination services benefit birds as well, particularly nectar-feeding birds, for example. When nectar is freely accessible, different bird species consume it as a primary source of nutrition or as a source of enjoyment. For example Bananaquits, Chickadees, Finches, Flowerpeckers, Hummingbirds, Honeyeaters, Lorikeets, Orioles, Sunbirds, Verdins, Warblers, White-eyed Woodpeckers, and White-eyed Woodpeckers are among the birds that ingest nectar in varying degrees. Not only would agrisilviculture help to conserve plants, arthropods, and vertebrates, but it will also aid in the creation of pollinator nests and pest regulator. Hummingbirds, Honeyeaters, Lorikeets, Orioles, and other birds are known to consume nectar to varied degrees. Fruit-eating birds like Mockingbirds, Orioles, Finches and Robins, also find their food from this system. When nectarivore birds travel, the agrisilvicultural system provides food for them, and they are key pollinators, which means they transport pollen from flower to flower to help fertilize sex cells and form new plants for example Bananaquits, Chickadees, Finches and Flowerpeckers. Therefore, nectar serves as a good source of nourishment to nectarivorous birds.

***Reduction of Bioaccumulation of Heavy Metals and Pesticide Residue***

Agroforestry is analogous to organic farming in the tropics, where mineral fertilizers and industrial pesticides are not utilized on a regular basis. This is beneficial because it makes healthy food available to bird species, minimizing heavy metal and pesticide residue bioaccumulation in birds. Acceptance of agroforestry techniques might promote an increase in organic agriculture in a sustainable manner, apart from its unique challenges and prospects associated with it (Rosati *et al*., 2021). Silvopasture is a worthwhile agroforestry land use alternative because it protect the soil through provision of soil cover coupled with assemblage of diverse improved quality products such as timber, dairy products and meat (Jose and Dollinger 2019). Some insectivorous birds, on the other hand, benefit from silvopasture by preying on insects found on livestock's bodies. Some of the birds who gain from it red-eyed vireo *Vireo olivaceus* black-throated green warbler *Setophaga virens* and cattle egrets *Bubulcus ibis*.

Birds are particularly vulnerable to unselective felling of trees, which occurs as a result of transformation of forestland into cropland, firewood collecting, tree chopping for lumber, charcoal production, and wildfires. All the aforementioned factors renders bird species homeless (Egwumah *et al*., 2014). Surface runoff can introduce contaminated substance such as pesticides, herbicides, and fertilizer remainder into water that is not flowing, owing to the vulnerability of naked land to excessive runoff due to intensive cultivation of crops. This discharge contains contaminants such as salts, nutrients such as phosphate and nitrogen, and pesticide residue (Gohary 2015) Pesticides can pollute soil, water, and air. Increased pesticide usage, reduces arthropod prey and weed availability (Ratcliffe and Crowe 2001; Egwumah *et al*., 2015) for bird species. Agroforestry helps to prevent all this from happening by providing sufficient trees in degraded areas. These trees helps to prevent excessive runoff which could introduce pollutants into natural water bodies.

***Provision of Shade which serves as Relaxation Spot and Protection***

Birds are safeguarded from predators by crops and crops serves as recreational centers where birds relaxes (Hutto, 1998; Linscott and Senner, 2021). Sparrows and finches, including juncos and redpolls, grouse, quail, pheasants, partridges, doves and pigeons, smaller parrot and parakeet species, and many others are among the birds that benefits from agrisilviculture systems. Shade trees' influence on local climatic conditions, may help to moderate present and prospective temperature and relative humidity excesses, resulting to sustenance of habitat for bird species (Pearson and Dawson 2003, Buechley *et al*., 2015). Shade provided by agroforestry tree species may alleviate temperatures and precipitation excesses coupled with wind and storm proceedings, thereby preventing prospective habitat loss by bird species (Philpott *et al*., 2007; Lin *et al*., 2008). Serious arid conditions equally promotes rise in forest-fire risk which might affect nest, nesting materials and nestling (Johns, 1999).

In the presence of shade provided by agroforestry tree species, lesser temperatures are usually recorded in air

and soil. However, in the presence of shade, advanced air humidity intensities are recorded, but with frequently decreased water stress in the environment for bird species (Lin *et al*., 2008). The presence of shade trees reduces the rate of water evaporation in the surroundings. Apart from that, dense canopy cover resulting from the presence of more tree species, might promote increase in water uptake and increase in diameter at breast height and leaf area of tree species (Köhler *et al*., 2009).Increase in diameter at breast height and leaf area of tree species might provide quality nesting materials for bird species especially cavity nesting birds. Rapid vegetation growth are associated with shade trees which may improve the quality of habitat available to bird species (Isaac *et al*., 2007b). Therefore, the presence of shade might serve as habitat for bird species through establishment of relaxation spots. It also protect bird species from homelessness.

***Provision of Improved Microclimate***

Climate can be defined as a combination of weather proceedings above a prolonged period. Weather has a huge effect on avian species, this is a well-known problem (Crick, 2004), being both dissimilar and essential. As a result, birds are very sensitive to environmental changes. In addition to enhanced soil fertility, shade for understory crops, trees functioning as stakes for climbing plants, soil erosion control, improved microclimate, and increased yield stability are some of the benefits sought by farmers. However, in the course of seeking improved yield by farmers, provision of shade for understory crops improves the microclimate which could be beneficial to birds. Norman and Peach (2013), used 23 years' research statistics on capture, mark and recapture techniques to evaluate the survival proportions of bird species between year changes in enrolment. However, the survival of fully-grown birds correlated positively to precipitation in wintering ground in sub-Saharan Africa, but in their breeding sites, dissimilar correlation occurs between precipitations. They reiterated that, additional satisfactory conditions may stimulate a rise in avian population and survival rates of fully-grown birds in their sub-Sahara African wintering sites. Bird species equally needs favourable conditions to stimulate increase in survival rates of adults, because survival rate is a function of the number of birds exploiting a specific habitat. As rainfall commences it send vital breeding signals to birds and they are forced to migratory to African. However, the variation in precipitation pattern coupled with the volume of rainfall and period of the year, may affect breeding venture (Boere *et al*., 2006). This could be attributed to climate change because with climate change, the volume of rain may be absence or erratic in some areas, all year round. This could affect the quantity and quality of feeding items available for bird species. Birds may not breed once there is a decline in quantity and quality of feeding items available ((Egwumah and Iboyi, 2017).

There is a major relationship between birds and climatic factors. As rainfall increase, there is also an increases in population of bird species because increased rainfall provides more food and improved microhabitat for birds to breeding. During rainy season the trees are luscious, resulting to production of more flowers and fruits especially between the months of August to October. This period coincided with the period when bird's populations demonstrated great correlation with precipitation (Egwumah *et al*., 2014). Birds are more spread in population during the rainy season, but during arid months of the year, they are restricted to rivers bathing, drinking and preening. The presence of water (Warburton and Perrin, 2006) also serves as a paramount factor influencing the distribution of parrots and lovebirds but infiltration of rainwater into the nests could be responsible for nest failure during the nesting period in African grey parrots (Piebeng *et al*., 2017).

Apart from that, food and excellent microclimate are fundamental elements influencing distribution and supporting their breeding performance. Due to variation in environmental temperature, more lovebirds were sighted during chilling environmental conditions in daylight period compare to sunset (Warburton and Perrin, 2006). Anyway, production of sperm takes place at night in fully grown male birds due to lowest receding of body temperature but, hatching failure may occur during breeding season, if the microclimate temperature within the nest cavities is not suitable for parrots and lovebirds. Therefore, food, water and microclimate are essential for healthier home range improvement to enable the aforementioned species breed maximally with little or absence of mortality.

There is also growing evidence from continuous research which shows that, birds have a relationship with their date of laying eggs and increase average temperatures, but the period of laying has great impacts on total breeding performance, because they are tough genetic and phenotypic (Garant *et al*., 2008). In addition to time of breeding and clutch size, which are key indicators of overall reproductive success in birds generally moderate temperature also contribute to improved reproductive

success. By modifying their breeding period, variation in climate conditions might likely adjust a number of other factors of reproductive processes in parrots and lovebirds such as the number of clutches and size of clutches, incubation behaviour and recruitment (Egwumah and Iboyi, 2017). Therefore, avian survival rates, reproductive success, breeding time, species distribution, and habitat choices are all influenced by microclimate and habitat architecture (Zharikov and Skilleter, 2002; Norvell *et al.,* 2003; Rajpar and Zakaria, 2011).

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

The overall contribution of agroforestry as habitat for bird species is a function of the type of land-use that it substitutes coupled with the characteristics of the individual agroforestry system. The level of effectiveness of any agroforestry systems in safeguarding bird species depends on how well the system is design coupled with the biodiversity of interest the agroforestry system is established to conserve. In addressing global sustainability and warming challenges, agroforestry approaches has a very good prospect in combating both challenges, using the benefits derived from agroforestry as criteria for assessment. Deliberate integration of tree crops into agronomic crops with the main aim of promoting sustainable land management could be referred to as agroforestry. The three main types of agroforestry systems are agrisilvicultural, silvopastoral and agrisilvopastoral. However, the roles of agroforestry as habitat for bird species are provision food, provision of nesting site and resources, provision of nectar, reduction of bioaccumulation of heavy metals and pesticide residue, provision of shade which serves as relaxation spot and protection for bird species, coupled with provision of improved microclimate. Foraging items for bird species can be categorized into plants, seeds, or vertebrates and invertebrates. These food source are in high supply in agroforestry system. Apart from that, nectar serves as a good source of nourishment to nectarivorous birds and agroforestry makes healthy food available to bird species, minimizing heavy metal and pesticide residue bioaccumulation in birds. Birds are safeguarded from predators by crops and crops serves as recreational centers where birds relaxes. Shade provided by agroforestry tree species may alleviate temperatures and precipitation excesses coupled with wind and storm proceedings, thereby preventing prospective habitat loss by bird species. Similarly, avian survival rates, reproductive success, breeding time, species distribution, and habitat choices are all influenced by microclimate and habitat architecture.

### Recommendations

In order to widen the agro-ecological emphasis of agroforestry systems and bird diversity, more study is needed, including suitable measurement, modelling, and testing to categorize the essential components of agroforestry systems that are most imperative for supporting avian species in the landscape.

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