International Journal of Recent Innovations in Academic Research
E-ISSN: 2635-3040; P-ISSN: 2659-1561
Homepage: https://www.ijriar.com/
Volume-9, Issue-4, October-December-2025: 242-254

Review Article

The Role of Insects in Agricultural and Natural Ecosystems–Overview

[a]Shobha Rani, A., [b]Siva Kumar, T., [a]Divyabharathi, M., [a]Shanthi Sree, K.S. and *[a]Savithri, G.

[a]Department of Biosciences and Sericulture, Sri Padmavati Mahila Visvavidyalayam (Women's University), Tirupati-517 502, Andhra Pradesh, India
[b]AP Model School and Jr. College, Settur, Anantapur, Andhra Pradesh, India
*Corresponding Author Email: gantasavithri@gmail.com

Received: October 28, 2025 **Accepted:** November 17, 2025 **Published:** November 23, 2025

Abstract
Insects, peerless biodiversity warriors on earth, play very important roles in our habitat. They are, so to speak, the labor force of nature, wherein they offer important functions like pollination, pest control, and decomposition. Although they are important, they have been neglected in biodiversity studies, particularly in the study of nutrient cycling and ecosystem processes. Although minuscule in size, these species play a huge role in the environment as providers, eliminators, and facilitators on numerous levels. The existence or lack of them dictates the future of plants and vertebrates, and that is where the conservation programs lie. When policymakers are formulating environmental management programs, they should be aware of the importance of insects in ensuring that the environment is balanced. Inclusion of their involvement in conservation and setting goals should be essential in protecting species and biodiversity. Besides playing an important role in ecological services, insects are becoming the future in innovative industries like biofuel production, biomedicine, and sustainable agriculture. They provide beneficial economic and environmental value through their assistance in feeding systems, handling organic waste, and increasing soil fertility. Their multifunctional importance must be appreciated to have comprehensive policies on conservation and sustainable development. The present review highlights the importance of conservation of insect biodiversity and the problems of using insects in agriculture.
Keywords: Insects, Preserving Species, Behaviour, Agriculture, Biodiversity and Environmental Balance.

Introduction

Insect natural history encompasses a great diversity of species and of behavior and ecological importance in the environment and agriculture. The opportunities of insects include numerous and varied opportunities for observation, collection, and photography. Nevertheless, although they are important, data gathered and analyzed by observations of insect natural history have been hard to collect and examine, thus limiting large-scale studies in this field. Standardized information systems and vocabularies are now being developed to enhance the aggregation and transmission of insect natural history data (Sánchez Herrera *et al.,* 2024).

Samplings like museum specimen collections give data on long-term trends of insect populations. Nevertheless, it is necessary to take into account some issues like spatial biases and temporal inadequacy. The insects have a great influence on the environment's structure as well as the dynamics of the environment at different trophic levels. These roles are important in the conservation and biodiversity of species in environmental management programs. Insects have been found to exist in a natural history spectrum between apparently simple behaviors and more complex tritrophic interactions. They have more diverse behavior and interaction than any other species. The taxonomy of insects has been established over the course of time, which has impacted our understanding of their relationships in the order of Hexapoda (Janousek *et al.,* 2023).

The relevance of insects in the sustainability of agriculture is high. They feed, provide food, and assist in the management of organic waste, as well as biological pest management. The use of insects in agriculture, however, poses a challenge of automation of the rearing systems, disease control, and insect care. To minimize the damage to crops and maximize yields, it is necessary to control the agricultural insects with the help of the landscape composition, enhancing the spatiotemporal isolation of the fields with host crops and restoring habitats (Csorba *et al.,* 2024). There are various environmental services insects render, among them being pollination, nutrient cycling, and the reduction of pests. But environmental stability and food security are threatened by the decrease in insect biomass and diversification brought about by agricultural activities and global warming. Insects interact with other animals in a number of ways, where they have mutualism, antagonism, and trophic relationships. Such interactions play an important role in the ecosystem. The insects affect the cyber cycles of nutrients within the ecosystem in varied ways, varying environmental conditions and stability. The possibility of insect-based protein, soil supplementation, medical applications, biofuels, gene editing, fertilizers, aquaponics, agroforestry, and pollination reveals the diversity of applications and potential of insects across numerous industries. Moreover, insects can be used as an indicator of the environment, through which it is possible to understand climate change, pollution levels, and degradation. They are sensitive to environmental changes and can be used to track environmental changes and in conservation planning. By providing entomological information in environmental evaluation, we can make more precise forecasts and manage the ecosystem in a more specific way. In contemporary agricultural lands, insects are not only considered agents of nature but also friendly companions of sustainable and regenerative food systems (Samways *et al.,* 2020).

Natural History of Insects

Several advantages of insects include insect natural history, which is the study of the diversity of insect species, their behaviors, and their role in the ecology. Due to their abundance and variety, insects provide unmatched opportunities to study, collect, and shoot. Nonetheless, the challenges of gathering and examining information on natural history observations of insects have slowed the conduct of large-scale studies in the field. Standardized vocabularies and ontologies of insect natural history information and stable information systems of its publication are being worked upon. Museum specimens may give information about long-term trends in the population of insects, though limitations, including spatial and chronological bias, have to be overcome. The insects play significant roles in the environment, as they are the providers of food, removers, and transporters in different trophic levels, which influence the structure and processes of the ecosystem (Gebreyes and Teka, 2025).

To preserve species and biodiversity, the environmental management plans should consider the contribution that the insects would make to the environment. The natural history of insects is very diverse and complex, both in terms of simple and complex tritrophic interactions. Insect natural history may be a challenging and thrilling subject to study because the assortment of their behavior and relationships is wider than in any other organism group. The classification of insects has gone through three periods: pre-Linnaean, Darwinian and Hennigian. These were the eras of our existing understanding of insect relations, and the Hexapoda is indicative of this.

The most significant role in eukaryote evolution belongs to bacterial symbiosis, and the presence of facultative symbionts in aphids is a life history and environmentally controlled phenomenon. Other than symbiotic relationships, insects have adaptive strategies like mimicry, camouflage, and pheromone signaling and all these have been important in their survival and reproduction. These plans bring out the evolutionary complexity of insects and the significance of behavioral study in the study of insect ecology. Such adaptation realizations can also be incorporated in biodiversity conservation as they would assist in setting up species' unique vulnerability to the disruption of the habitat and climatic changes. Insects have a significant role in the environment, where they are suppliers, eliminators, and facilitators at various trophic levels (Chapman, 2013).

They have effects on the composition, dynamics, and conservation of plants and animals. Insect diversity and distribution are improved nowadays with the use of modern research tools such as DNA barcoding and remote sensing. These technologies are transforming the manner in which researchers examine insect populations in ecosystems and provoke more specific conservation remedies and more inclusive ecological paradigms (Hebert *et al.,* 2003).

Insects in Agriculture

Insects may also play a vital role in improving the sustainability of agricultural activities in many ways. To begin with, they are an effective food and animal feed source that generates lower emissions of greenhouse gases, and the production necessitates less land than conventional livestock production. Second, insect farming is another form of food reuse since organic waste can be utilized to breed insect species that are detritivores. Alternative use of insects to provide a sustainable alternative to meat, which is also a source of protein, could solve some of the environmental and resource-related problems in contemporary farming.

Natural pest control is also essential, as insects play a significant role in the regulation of invasive plant and animal species that help in increasing the productivity of crops to facilitate food security and environmental conservation. To get the most out of the insects in sustainable farming, clear specifications of production, harvesting, post-harvesting, and consumption of insects are necessary. Intervention using technology, addressing consumer attitudes, and increasing the availability of the insect-based products are also critical in increasing their adoption (Lavelle *et al.,* 2006; Hancz *et al.,* 2024).

In addition to food and pest control, insects are directly involved in promoting soil health by bioturbation, or the promotion of soil structure and soil fertility through the transport of organic matter and organisms across bed layers. Their contact with positive fungi and bacteria in the rhizosphere enhances the growth and resistance of plants. Some insect species are also applied in precision agriculture. An example is the pollination drones and robots based on insect flying patterns, which are currently being developed to apply entomology to artificial intelligence to enhance agricultural efficiency. Furthermore, the incorporation of insect farming into the circular agriculture paradigms, in which the waste of one cycle becomes the input of another one, could change the way resources are utilized and recycled on the farm, particularly in the low-resource rural conditions (Floreano and Wood, 2016; Smetana *et al.,* 2019).

Insects: Problems with Using Insects in Agriculture

Agriculture has been the center of interest due to the increased desire to have sustainable agricultural practices and insects have emerged as the most appropriate in increasing food security, environmental safety, and containment of agricultural waste. The insects can also serve many functions in the agricultural sector such as natural pest management, organic feed, and a sustainable source of protein. Despite these advantages, the exploitation of insects in Indian agriculture has a number of challenges, which have hindered their exploitation and commercialization.

A) Regulatory and Policy Constraints: One of the most pressing problems is the lack of visibility of regulatory structures. India has no particular policies that control the production, processing and consumption of insects in the agricultural field and as cuisine. This uncertainty in regulation puts investors, businesspeople and farmers at a loss. The Food Safety and Standards Authority of India (FSSAI) lacks comprehensive principles on edible insect farming, which inhibits the emergence of the new business.

B) Cultural and Social Barriers: In India cultural norms and eating habits have a strong influence that is connected with the development of food consumption patterns. Nevertheless, insects are considered dirty or inedible by the majority of Indian communities, which is not true in some of the countries of Southeast Asia, where entomophagy (eating insects) is a common practice. The reason behind this is that insect-based food is not easy to sell to this culture, and it is difficult to promote insects as a source of viable protein or even use them as a crop input.

C) Deficiency in Awareness and Education: Indian farmers and consumers have not been aware of the use of insects in farming. Other insects such as ladybugs, parasitoid wasps and predatory beetles, can be employed as natural agents of pest control instead of using chemical pesticides. However, the challenge of introducing a positive practice in Indian farming activities due to the lack of awareness and training in the application of beneficial insects as integrated pest management (IPM) has curtailed Indian farmers.

D) Poor Infrastructure and Technology: Insect farming needs certain infrastructure to be established, including controlled breeding, temperature control, and sanitary processing facilities. These facilities are not readily available, and smallholder farmers, who are the bulk of the agricultural labor in India, are the ones who would benefit the most from them. Moreover, the technological expertise of rearing insects on a large scale is yet to be developed in the nation. Moreover, in the countryside, stable electricity and modern facilities are frequently unavailable, and it is hard to guarantee desirable conditions for insect rearing. The development of the insect-based agriculture sector will not be able to grow without specific investment in infrastructure (Parodi *et al.,* 2018).

E) Food Safety and Quality Concerns: The other issue of concern is the safety of insect-based products. Absence of standard practices in the hygiene storage as well as processing can result in contamination or health hazards. Consumer confidence requires and relies on the safety of foods to grow the use of insects in the agricultural and food industries. It is also difficult to combat quality and traceability across the whole supply chain since there are no registered laboratories to test insect products and the industry norms are also non-existent (Halloran *et al.,* 2018).

F) Weak Market and Supply Chains: India does not have a structured market or supply chain of insect farming at the moment. The companies producing and distributing insect-based products are extremely small in number, and the ones that can do it on a large scale are even fewer. This restricts the exposure to inputs and markets, which forms a barrier to new entrants.

G) Financial and Investment Problems: Insect farming is considered to be a niche industry in India, and therefore, it is hard to find investment. The startups and farmers have difficulties accessing credit (or government subsidies) because the industry is new, and the policy is not yet recognized. Moreover, the lack of successful case studies or projects that show proof of concept scares away venture capitalists and institutional investors. Financial obstacles can be overcome by creating awareness patterns with pilot programs and through public-private partnerships (Meyer-Rochow *et al.,* 2017).

H) Southern Contest with Well-Developed Traditions: Indian agriculture is dominated by traditional methods of pest control (using chemicals) and traditional animal farming. These well-established systems have to compete with insects and are commonly better known and more available to farmers. To beat the competition, it is essential to demonstrate the cost-effectiveness and the long-term advantages of insect-based solutions. Moreover, the existence of entrenched supply chains and subsidized inputs of chemicals offers an unequal playing field that disfavors insect-based alternatives. Policy reforms and incentives can be required to change the behavior of farmers. Although insects are considered to have an enormous potential in changing Indian agriculture to a more sustainable and resilient system, a series of obstacles needs to be overcome to achieve the potential. These involve setting up regulatory systems, increasing awareness among the populace, and investing in infrastructure and research, as well as incorporating insects into the current agriculture. India has the potential to use the power of insects to build a more sustainable future in agriculture, given the right assistance of policymakers, industry players, and academic institutions. Insect farming cooperatives at the grassroots level and training programs can enable farmers to embrace insect-driven solutions and make contributions to inclusive, climate-resilient agriculture (van Huis and Oonincx, 2017; Food and Agriculture Organization (FAO, 2021).

Insects Interact with Other Organisms in the Environment

Insects are some of the most varied and the richest living organisms on Earth. Their contact with other living organisms is crucial in balancing ecology. Such interactions may be mutualistic, predatory, parasitic, or competitive, and all the interactions are facilitative to the health and functioning of the environment. Pollination is one of the most fruitful associations. Flowers serve as food to insects such as bees, butterflies and beetles as they nourish themselves on nectar. The interrelationship aids in the reproduction of plants and their fruit and seed production. Fruits and vegetables are some of the crops that require insect pollinators because they are vital to food security in the world. The natural pests are also controlled by insects. Predatory insects like ladybugs and dragonflies eat destructive pests like aphids and mosquitoes. This reduces the use of chemical pesticides and promotes healthy agricultural practices. As well as some insects, e.g., parasitic wasps, lay eggs in or on pests. The larvae suck and consequently kill the host and this comes in handy to keep the population of pests down. Insects like termites and dung beetles also contribute to the recycling and breakdown of nutrients. These insects lead to the accumulation of the soil as they decompose dead plants and animals, which in the long run enriches the soil to the benefit of other living organisms like plants and soil microbes.

The insects also compete with each other and other species for resources such as space and food. In other cases, invasive species of insects can also disrupt the local ecosystem by competing with local species. As an indication, the extinction of local insect species and alteration of the food web landscape have occurred with the introduction of invasive beetles or ants into non-native habitats. This disruption can propagate across the ecosystem with effects on the survival of the birds as well as plant pollination rates and even the soil chemistry (Kenis *et al.,* 2009). Also, insects establish symbiotic associations with fungi, bacteria and plants facilitating nutrient acquisition and plant immunity. Beetles that have a mycorrhizal relationship and ant-plant mutualism are examples of that level of insect integration into ecosystem processes (Borer *et al.,* 2014). The knowledge of such ecological networks can assist in creating more resilient agricultural and forestry systems in which insects are not tolerated but are instead encouraged due to the services that they offer (Kremen *et al.,* 2007).

Benefits and Costs of Insects to the Environment

Insects are very important to the environment, as they help in generating an ecological balance as well as biodiversity. Nevertheless, even though most insects are very beneficial, some have detrimental effects on the environment, food production, and other human beings. One of the most beneficial insect benefits is pollination. Insects including bees, butterflies and beetles promote pollination of flowering plants, including most crops. This is a requirement in the production of plants and food on Earth. Even the insects are useful in the decomposition process; they also break down the dead plant and animal matter, which allows more nutrients to be drawn into the soil and they are also useful in the process of nutrient recycling. Furthermore, some insects are known to undertake the pest controller role since they feed on the destructive pests in the agricultural fields and do not require chemical pesticides. Insects are also a source of food to a large number of animals including birds, amphibians and mammals; therefore, insects play a vital role in the food chain. The insects have come into the limelight within the last few years as a source of protein that can be consumed by humans and as animal fodder (Cardinale *et al.,* 2012).

In spite of all these positive effects, there are also negative effects of insects. There are those species, like locusts, that can cause huge destruction to the crops, resulting in shortages of food and loss of money. Mosquitoes are the carriers of lethal diseases such as malaria and dengue fever, against which other insects, such as mosquitoes, are a significant threat to the health of people. The invasive insect species have the capability of upsetting local ecology by competing with or feeding on the local species. Insect-borne diseases are not just related to human beings but also to livestock and companion animals, with a wider economic impact and a wider health concern in the population. These risks can be mitigated by the incorporation of an integrated system of vector management and early warning (Gubler, 2002).

Moreover, there is the chance that when massively controlled honeybees are used as secondary pollinators, agricultural systems are also exposed to such diseases as colony collapse disorder. Enhancing pollinator diversity promotes ecological redundancy and ecological resilience. The insects are beneficial in the sequestration of carbon because they provide biodiversity and plant health and development and also pollination of the plants and recycling of nutrients. They are major contributors to the sustainability of wild plants in the forest and the grassland ecosystem. The promotion of the beneficial insects and the suppression of the harmful ones should be balanced between the sensitive science-based practices to comply with the local environmental and socio-economic requirements (vanEngelsdorp and Meixner, 2010; Sánchez-Bayo and Wyckhuys, 2019).

Cycling of Nutrients in the Environment

Nutrient cycling keeps the ecosystem healthy and balanced. These cycles describe the circulation and distribution of the fundamental elements, which are carbon, nitrogen, phosphorus and water in the atmosphere, soil, water and life. In the process of photosynthesis plants sequester carbon dioxide from the atmosphere to generate energy that is utilized to perform the necessary bodily processes. Animals feed on plants, and the carbon is transported through the food chain. When the remains are respired, decomposed and subjected to human activities such as the burning of fossil fuels, the carbon is released back to the atmosphere. The nitrogen cycle is the process that recycles nitrogen in the air on the earth, which is then brought out to bacteria that transform it into plant-useful forms. Animals get nitrogen by feeding on plants. As the organisms die, decomposers put nitrogen back into the soil and atmosphere. The phosphorus cycle begins with the breaking off of the rock, which releases phosphorus to the soil. It is absorbed through plants and passed on in the food chain. Phosphorus is not released to the atmosphere, unlike carbon and nitrogen; it remains in the soil and water. Decomposers: Bacteria, fungi and insects are also required because they decompose dead bodies and garbage and bring the nutrients back into the soil, which can be utilised again by the plants. Saprophagous beetles, termites and fly larvae are some of the insects that can be utilised to enhance the process of decomposition by breaking down the organic matter, exposing more surface to microorganisms and increasing the rate at which nutrients are released. The organic matter is transported up and down the soil by the ants and other burrowing insects, enhancing the nutrient and root availability. This circulation combined with aeration develops useful microbial communities. The excretions (frass) of insects have high amounts of nitrogen and phosphorus that are natural fertilizers and lead to improved growth of plants. The overall result of the nutrient cycle through insects is very fruitful in the ecosystem, especially in forests and agroecosystems (Brussaard, 2012; Yang and Gratton, 2014).

Biological Soil Enhancement

Insects play significant roles in enhancing the fertility of the soil and providing environmental services. The physical, chemical, and biological processes in soil are actively developed by the soil invertebrates, including insects. These organisms contribute to the self-organization of soil and environmental engineering at different scales. Invertebrates of soil, namely, earthworms, termites, springtails, and nematodes, are known to be important in the determination of the quality of soil and enhancement of soil health. They assist in the decomposition of complex organic matter, enhance aeration of soil, and also stimulate nutrient cycling. Moreover, insects may serve as biological control agents and, therefore, allow the management of pests in agricultural systems naturally. Both natural and farm environments have insects, and more importantly, insects offer important pollination services. All in all, insects can enhance the fertility of the soil and the future growth of healthy crops or trees that are healthy.

Collembolans and mites are examples of microarthropods that come in contact with the microbial communities within the rhizosphere; they regulate mineralization of nutrients and root development. These interactions between the microbes and insects contribute to dynamic soil food webs that are required in healthy interactions between plants and soils (Bardgett and van der Putten, 2014). Certain insects can also affect the pH and moisture levels of soils by nesting and foraging behavior, notably insects such as ants and beetles that change the microtopography of soils. The changes influence the rate of water infiltration and root zone conditions (Jouquet *et al.,* 2006). Also, insect activity helps in creating stable soil aggregates that enhance the structural integrity and resistance of the soil to erosion. The role is especially useful in dryland farming, where cohesion of soil is essential to the sustainability of productivity (Lavelle *et al.,* 1992).

Insect Farming for Medicinal Purposes

The use of insects as a source of medicine has potential in the future of insect farming, as insects and their bioactive compounds have therapeutic potential. In the past, insects were used in traditional medicine because of their healing, analgesic, antibacterial, and other health-promoting qualities. Their potential has been recognized as a potential source of novel medicinal products in the growing scientific interest in recent years. Studies have revealed that insect-derived products have the potential to have immunological, analgesic, antibacterial, and anti-rheumatic properties, which are useful in developing pharmaceuticals. Besides medicinal, insects can be sources of industrially useful compounds like fatty acids, peptides, enzymes and antimicrobial agents. To realize this potential, the identification and culture of insect strains with high levels of beneficial active compounds are a necessity. Insect farming ought to be intentional, and the emphasis of it must be on safety, nutritional value, and production efficiency. Insect farming has the potential to promote the design of novel therapeutic products along with providing food and nutritional security by discussing the medicinal values of insects and their products.

To illustrate, silkworms have been found to promise potential in the future recombinant protein production of vaccines, and bee venom is also under study as an anti-inflammatory agent in the treatment of arthritis and cancer. The applications are a sign of new enthusiasm in biotechnology, where insects are used as biofactories (Wang *et al.,* 2020). Moreover, antimicrobial peptides (AMPs) are found in some insect hemolymph (insect blood), which demonstrates a high degree of resistance to antibiotic-resistant bacteria, which is an encouraging prospect in the world against superbugs. This has seen it become excited to scale up AMP extraction with sustainable technologies of insect farming. Insect farming can be promoted to generate pharmacological products in cost-effective, ethically viable and environmentally sustainable amounts by integrating insect farming with biomedical research centres, especially in the nations that desire to bridge the gap between traditional and modern science (Dossey, 2010; Yi *et al.,* 2014).

Insect Biomass for Biofuel Production

Insect biomass can provide a new sustainable and innovative solution to biofuel, especially the transformation of organic waste into biodiesel. Some insects, like black soldier flies and fly larvae, can effectively decompose organic waste products as they build fatty biomass. This lipid can then be extracted and utilized in the production of biodiesel. More recent developments in the production of biodiesel and insects have been aimed at enhancing efficiency in yield, reducing costs of production, and minimizing environmental effects. The conversion of agricultural residues to useful products such as biodiesel, protein, and biofertilizers using insects such as the yellow mealworm and black soldier fly has been widely researched.

Black soldier flies have become especially promising as one of them. Their ability to make crop straws and other organic waste into insect protein and grease provides a multi-value solution, which will yield renewable energy and high-protein feed supplements and reduce waste simultaneously. The process is eco-friendly in many ways, and conversion is also cost-effective, so insect biomass can be regarded as a component of the future eco-friendly system of energy and agriculture. In addition, biofuels such as insect-based oils would reduce the use of fossil energy and reduce greenhouse gas emissions, which is compliant with the global climate targets. Lifecycle analysis reveals that insect biodiesel exhibits a smaller carbon footprint than plant or animal biodiesel. Insect biomass biorefineries are also capable of producing several co-products, such as glycerol, chitin, and compost, which increase the profitability of the system. This is value-added to the waste-to-energy concept and advances the concept of a circular economy in the agricultural areas (Makkar *et al.,* 2014; Surendra *et al.,* 2016). In Asia and Europe, pilot projects are showing that insect-derived energy systems, which are decentralized, have the potential to serve rural farms, leading to energy equity and local sustainability (Lähteenmäki-Uutela *et al.,* 2017).

Insect-Derived Fertilizers

Insect-based fertilisers are a new way to approach agricultural output. These methods apply agricultural waste to manufacture liquid ferment bacterium fertilisers that are insect-repelling. They are also rich in nutrients, they have a slow-release effect, and they enhance flower resistance. Compound microbial fertilisers provide crops with nutrients, thereby killing insects and plant diseases. The other form of fertiliser containing pesticides can offer important nutrient requirements to plants and serve as an insecticidal and bactericidal agent and bear greater resistance in plants. In addition, pesticide fertilisers not only kill insects and prevent diseases but also enhance the immunity of plants as well with a lot of microelements. One of the solutions for sustainable and environmentally friendly agriculture is insect-based fertiliser. Frass (insect excrement), a byproduct of insect farming, is also finding application as an organic soil enhancer. It contains a lot of nitrogen, phosphorus and useful microbes, which promote plant growth and enhance soil structure (Beesigamukama *et al.,* 2020).

Insect-derived inputs are biodegradable and enhance soil biodiversity with time in comparison to synthetic fertilisers; thus, they are considered to be ideal in organic farming systems. It has also been found that the use of insect frass can improve the growth of plant roots and their ability to withstand environmental stress (drought and salinity) because of the availability of chitin and secondary metabolites (Lalander *et al.,* 2019). These manure types provide two functions: not only feeding the plants but also providing a low-input, high-efficiency method of crop nutrition as mild biopesticides (Klammsteiner *et al.,* 2020).

Insect-Inclusive Agroforestry Practices

There are numerous ecological and economic advantages associated with the introduction of insects into agroforestry systems, such as food production, animal feeds, timber, medicine, pollination services, pest and weed control, soil formation, and soil enrichment. These heterogeneous systems create habitats that support the biodiversity of insects and ecological connectivity and reduce exposure to pesticides, particularly by the pollinators. Agroforestry also has the potential to increase the abundance and diversity of useful insect species, which will contribute to the natural regulation of pests and the reduction of chemical use.

Intercropping and landscape diversification are methods that improve the occurrence of natural enemies of crop pests and are applied to restore ecological balance. The Hymenoptera (bees, wasps and ants) and Orthoptera (grasshoppers and crickets) orders of hemipterids are both common and the insects are an essential component of the agroforestry ecosystems. In agroforestry, food crops that are grown in shade, e.g., coffee, cocoa, and spices, are more likely to encounter pollination by insects and insect control due to the stratified vegetation cover (Barragán-Fonseca *et al.,* 2022).

A higher diversity of predatory and pollinating insects is favoured by this complexity of habitat. Pollinator services throughout the year are also promoted by the introduction of insect-attracting native flowering plants and perennial legumes in agroforestry structures. The practices can increase and improve the yield of crops, quality of fruits and regeneration of soils in the long term (Perfecto and Vandermeer, 2008). Besides, the agroforestry systems that offer the ecosystem of decomposing insects, such as beetles and termites, accelerate the nutrients and organic matter turnover, and hence do not require the use of external soil amendments (Bhagwat *et al.,* 2008). The emergence of insect-inclusive agroforestry is linked with the promotion of ecological restoration alongside livelihood improvement especially for smallholder farmers participating in climate-smart farming (Mbow *et al.,* 2014).

Insects as Pollination Sources

Insects are extremely important as natural pollinators of ecosystems and agricultural systems. During feeding on nectar or pollen, species like bees, butterflies, beetles, flies, and wasps help to transfer pollen among flowers. This process is needed in the reproduction of most flowering plants as well as in the production of fruits, seeds, and vegetables. Insect pollination boosts crop yields and quality of food items in farming, and in that regard, has a significant contribution in advancing food security. The most effective and the most well-known pollinators are bees, both wild and domestic. Their maintenance as pollinators is paramount since their disappearance, with its attendant pollution of habitats, use of pesticides, and global warming, is a severe problem for biodiversity and agricultural productive areas. This invaluable service of nature can be preserved into the future by encouraging the insect-friendly practices.

Insects help in pollinating more than 75 percent of all species of crops in the world and others in the world like tomatoes, apples, and almonds among others, also rely on insect pollination. Without the appropriate insect pollination, most of these crops lose a lot of quantity and quality (Klein *et al.,* 2007). In addition to pollination crops, insects also maintain the genetic diversity of the wild plant species by cross-pollination, which enriches ecosystems and adds to the abundance of highly diversified fauna (Ollerton *et al.,* 2011). The new studies indicate that the insect pollinators, such as hoverflies and solitary bees, when underutilized, still play a great role in plant-pollinator networks and are potentially vital as honeybee populations are exposed to mounting stress (Rader *et al.,* 2016). There is now the incorporation of pollinator corridors, hedges, and pesticide-reduced zones in the agricultural landscape so that there are safe passageways for the pollinators and to promote ecological resilience (Dicks *et al.,* 2016).

Medical and Scientific Research

The significance of insects in medical and scientific studies lies in their unique biological characteristics and the variety of their applications. Application of insects in natural medicine is not an unfamiliar phenomenon and scientific research is already in progress to find out the possibilities of insects as a source of therapeutic agents. An example is bee venom, which contains peptides that have been encouraging in their utilization in targeting cancer cells and induction of apoptosis or a form of programmed cell death. An established medical approach has contributed to the awareness of the clinical importance of insects and is called maggot therapy, using fly larvae to clean and heal chronic wounds. Insects are direct tools as well as inspirational sources used in the creation of new treatment methods and medical devices in the field of biomedical engineering. The insects are also useful in the scientific world, particularly in the area of developmental and neural plasticity, where scientists are able to understand the behavior and brain activity changes over time.

The behavioral ecology of insects in the natural ecosystem provides a deeper analysis of the ecological mechanisms and evolution. The fruit flies (*Drosophila melanogaster*) have been a model organism in genetic research and have played a major part in the discovery of the role of mechanisms of inheritance, neurodegeneration, and aging. Their life cycle is short and they are fully sequenced; thus, they are best used in high-throughput studies. Other fields where insects have been used in forensic science are forensic entomology, blowflies, and insect development, which have been used to compute the time of death of a criminal at the scene. The application of chitin and chitosan in insect exoskeletons in the pharmaceutical industry is under exploration in the use of these compounds in wound dressings, drug delivery systems, and biodegradable surgical materials. In addition, insect robotics like micro-drones with dragonfly flight dynamics are transforming the design and emergency response technologies in the medical sector.

The significance of insects in medical and scientific studies is a result of their biological features and a variety of applications. Insects have traditionally been used in natural medicine, and the current research is examining their use as a source of therapeutic compounds. As an example, the bee venom contains peptides that have been demonstrated to target cancer cells and trigger the process of apoptosis, which is a cell death program. Maggot therapy is a long-established medical treatment where fly larvae are used to clean and treat non-healing wounds, emphasizing the clinical usefulness of insects. In biomedical engineering, insects have been used as direct materials and as inspiration for the invention of new treatments and medical devices.

Another area of insects is useful in the field of scientific exploration, especially in the area of developmental and neural plasticity, in which scientists can learn how behavior and brain function evolve. Taking a closer look at the behavior of insects in the natural ecosystem offers a more in-depth insight into the process of ecological interaction and evolutionary changes. Fruit flies (*Drosophila melanogaster*) are currently utilized as a model organism in genetic studies and have been at the center of the discovery of inheritance, neurodegeneration, and aging mechanisms. They are perfect in high-throughput studies because they have a very short life cycle and have a fully sequenced genome (Bellen *et al.,* 2010). Another application of insects in forensics is forensic entomology, which is a science that employs blowflies and their larvae to identify the death time of a victim in a crime (Byrd and Castner, 2009). The pharmaceutical industry is looking at chitin and chitosan isolated from insect exoskeletons as wound dressings, drug delivery and biodegradable surgical materials (Ravi Kumar *et al.,* 2000). Moreover, insect robotics including micro-drones, which have been designed using dragonfly flights and are transforming the medical device design and emergency response technologies (Sitti *et al.,* 2009).

Insects in Environmental Services in India

The insects in India have relevant roles in supplying environmental health and agricultural production in various ecosystem services. They also contribute significantly to soil fertility in that they help in the decomposition and recycling of nutrients because they break down organic matter in the soil to make the soil fertile. Pollination is another service provided by other insects, such as honeybees, butterflies and beetles, and helps to sustain biodiversity and increase the yield of many significant food crops, such as fruit crops, vegetable crops and oilseeds.

In India, biological pest control is especially important, where natural predators include ladybugs, parasitic wasps, predatory beetles and so on, to reduce the population of crop pests, which in turn may lower the application of chemical pesticides. This not only improves sustainable farming but also protects the environment and human health. The social insects like ants, termites and bees are extremely prevalent in the varied terrain and surroundings of India. They contribute to the aeration of soils and the decay of organic material and form mutualistic relations with vegetation that increase the ecological balance. Traditional Medicine: Insects add to their cultural and economic importance in being an important source of food in many indigenous cultures and play a role in traditional medicine. However, in India, there is pressure on the population of insects and the useful services they provide due to the high rate of urbanization, overuse of pesticides, habitat loss, and climate change. In a bid to preserve such benefits, research, conservation, and encouraging insect-friendly farming and environmental activities are increasingly demanded.

The recent campaigns like the National Pollinator Conservation Strategy and farmer-led Integrated Pest Management schemes indicate increasing awareness of the benefits of insect services in the Indian agroecological zones. There is also the participation of non-governmental organizations and research institutions in field-based research to track pollinator health, recreation of insect habitat, and educating farming communities about the importance of insects in maintaining ecosystems (Ministry of Environment, Forest and Climate Change (MoEFCC, 2018; Chandran *et al.,* 2021). Insect conservation should be implemented in the biodiversity action plans of India in order to close the divide between traditional ecological knowledge and the new environmental policy to ensure that insects continue to be important partners in climate-resistant agriculture and rural livelihoods (Bawa *et al.,* 2020).

Insects and Soil Aeration in Agriculture

Insects are one of the main helpers in nature to have healthy soil through soil aeration. Some insects inhabit the soil, such as ants, termites, beetle larvae and earthworms (but they are not insects; they are usually considered soil fauna) that dig tunnels in the soil. They provide avenues and holes through which air, water, and foodstuffs trickle into the soil through their activities. Therefore, not only are the aerated soils better structured, but the roots are also provided with more space to expand, and the soil-dwelling microbes that are helpful to the plants and sequester their food are also further energized. The improved soil aeration also helps in waterlogging prevention, and better drainage is promoted. By making sure that soil aeration is always at its best, insects are also the main contributors to increased agricultural productivity and sustainable farming practices.

Insects like dung beetles are not only the most important players in the cycle of nutrients in nature, but at the same time, they are helping to break down the toughest soils by burying the organic matter. The tillage that this natural way does to the soil cuts down the demand for mechanical soil disturbance; thus, the soil is kept intact. Further, the complex systems of tunnels that the ant colonies construct not only enrich the soil in dry and semi-arid areas, but they also increase moisture retention and infiltration. Gases are also easily exchanged in the air between plant roots and the atmosphere through aeration, and this is very crucial not only to the respiration of roots but also to the activity of microbes. The interaction nourishes the root areas and makes crops stronger in facing abiotic stresses (Folgarait *et al.,* 1998; Scholtz *et al.,* 2009). Supporting insects by less pesticide use, cover cropping, and organic mulching can greatly help to have the aeration benefits at their maximum level in both conventional and regenerative agricultural systems (Kremen and Miles, 2012).

Conclusion

Finally, the review paper places a great emphasis on the idea that insects cannot be neglected in terms of ensuring the equilibrium in the ecosystem and are instrumental in supporting biodiversity, enhancing human welfare by providing services related to the pollination of plants, pest control, soil health and nutrient cycling. The ecological significance of them covers basic services to both natural and agricultural ecosystems and new functions in emerging industries, including biofuel, medicine and sustainable agriculture. Although insects play a very crucial role, they are also endangered by environmental change and a lack of inclusive research in scientific fields, which requires timely conservation and policy to protect insect populations. Integration of insects in the management of ecosystems and agricultural undertakings will be pivotal towards food security, soil fertility, waste management and general stability of environmental systems. Realising that they are multifaceted and what is needed is that they can be encountered by bringing in more creative, sustainable and inclusive solutions to conservation and development in the world.

Declarations

Acknowledgments: The authors gratefully acknowledge the contributions of previous researchers whose studies formed the foundation of this review.

Author Contributions: SRA: Concept, design, literature survey, drafting manuscript; SKT: Data collection submission of article; DM: Literature survey, manuscript preparation; SSKS: Data acquisition; SG: Concept, design, correction of manuscript and supervision.

Conflict of Interest: The authors declare that is there is no conflict of interest.

Consent to Publish: All authors agree to publish the paper in International Journal of Recent Innovations in Academic Research.

Data Availability Statement: Data are contained within the article.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Research Content: The research content of this manuscript is original and has not been published elsewhere.

References

1. Bardgett, R.D. and van der Putten, W.H. 2014. Belowground biodiversity and ecosystem functioning. Nature, 515(7528): 505-511.
2. Barragán-Fonseca, K.B., Dicke, M. and van Loon, J.J.A. 2022. Use of black soldier fly larvae and their byproducts in agriculture: Prospects and challenges. Agronomy, 12(1): 103.
3. Bawa, K.S., Rai, N.D. and Setty, R.S. 2020. Conserving biodiversity in India: The role of traditional knowledge. Current Science, 118(1): 75–80.
4. Beesigamukama, D., Mochoge, B., Korir, N.K., et al. 2020. Exploring black soldier fly frass as novel fertilizer for improved growth, yield, and nitrogen use efficiency of maize under field conditions. Frontiers in Plant Science, 11: 574592.
5. Bellen, H.J., Tong, C. and Tsuda, H. 2010. 100 years of Drosophila research and its impact on vertebrate neuroscience: A history lesson for the future. Nature Reviews Neuroscience, 11(7): 514-522.
6. Bhagwat, S.A., Willis, K.J., Birks, H.J.B. and Whittaker, R.J. 2008. Agroforestry: A refuge for tropical biodiversity? Trends in Ecology and Evolution, 23(5): 261–267.
7. Borer, E.T., Seabloom, E.W., Mitchell, C.E. and Power, A.G. 2014. Local context drives infection of grasses by pathogen communities. Ecology Letters, 17(6): 752–761.
8. Brussaard, L. 2012. Ecosystem services provided by the soil biota. In: Wall, D.H., (Ed.), Soil ecology and ecosystem services (pp. 263–284). Oxford University Press.
9. Byrd, J.H. and Castner, J.L. 2009. Forensic entomology: The utility of arthropods in legal investigations. CRC Press.
10. Cardinale, B.J., Duffy, J.E., Gonzalez, A., et al. 2012. Biodiversity loss and its impact on humanity. Nature, 486(7401): 59–67.
11. Chandran, MD.S., Krishnan, R. and Shrestha, A. 2021. Protecting pollinators in South Asia: Local innovations and policy pathways. Indian Journal of Ecology, 48(1): 12–21.
12. Chapman, A.D. 2013. Numbers of living species in Australia and the world (2nd Edition). Australian Biodiversity Information Services.
13. Csorba, A.B., Dinescu, S., Pircalabioru, G.G., Fora, C.G., Bálint, J., Loxdale, H.D. and Balog, A. 2024. Aphid adaptation in a changing environment through their bacterial endosymbionts: An overview, including a new major cereal pest (*Rhopalosiphum maidis* (Fitch) scenario. Symbiosis, 93(2): 139-152.

14. Dicks, L.V., Viana, B., Bommarco, R., Brosi, B., et al. 2016. Ten policies for pollinators. Science, 354(6315): 975-976.

15. Dossey, A.T. 2010. Insects and their chemical weaponry: New potential for drug discovery. Natural Product Reports, 27(12): 1737-1757.

16. Floreano, D. and Wood, R.J. 2015. Science, technology and the future of small autonomous drones. Nature, 521(7553): 460-466

17. Folgarait, P.J. 1998. Ant biodiversity and its relationship to ecosystem functioning: A review. Biodiversity and Conservation, 7(9): 1221-1244.

18. Food and Agriculture Organization of the United Nations. 2021. Guidance on sustainable insect farming: Practices for rural development. FAO: Rome.

19. Gebreyes, B.G. and Teka, T.A. 2025. The environmental and ecological benefits of edible insects: A review. Food Science and Nutrition, 13(6): e70459. Erratum in Food Science and Nutrition, 13(8): e70753.

20. Gubler, D.J. 2002. The global emergence/resurgence of arboviral diseases as public health problems. Archives of Medical Research, 33(4): 330-342.

21. Halloran, A., Roos, N., Flore, R. and Vantomme, P. 2018. Edible insects in sustainable food systems. Springer.

22. Hancz, C., Sultana, S., Nagy, Z. and Biró, J. 2024. The role of insects in sustainable animal feed production for environmentally friendly agriculture: A review. Animals, 14(7): 1009.

23. Hebert, P.D., Ratnasingham, S. and de Waard, J.R. 2003. Barcoding animal life: Cytochrome c oxidase subunit 1 divergences among closely related species. Proceedings of the Royal Society of London. Series B: Biological Sciences, 270(Suppl_1): S96-S99.

24. Janousek, W.M., Douglas, M.R., Cannings, S., Clément, M.A., et al. 2023. Recent and future declines of a historically widespread pollinator linked to climate, land cover, and pesticides. Proceedings of the National Academy of Sciences of the United States of America, 120(5): e2211223120.

25. Jouquet, P., Dauber, J., Lagerlöf, J., Lavelle, P. and Lepage, M. 2006. Soil invertebrates as ecosystem engineers: Intended and accidental effects on soil and feedback loops. Applied Soil Ecology, 32(2): 153-164.

26. Kenis, M., Auger-Rozenberg, M.A., Roques, A., Timms, L., et al. 2009. Ecological effects of invasive alien insects. Biological Invasions, 11(1): 21-45.

27. Klammsteiner, T., Turan, V., Fernández-Delgado Juárez, M., Oberegger, S. and Insam, H. 2020. Suitability of black soldier fly frass as soil amendment and implication for organic waste hygienization. Agronomy, 10(10): 1578.

28. Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C. and Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences, 274(1608): 303-313.

29. Kremen, C. and Miles, A. 2012. Ecosystem services in biologically diversified versus conventional farming systems: Benefits, externalities, and trade-offs. Ecology and Society, 17(4): 40.

30. Kremen, C., Williams, N.M. and Thorp, R.W. 2007. Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Sciences, 104(31): 14718–14723.

31. Lähteenmäki-Uutela, A., Marimuthu, S.B. and Meijer, N. 2017. Insects as food and feed: Laws of the European Union, United States, Canada, Australia, and India. European Food and Feed Law Review, 12(1): 22–36.

32. Lalander, C., Diener, S., Zurbrügg, C. and Vinnerås, B. 2019. Effects of feedstock on larval development and process efficiency in waste treatment with black soldier fly (*Hermetia illucens*). Journal of Cleaner Production, 208: 211-219.

33. Lavelle, P., Blanchart, E., Martin, A., Spain, A.V. and Martin, S. 1992. Impact of soil fauna on the properties of soils in the humid tropics. Myths and Science of Soils of the Tropics, 29: 157-185.

34. Lavelle, P., Decaëns, T., Aubert, M., Barot, S., Blouin, M., et al. 2006. Soil invertebrates and ecosystem services. European Journal of Soil Biology, 42: S3-S15.

35. Makkar, H.P., Tran, G., Heuzé, V. and Ankers, P. 2014. State-of-the-art on use of insects as animal feed. Animal Feed Science and Technology, 197: 1-33.

36. Mbow, C., van Noordwijk, M., Prabhu, R. and Simons, T. 2014. Knowledge gaps and research needs concerning agroforestry's contribution to sustainable development goals in Africa. Current Opinion in Environmental Sustainability, 6: 162-170.

37. Meyer-Rochow, V.B. 2017. Edible insects in a changing world. Journal of Insects as Food and Feed, 3(2): 93–102.

38. Ministry of Environment, Forest and Climate Change (MoEFCC). 2018. National pollinator conservation strategy for India. Government of India. https://moef.gov.in

39. Ollerton, J., Winfree, R. and Tarrant, S. 2011. How many flowering plants are pollinated by animals? Oikos, 120(3): 321-326.

40. Parodi, A., Coderoni, S., Paci, G. and Ricci, A. 2018. The potential of insect farming to contribute to sustainable food systems: A review. Global Food Security, 17: 605–614.

41. Perfecto, I. and Vandermeer, J. 2008. Biodiversity conservation in tropical agroecosystems: A new conservation paradigm. Annals of the New York Academy of Sciences, 1134(1): 173-200.

42. Rader, R., Bartomeus, I., Garibaldi, L.A., et al. 2016. Non-bee insects are important contributors to global crop pollination. Proceedings of the National Academy of Sciences, 113(1): 146-151.

43. Ravi Kumar, M.N.V. 2000. A review of chitin and chitosan applications. Reactive and Functional Polymers, 46(1): 1–27.

44. Samways, M.J., Barton, P.S., Birkhofer, K., Chichorro, F., et al. 2020. Solutions for humanity on how to conserve insects. Biological Conservation, 242: 108427.

45. Sánchez Herrera, M., Forero, D., Calor, A.R., Romero, G.Q., et al. 2024. Systematic challenges and opportunities in insect monitoring: a Global South perspective. Philosophical Transactions of the Royal Society B, 379(1904): 20230102.

46. Sánchez-Bayo, F. and Wyckhuys, K.A.G. 2019. Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation, 232: 8-27.

47. Scholtz, C.H., Chown, S.L. and Johnson, S.D. 2009. Ecology and evolution of dung beetles. Pensoft Publishers.

48. Sitti, M. 2009. Miniature devices: Voyage of the microrobots. Nature, 458(7242): 1121–1122.

49. Smetana, S., Schmitt, E. and Mathys, A. 2019. Sustainable use of *Hermetia illucens* insect biomass for feed and food: Attributional and consequential life cycle assessment. Resources, Conservation and Recycling, 144: 285-296.

50. Surendra, K.C., Olivier, R., Tomberlin, J.K., Jha, R. and Khanal, S.K. 2016. Bioconversion of organic wastes into biodiesel and animal feed via insect farming. Renewable Energy, 98: 197-202.

51. van Huis, A. and Oonincx, D.G.A.B. 2017. The environmental sustainability of insects as food and feed: A review. Agronomy for Sustainable Development, 37: 43.

52. vanEngelsdorp, D. and Meixner, M.D. 2010. A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them. Journal of Invertebrate Pathology, 103: S80–S95.

53. Wang, Y., Zhang, Y., Zhang, R. and Liu, Y. 2020. Silkworms as bioreactors for producing recombinant proteins. Biotechnology Advances, 43: 107572

54. Yang, L.H. and Gratton, C. 2014. Insects as drivers of ecosystem processes. Current Opinion in Insect Science, 2: 26-32.

55. Yi, H.Y., Chowdhury, M., Huang, Y.D. and Yu, X.Q. 2014. Insect antimicrobial peptides and their applications. Applied Microbiology and Biotechnology, 98(13): 5807-5822.

Citation: Shobha Rani, A., Siva Kumar, T., Divyabharathi, M., Shanthi Sree, K.S. and Savithri, G. 2025. The Role of Insects in Agricultural and Natural Ecosystems–Overview. International Journal of Recent Innovations in Academic Research, 9(4): 242-254.