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Butterflies and their contribution in Agro-forestry

Abstract:

Butterflies are essential to the agro-forestry ecosystem, and their lives are intertwined with those of plants due to their co-evolution. Agroforestry contributes significantly to sustainable development, biodiversity maintenance, and food security. In fragmented agricultural landscapes, agroforestry activities may offer a habitat for forest butterflies and aid in their protection. Butterflies are the ecosystem's natural indicators as well as great pollinators. Some butterfly species travel great distances and transport pollen to plants located far apart from one another. Pollen migration causes genetic variation in plant species, improving their chances of surviving certain biotic and abiotic stresses. These insects also work as biological pest management tools and act as food for other creatures including birds, reptiles, and amphibians. However, because of the non-availability of suitable host plants, indiscriminate pesticide use, and a lack of knowledge about the value of these flying gems, the population of these insects is declining quickly. Agroforestry ecosystems provide suitable habitat for butterfly conservation; in turn, agroforestry cultivation can be greatly benefitted from beneficial insects such as butterflies in multifaceted ways, including pollination benefits, aesthetic value, and attraction spots as butterfly parks. Therefore, in this review we have attempted to discuss comprehensive role of butterflies in agroforestry system.

Keywords: Butterflies, agro-forestry, ecological indicators, pollinators, butterfly garden, conservation

Introduction

Agroforestry is a land management practice that combines agriculture and forestry by integrating trees and shrubs into cropping and animal farming systems. It provides multitude of benefits such as increased economic gains, improved soil health, environmental benefits, recycling of the components and cutting down the production costs, etc. Agroforestry system can be benefitted from insect pollinators. In turn, agroforestry ecosystems are the most suitable systems for multiplication or butterfly conservation activities.

Butterfly belongs to one of the most specious insect groups that come in a variety of colours and sizes. Butterflies are part of arthropods with around 19,000 species widespread throughout the world (Ponder and Lunney, 1999). Majority of the species are found in tropical areas (approximately 80 percent of known species). Adult butterflies need liquid-based nourishment (Larson et. al., 2001). Their ability to survive depends on the nectar that flowers generate as well as overripe fruits. The butterflies are the crucial component of ecosystems and provide numerous ecosystem services, where they serve as a pollinators, acts as a food source, and act as an indicators of the health of the ecosystem, play role in ecosystem restoration as well as offer some direct benefits to humans (Tiple at. al., 2005). A significant part of pollination in the flowers that open throughout the day is done by butterflies. Butterflies acts as pollinators to over 20,000 species of wild and domesticated plants and rank next to bees and wasps (Corlett, 2004). Butterflies often prefer large, vibrant blooms with a platform for landing, and while they sip nectar from a flower, they collect pollen on their long, thin legs (Stökl et. al., 2011). Numerous butterfly species can travel up to 3,000 miles at a time. Long-distance pollination is made possible by these journeys, which have also raised public interest in the species.

Butterflies are not only a beautiful addition to a flower garden, but they are also an important element of it because they are a good indicator of ecosystem health and provide practically all of the information about ecosystem balance. Aside from being a fascinating component of biodiversity, butterflies serve as indicators of environmental health and change (Fleishman and Murphy, 2009). Butterfly population increase often indicates a healthy ecosystem (Shi et. al., 2009). In restored habitats, an increase in butterfly populations may indicate greater plant diversity and the presence of other pollinator species. It is known fact that in any given ecosystem, several plant and animal species co-habitat an ecological niche and prefer similar combinations of soil, topography, climate, and geography. This also applies to butterflies, as certain types of vegetation are required for butterfly species to exist. Butterflies have specific habitat requirements. A fascinating aspect of studying localized butterflies is determining what microhabitats they require (Swengel, 2003). It in turn provides information on management of local habitat, flora and fauna. Moreover, these insects are excellent model organisms for environmental and biological research. For example, butterflies are used to study various biological phenomenon such as mimicry, development, genetics, evolution, population dynamics, and conservation (Wang et. al.,2020).

Furthermore, butterflies are important ecological players in agricultural environments. In addition to pollination, they also play role in crucial ecological functions such as recycling of nutrients (N, P, K) highly needed by crops that were previously taken through plant absorption and uptake (Schmidt and Roland, 2006). Their larval stages release faeces that are rather nutrient-rich after feeding on the leaves of several wild plants that are present in agricultural systems (Marchiori and Romanowski, 2006). However, a thorough understanding of Lepidoptera foraging behaviour as well as their temporal and spatial distribution in agricultural environments is necessary for the protection, conservation, and utilization of this diversity of pollinators. Agroforestry settings can support the butterfly community's richness and functional diversity (Kuefler, 2008). Additionally, butterflies can bring direct economic benefits. Butterfly eco-tourism that attracts numerous tourists around the world each year, bringing significant income to local citizens (Lemelin, 2019).

Thus, butterflies are vital to the productivity of natural and agricultural landscapes because they offer various ecological services to native wild plant species and crops in numerous environments across the world and bring economical and aesthetic benefits which are explained in detail in the subsequent sections.

Ecosystem services of Butterflies

Butterflies as pollinating animals in the agroforestry ecosystem

Pollination is a vital part of plant reproduction that allows for the transfer of genetic
material and the production of seeds. Pollen is a powdery substance produced by the anthers
13 or the male parts of a flower, and the female part of the flower is called the pistil, which is
8 made up of the stigma, style, and ovary. The movement of pollen from the male to the female
portions of a flower initiates conversion of female portion ovary into the fruit while the ovule
turns into a seed. Pollen can be transferred by pollinating agents such as animals, water,
wind, or even plants themselves. Pollinating animals, like bees, butterflies, and birds, carry
33 pollen from plant to plant on their bodies. The various parts of flower such as petals and
nectar produced by flowers attracts pollinating animals including butterflies. The flower
petals are typically the most visible sections which draw in pollinating insects and act as
landing pads. Nectar is a very nutritious liquid that includes lipids, carbohydrates, amino
acids, B vitamins, and other organic components and serves as essential food source for
pollinators (Webb, 2008). Pollen from the flowers sticks to the small scales on the bodies of
butterflies, who visit flowers to feed on nectar. Upon visiting another flower, the butterfly
deposits pollen that adheres to its scales and brushes against the stigma of the flower. Pollen
grain can be transferred by pollinators to far-distant areas (Pollinator.org). Further, the nectar
6 feeding innovation plays a role in the reproductive and population biology of pollinating
6 insects. Various aspects of the life history and reproductive biology of pollen-collecting
butterflies are consistent with the hypothesis that the nutrients provided by pollens are of
major importance to adult maintenance and reproductive activity.

18 37 11 11 10 25 16

Agroforestry system involves cultivating different crops and tress and many of them depends on cross pollination to produce economical yields. Butterflies and other invertebrates are vital for effective pollination of both cultivated and wild plants (Buchmann and Nabhan 1996). Butterflies of several families pollinate woody species such as *Ixora*, *Clerodendron* and *Bauhinia* (Momose,1998). Among the individual butterfly families, the Nymphalidae have been implicated in the pollination of *Syzygium* species (Appanah, 1990). At open sites, butterflies (including Hesperiidae) are conspicuous visitors to many herbaceous plants (Balasubramanian,1989). The *Phlox pilosa* and *P. glaberrima* rely for their reproductive success on several species of butterflies (*Colias, Pieris, Danaus and Polities*). *Anguria* is pollinated by *Heliconius* butterfly. *Cadaba fruiticosa* is pollinated by *Colotis eucharis*, *C. danae*, and *Anaphaeis aurota* ((Reddi and Bai, 1984). Butterfly species, including other insect orders, are the majority pollinators of vegetable crops such as lettuce. So, insect pollinators are considered one of the cheapest and most eco-friendly approaches to maximizing the yield of cross-pollinated crops (Negi et. al., 2020). List of pollinating butterfly species in different cropping elements of agroforestry system such as vegetables, trees, medicinal plants, flowers plants are provided in the table 1 and 2.

Table 1. Vegetable/Fruit/medicinal plants dependent upon butterfly pollinators

Sr. No.	**Butterfly Species**	**Crop**
1.	Multiple species	Lettuce (*Lactuca sativa*) (Negi et. al., 2020)
2.	*Helconius* genus	Anguria (*Cucumis anguria*) (Reddi and Bai, 1984)
3.	Nymphalidae Species	*Syzygium* genus (Appanah, 1990)
4.	Plain Orange-tip *(Colotis eucharis)*, crimson tip *(Colotis danae)*, Pioneer white (*Anaphaeis aurota)*	Indian Cadaba (*Cadaba fruiticosa)* (Reddi and Bai, 1984)
5.	Gray hairstreak (*Strymon melinus*) and the little yellow (*Eurema lisa*)	*Cotton (Gossypium arboretum)* (Stokstad, 2021)
6.	Dingy skipper (*Erynnis tages*), grizzled skipper *(Pyrgus malvae)*	Salad burnet (*Sanguisorba minor*) (Askham and Hendry)

29 26 31

Table 2. Flower crops dependent upon butterfly pollinators

Sr. No.	Butterfly Species	Crop
1.	*Troides brookiana* (Papilionidae)	*Bauhinia* genus (Leguminosae) (Momose,1998).
2.	Multiple species	*Ixora* genus (Momose,1998).
3.	*Colias, Pieris, Danaus*	*Phlox genus* (Reddi and Bai, 1984)
4.	Common blue *(Polyommatus icarus),* Common emigrant *(Catopsilia Pomona),* Large Cabbage White *(Pieris brassicae),* Pea Blue *(Lampides boeticus),* Plain tiger *Danaus chrysippus*	Coriander (*Coriandrum sativum*) (Shivashankara et. al., 2016)
5.	Black swallowtail (*Papilio polyxenes*)	Dill *(Anethum graveolens)* (Eisenstein)
6.	Multiple Species	Carrot (*Daucus carota subsp. Sativus*) (Cerruti et. al.)

Role of butterflies in induction of genetic variation in plants and co-evolution of flowering plants and butterflies

Insects are the sole pollen vectors of many flowering plants, especially in tropical and subtropical regions. Several reports have supported "pollinator-driven ecological speciation model", where ecological shifts in pollination systems drive the evolution and species diversity of the plants. For example, as per studies of Valente et. al. (2012) in the in southern African *Gladiolus*, recent pollinators like butterflies and moths, etc. are associated with increased diversification rates as compared to ancestral pollinators like increased tongue bees. Some butterfly species migrate over great distances, transferring pollen from one distant plant species to another. These mechanisms cause genetic variation in the plants as well as aids in the plant's ability to withstand disease and increases their chances of surviving (Kearney, 2015). Plants exhibiting an allogamous mating system with self-incompatibility are

3 dependent on insects for both seed production and the maintenance of genetic diversity. Thus,
3 pollinators are crucial for the long-term adaptive potential of rare, endemic plants.
Conservation of rare endemics is dependent on community-level interactions such as plant–
3 pollinator mutualisms. Butterflies from three families Hesperiidae (skippers), Papilionidae
(swallowtails), Nymphalidae (brush-footed butterflies), were observed displaying potentially
3 “effective” pollinator behavior in *Abronia alpina*, a rare alpine endemic of the California
3 Floristic Province. Thirteen species in the *Nyctaginaceae* have been documented to be
sphingophilous, pollinated by hawk moths and nocturnal butterflies (Jabis et. al., 2011).
3 Butterflies and large moths are expected to travel between plants and between subpopulations
more than other insect pollinators, affecting long-distance pollen dispersal (Courtney, 1982).

There are several reports from different parts of the world which have proved co-evolution of butterflies and plants. These findings can be extrapolated to agroforestry systems. For example, Asthon et al (Asthon, 1988) studied the phenology of plant reproduction and evolution in mast-fruiting dipterocarps from West Malaysia and reported co-evolution between plants and pollinators. Ehrlich gave evidence that butterflies depend on nectar of
12 flowers so they co-evolved corresponding to flowers of a plants (Ehrlich, 1984). Ehrlich and
Raven popularized coevolution with their pivotal study integrating chemical ecology,
adaptive evolution, and macroevolutionary hypotheses based on detailed natural history of
butterflies and flowering plants (Ehrlich and Raven, 1964). Feeny (1975) and Gilbert (1972)
24 explained about biological process co-evolution that where two or more species affect each
38 other's evolution through natural selection. The theory of plant-insect coevolution suggests
20 that plants develop broad-spectrum chemical defenses, and some insects coevolve by
detoxifying and using these compounds. Herbivores evolutionarily exhibit ability to escape
4 host defences, after which plants that have developed relative chemical protection from
herbivores undergo adaptive changes. Nahrstedt (1981)and Cavin (1988) demonstrated the

coevolution of *Passiflora* plant against *Heliconius* butterfly species. *Passiflora* is specialised host plant for *Heliconius* larvae, and Passiflora has acquired strong chemical and morphological defences against *Heliconius* herbivory, including cyanogenic glycosides. Thus, several species of *Heliconius* developed the capacity to withstand or store elevated concentrations of these poisons. There is a remarkable closeness between the vegetation cover, composition, and butterfly's species (Keren et. al., 2022). Fordyce (2010) experimentally proved that the host plant association plays profound role in the evolutionary history of butterflies. Comprehensive research on the evolution of pollinators and host components in agroforestry systems can be conducted to better understand host compatibility and incompatibility mechanisms with butterflies. This knowledge is useful for both butterfly conservation and crop protection.

Butterfly species composition and population level as ecological indicator of a healthier ecosystem

Currently, biodiversity assessment is a crucial instrument in determining how the environment and habitat are changing. The primary causes of changes in a habitat's biodiversity are human activity and environmental deterioration. As one of the planet's most diverse organisms, insects may be a key factor in determining the richness of the terrestrial ecosystem. According to research on biodiversity, butterflies are regarded as the "flagship of taxa" among insects. In 1988, Landres and in 1998, Simberlof proved that indicator species use variations in their own abundance to signal changes in the physical and chemical composition of the environment or the abundance of other species. These are referred to as ecological indicators, and their primary objective is to quantify the intricate system without overlooking other details.

5 Due to their fragility butterfly acts as indicators as they are quick to react to change so their struggle to survive is a serious warning about our environment. Habitats have been destroyed on a massive scale, and now patterns of climate and weather are shifting unpredictably in response to pollution of the atmosphere. However, the disappearance of these beautiful creatures is more serious than just a loss of colour in the countryside. As a 9 significant herbivore in terrestrial ecosystems, butterflies rely on plants or other food sources during two life stages: as larvae, they chew on plants, and as adults, they eat on nectar. Butterfly diversity can be used as a proxy for the health of terrestrial ecosystems because of 9 the close interaction between plants and insects in terms of functional diversity (Nelson, 2007). Furthermore, mature butterflies require a wide variety of additional materials for their 9 survival and reproduction, such as water, pollen, mud, damp sand, carcasses, and animal excrement (Hardy et. al., 2007). which are available in agricultural and agroforestry ecosystems. The butterfly diversity can act as indicator of condition of riparian habitat also, as the diversity of butterfly species in riparian zones is influenced by the connection between the area and a river. Since plants found in wetland environments play a crucial role as larval food sources and provide nectar for adult insects.

Several butterflies have specific host plants as larvae and are therefore vulnerable to any alterations that impact those plants (Ward, 2001). Butterfly communities are very responsive to alterations in the forest environment also, as they are highly affected by shifts 5 in habitat disturbance or quality (Collinge, 2003). Additionally, butterflies are easily observed and their species are more well-known than many other insect groups, making them valuable subjects for studying ecological disturbance indicators. Their small size, small reproductive cycle, and positioning at lower levels in the food chain, enable them to adapt rapidly to 8 environmental challenges. Therefore, in many regions of the world, Lepidoptera are widely 14 accepted as ecological indicators of ecosystem health (Oostermeijer and Swaay, 1998).and

14 meet a number of the criteria set forth by Hilty and Merenlender (2000). The taxonomy of butterflies is well understood, with a well-defined life history and biology. Several of their physical tolerances, like light, temperature, and the conditions in which they live, have been measured (Pollard et. al., 1998). Demonstrations have been made regarding associations with changes in ecosystem conditions (Swengel, 1998). All these studies highlight the use of
8 butterflies as indicators of ecosystem health and suggest that they can also be employed to monitor changes in agroforestry systems, reflecting biodiversity and other key ecosystem health parameters.

Butterfly as integral part of food chain: Providers and Predators

28 Butterflies play a significant role in the food chain. Different developmental stages of butterflies serve as food source for other organisms. Birds and other predators feed on butterflies and also, they serve as hosts to numerous parasitoids that help control crop pests. Numerous birds will consume monarch butterflies if they are readily accessible (Petersen, 1964). Monarchs grouped in large numbers can provide ample food and are easy targets for predators (Journeynorth.org). They provide food for mice, lizards, spiders, and other creatures (Goodliving.org, Halali et. al., 2019). A decline in butterfly populations could affect
4 the entire ecosystem. According to studies of Stephen Dickie, birds organize their entire breeding season around the time when caterpillars will be most plentiful. Particularly in agricultural and agroforestry systems, when combined with poultry, butterflies and their caterpillars can serve as food for growing chicks. Additionally, caterpillars act as preferred hosts for egg-laying and reproduction of certain parasitic flies and wasps (carbon-based-ghg.blogspot.com).

22 Majority of the caterpillars are plant eaters, but a few are carnivorous. Caterpillars of the carnivorous Harvester butterfly (*Feniseca tarquinius*) eat woolly aphids. The carnivorous
22 Harvester butterfly *(Feniseca tarquinius)* larvae feed on woolly aphids. The female butterfly

lays her eggs in the centre of aphid colonies, making the caterpillars useful for biological pest control (Opler and Krizek, 1984). Some butterfly larvae feed on harmful insects, and a few even prey on ants. Certain carnivorous butterflies consume other insects, such as mites, during their larval stage. It is estimated that less than 1% of Lepidoptera species are carnivorous, and only a few of them are obligate carnivores, as some will eat other insects only when plant food is scarce (speciesconnect.com). Caterpillar of butterfly *Electrostrymon denarius* are known to feed on mushroom (Nishida and Robbins, 2020).

Understanding the role of various developmental stages of butterflies in the food chain is crucial for designing agroforestry systems that prevent potential losses from herbivores while also leveraging butterflies to maintain a healthy food chain, thereby healthy cropping ecosystem.

Aesthetic value of butterfly and butterfly parks as education and research labs.

Butterflies hold significant aesthetic value, captivating people with their vibrant colors and graceful movements. The bright colors also help in preventing some potential predators by suggesting bad taste or poison (Manning, 2014). Butterflies are known for exhibiting mimicry behavior in different developmental stages and it is a mechanism to survive also. Caterpillar stage of different species show different character, forms and colors, which can simply resemble a plant twig, leaf or to fungus-infected late season old oak leaf. Moreover, metamorphosis of butterfly is a fascinating phenomenon where a stunning butterfly fully develops from a chrysalis spun by a crawling caterpillar (Kumar, 2013).

Thus, butterflies provide several ecological services which can be exploited for the benefit of agroforestry systems and in turn these systems can be utilized for butterfly conservation. The mutual role of butterflies and agroforestry is represented in the figure 1.

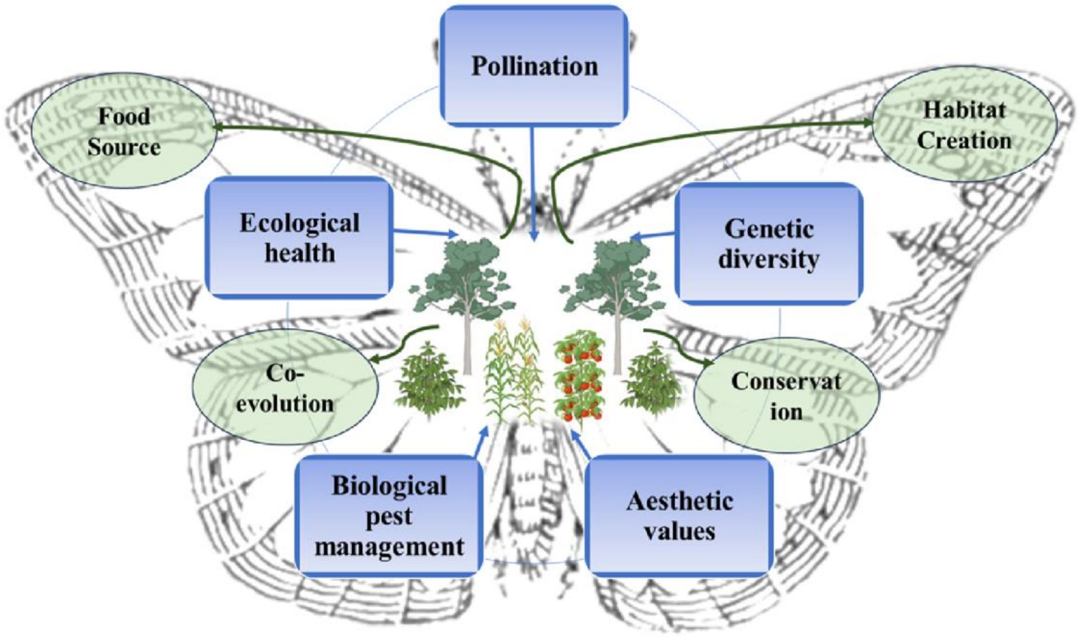

Figure 1: Mutual role of butterflies and agroforestry ecosystems.

Butterflies benefit agroecosystem via pollination, contribute to genetic diversity, maintain ecological health, pest management and add aesthetic values to the system (Represented in blue shaded boxes and blue arrows indicate butterfly to agroforestry system). Agroforestry supports butterflies by providing suitable habitat, food source, promote co-evolution and their conservation (Represented in green shaded boxes and green arrows indicate agroforestry system to butterfly).

Considering their exquisite aesthetic values, there are ample opportunities to convert a butterfly conservation area into butterfly parks and butterfly conservatories. Both urban and wild habitat conservation, as well as the conservation breeding of threatened and endangered species, benefit greatly from butterfly conservatories. Butterfly parks/gardens serve as beautiful and tranquil environments, providing a space for visitors to appreciate these creatures up close. Additionally, these parks function as valuable educational and research labs, offering opportunities to study butterfly behavior, life cycles, and ecosystems. They promote awareness about conservation and biodiversity while encouraging scientific exploration, making them important centers for both learning and research. There are numerous such parks/gardens in Indian states like Karnataka, Tamil Nadu, Gujarat, Kerala, Uttar Pradesh, Delhi, and Haryana. By educating people about butterfly conservation and motivating them to plant host and nectar plants, butterfly gardens can play a significant role. Common nectar plants include sunflowers, marigolds, petunias, and cosmos, hibiscus, while curry leaves, calotropis, tamarind, cotton trees, acacia, cassia, and numerous citrus plants act as host plants for Indian butterflies. List of Important butterfly parks/gardens alongwith species diversity of each, in different location and agroclimatic zone are provided in the table 3.

Table 3. Important Butterfly Gardens across India

Sr. No.	Name of Garden	Location	Agroclimatic Zone of the location	No. of species	Important Butterfly species
1.	Butterfly Park in Bannerghatta Biological Park	Bannerghatta National Park, Banglore, Karnataka	Eastern Dry Zone	77	Spot Swordtail, Syrian Babul Blue, Narrow Banded Blue Bottle (Remadevi et. al.,)
2.	Ovalekar Wadi Butterfly Garden	Thane, Maharashtra	North Konkan Coastal Zone	172	Transparent 6-Lineblue, Large Oakblue, Vindhyan Bob, Bevan's Swift (Kasambe, 2012)
3.	Butterfly Park (Asola Bhatti Wildlife Sanctuary)	Shooting Range Road, Tughlakabad, Delhi	Agro-ecological Subregion 4.1	56	African Babul Blue, Indian Red Flash, Banded Awl (abwls.eforest.delhi.gov.in)
4.	Tropical Butterfly Conservatory	Srirangam Taluk Road, Melur, Tamil Nadu.	Cauvery Delta Agroclimatic zone	113	Anomalous Nawab, Joker, Tamil Bush-Brown (Santhosini, 2022)
5.	Butterfly Conservatory of Goa	Ponda, South Goa, Goa	West Coast Plains and Ghat Region	144	Malabar banded peacock, southern birdwing, Tamil Lacewing, blue oakleaf, clipper and Plum Judy (gomantaktimes.com)
6.	Butterfly Park Chandigarh	Chandigarh College of Engineering and	Trans-Gangetic Plains Region	35	Commander, Tawny Coster, Common Onyx, Common Palmfly Angled Sunbeam (www.coveringindia.com)

		Technology, Sector 26, Chandigarh.			
7.	Butterfly Park at Lucknow Zoo	Nawab Wazid Ali Shah Zoological Garden, Hazratganj, Lucknow	Central Plain Zone	62	Commander, Spot swordtail, Indian Sunbeam (Sharma et. al., 2021)
8.	Thousand shades Butterfly Park, Gurgaon	Sector 52A, Gurugram, Haryana	Northern Plain and Central Highlands.	27	Mottled Emigrant, Great Eggfly, Peacock Pansy (cityflowers.co.in)
9.	Butterfly Garden, Narmada	Kevadiya, Narmada, Gujarat	Gujarat Plains and Hills agro-climatic zone	70	Common Crow, Glassy Tiger, Chocolate Pansy, Peacock Pansy, Common Rose (gujarattourism.com)
10.	Sammilan Shetty's Butterfly Park, Belvai	Beluvai, Karnataka	Northern Transitional Zone (KA-8)	100	Crimson rose, Blue Nawab (Kalleshwaraswamy, 2020)

Potential threats to butterflies and conservation of pollinator butterflies

Although it is well established that insects are essential to the health of ecosystems, insect biodiversity is under threat everywhere. Lepidopteran numbers have drastically decreased, which could result in the loss of forty percent of species in the coming decades (Sánchez-Bayo and Wyckhuys 2019). Minor changes in their habitat may lead to either migration or local extinction if the required attention is not given (Kunte, 1997) because many species require specific plants as food or sites for reproduction (Bernays, 1988). The degradation of insect habitat is the main danger that humans present to the survival of insects, especially populations of butterflies (New et. al., 1995). Anthropogenic changes are affecting butterflies through the loss of plant species that butterflies depend on and direct habitat loss due to the world's population growing at an accelerated rate (Hoyle and James, 2005). Moreover, butterflies are particularly sensitive to environmental changes (Stefanescu et. al., 2011), including the fast rise of industries, intense use of fertilizers and insecticides, climate change,

1 nitrogen pollution, mono-cropping, forest fires, fragmentation, and habitat degradation, all of
which make them vulnerable to extinction.

As butterflies are known to be flagship species for insect conservation (Tiple et. al.,
2 2005) any research aimed at conserving butterfly species will automatically save many other
species in the area. To protect this flagship group from further population, decline and
possible species extinction, studies investigating their diversity, habitat suitability and nectar
10 plant selection are needed. The study of the relationship between butterflies and host plants
1 has a significant impact on the conservation of not only butterfly species, but also the host
plants on which they depend, as well as the plants that depend on these butterflies for
pollination. Such information is necessary to develop effective conservation programs. Since
there is a positive correlation between the diversity of vegetation conditions and butterfly
1 diversity (Thomas, 1995) protecting and cultivating host plant species can help improve the
conservation of butterflies in their respective ecosystems (Swarnali et. al., 2019). Similarly,
1 diverse host plants, including cultivated species provide rich sources of nectar for butterflies
(Ramesh et. al., 2010).

2 Biodiversity decline will have direct and indirect effects on ecosystem functions and
2 services that are poorly quantified. Over the past decade, farmers in the Himalayan region
have been complaining about the decline in apple production and quality due to pollination
related problems. The general observation of farmers is that, in the past, there used to be a lot
of insects such as wild bees, butterflies and moths during the apple flowering season but now
they have all disappeared (Uma Partap and Tej Partap, 2001). To protect and maintain the
diversity of butterfly species, it is necessary to protect not only their primary habitats, but
1 also the surrounding semi-natural environment, which often consists mainly of plants and
shrubs (Shrestha et. al., 2020). Thus, both forests and seminatural habitats with help of local

stakeholders should be protected. Ecosystem restoration helps quickly restore insect communities that have typically declined over time (Nyafwono et. al., 2014).

Raising awareness about the importance of butterflies and other insects is essential. Proper recommendations must be generated for conservation of beneficial butterflies. Never capture a butterfly—let them fly freely. We should appreciate their beauty and inspire others to do the same. Schools should incorporate education on ecosystem and species conservation to instill a sense of responsibility from an early age. Supporting these insects' survival can be achieved by promoting organic farming, reducing the use of chemical pesticides and herbicides, adopting sustainable landscaping, and planting milkweed and other nectar-rich plants in gardens. Butterflies and other pollinators play a crucial role in maintaining ecosystems, and in turn, we depend on them for their invaluable contributions. Pollination is vital for food production and human well-being, linking wild ecosystems—where many animals find food and shelter—with agricultural systems. Without pollinators, numerous interconnected species and ecological processes would collapse (Das et. al., 2018).

In agroforestry systems, chemical free farming activities must be encouraged in order to protect beneficial pollinators. Diversifying crops can further support butterfly conservation by ensuring a continuous food supply. Establishing butterfly parks alongside agroforestry can not only generate additional income for farmers but also spread awareness about the importance of butterfly conservation.

Conclusion

In agroforestry systems, butterflies play a vital role as pollinators, contribute to improved crop production, pest control, genetic diversity, and improve the aesthetics of the environment. However, human activities and climate change are threatening their habitats, leading to a rapid decline in their populations. To counter this, greater emphasis must be placed on habitat conservation, sustainable land management, and the reduction of harmful pesticides. Protecting butterflies and other pollinators is crucial for maintaining food production, ecosystem balance, and economic stability. Ensuring their survival requires immediate action, public awareness, and policies that highlight their ecological and societal value. By prioritizing pollinator conservation, we can secure a healthier and more sustainable future for both nature and humanity.

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