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Impacts of Organic Farming on Insects Abundance and Diversity

Hamadttu Abdel Farag El-Shafie

Abstract

Organic farming encourages maximum utilization of the natural biological processes to manage the farm in terms of soil fertilization and pest control, which implies using none or less synthetic fertilizers, pesticides, and plant and animal growth-promoting substances. All these practices increase arthropod diversity, particularly soil-dwelling insects. Intercropping, cover crops, and hedges, which are common practices in organic fields, provide alternative habitats for arthropod communities. The refugia also provide a good source of food for pollinators in terms of pollen grains and nectar. The interactions among the different plant and animal taxa (weeds, birds, mammals) that are found in the organic farming ecosystem have a great impact on insects' abundance and diversity. This chapter summarizes the impacts of the organic farming system on the abundance and diversity of insects. The role of organic farming in mitigating the impact of agriculture intensification, urbanization, deforestation, and climate change on global insects' decline and diversity loss is discussed.

Keywords: insect biomass, biodiversity, ecosystem, organic farming, insect decline, landscape heterogeneity

1. Introduction

Compared with vertebrates, insects had not been given much more attention with respect to loss of diversity and conservation [1]. Recently, entomologists in Krefeld city in Germany published an article reporting a 76% decline in insects' biomass in a study that extended over 27 years [2]. This study "Krefeld study" has sparked a lot of global discussion among insect scientists as well as in the public media. Alarming terminologies were used to describe the event such as ecological Armageddon, insect Armageddon, insect defaunation, insect apocalypse, and insect decline in the Anthropocene. The Krefeld study has become connected with global insect decline as "silent spring" is connected with the negative impact of pesticides. Another study conducted by Lister and Garcia [3] in Mexico in rainforest over 36 years reported a decline of 98 and 78% for epigeal and canopy-dwelling arthropods, respectively. Sánchez-Bayo and Wyckhuys [4] performed a meta-analysis on 73 reports on insect decline all over the world and reported a drastic decline that may lead to the total loss of 40% of the world's insect species. These alarming indicators of global insect decline led many researchers to try to find the causes and the consequent impact of this decline on the ecosystems. The main causes of insect decline appear to be habitat loss, conversion to intensive agriculture, urbanization, invasive species, climate change, and pollution by synthetic pesticides and

fertilizers [4, 5]. Of the abovementioned possible causes, agricultural intensification and habitat loss are the main causes of global insect decline [2, 6–8]. Habitat losses are mainly through the removal of forest covers, urban expansion, light pollution, and industrialization, which is responsible for polluting terrestrial and aquatic environments of arthropods [5]. The overall impacts of global insect decline on the proper functioning of the ecosystem could be easily manifested through the decrease in the services that the ecosystem provides in terms of pollination, trophic interaction, and nutrient recycling [9]. Maintenance of insect habitats, cut in synthetic pesticide use [10], and organic farming [11, 12] are probably the most effective means to stop a further decline of insects and promote recovery of biodiversity. This chapter aims to summarize the possible causes of global insect decline, the impact on ecosystem services, and measures to alleviate it with emphasis on the organic farming system.

2. Role of insects in the ecosystems

The total number of insect species in the world is estimated to be about 1 million with approximately 4.5–7 million remaining to be identified and named [13]. Insects performed three natural processes, which are essential for the proper functioning of the ecosystem. These are pollination of fruit blossoms, decomposition of organic matter into humus, and natural pest regulation (**Figure 1**) [3, 14, 15].

Insects represent a major source in the food web particularly for birds, reptiles, amphibians, and fish, which represent higher trophic levels. Other invaluable ecosystem services provided by insects include pollination of more than 75% of crops and wild plants [16], waste disposal and nutrient cycling, provision of high-value products such as honey, silk, venom, and shellac. Insects also provide a source of protein for domestic animals and humans (entomophagy) [7, 15]. In the United States alone, the annual ecosystem services provided by wild pollinators were estimated at \$57 billion (**Figure 2**) [17]. The relationship between the diversity of pollinators and plants in an area is reciprocal. An unbalanced diversity of pollinators may lead to unbalanced plant diversity due to certain plants being selectively pollinated. Thus, the diversity of wild bees strongly influences the diversity of weeds

Figure 1.
Main ecosystem services provided by insects to maintain resilience, sustainability, and proper functioning.

Figure 2.
Bees and butterflies have a significant role in the ecosystem as pollinators.

and *vice versa* [18]. It is worth mentioning here that Garibaldi et al. [19] reported that the conservation of bees' diversity is essential for ecosystem biodiversity. Other pollinators, which are important but overlooked, include hoverflies (Syrphidae). They perform different ecological functions such as pollination of a wide range of plants, controlling insect pests as biocontrol agents, and being used as bioindicators for monitoring the ecosystem's functioning.

Insects are the *sine qua non* for proper functioning ecosystems that also provide intangible services such as collection for recreational and esthetic values [15, 20]. Understanding the significant role of insects in the well-being of the planet by the public will greatly help in the adoption of mitigating measures that at least decrease the rate of decline of this group of animals. In this respect, increasing the awareness of people about the significant ecological role of insects as pollinators, prey, and nutrient recyclers could be achieved through community (citizen) science and other extension media [15].

3. Possible causes of global insect decline and its impact on ecosystems

Destruction of insect habitat, agricultural intensification, urbanization, invasive species, agro-chemical pollution, and climate warming are the main causes of global insect declines and loss of biodiversity [4, 14, 21]. Climate warming is important in the tropics; however, it may have a limited impact on the number of species in temperate regions [4]. Agricultural intensification, urbanization, deforestation, and pesticide pollution account for about 78.7% of the decline causes, while other drivers such as invasive species, climate warming, and other pollutants account collectively for only 21.3% [4]. Destruction of insect habitat is one of the important anthropogenic activities, which is responsible for biodiversity loss (Figure 3) [4].

Pesticide use is considered an important cause of global insect decline and biodiversity loss [22]. Consequently, insect decline indirectly influences vertebrate predators [22]. Herbicides, which are extensively used in conventional agriculture largely, eliminate weeds and wild plants, which provide a source of food and shelter for arthropods, both pests and their natural enemies. Changes in insect biomass are more relevant for the ecological functioning of the ecosystem [2].

Figure 3.

A feral colony of the dwarf honeybees, *Apis florea* on a newly cut branch of the button mangrove, *Conocarpus erectus* L. (type of habitat destruction).

A seasonal decline of 76% of the flying insect biomass was reported to have occurred in Germany during 27-year study of continuous insect monitoring using Malaise trap [2].

Aquatic invertebrates including crustaceans, mayflies, caddisflies, and dragonflies are very much affected by pyrethroid insecticides. Neonicotinoids, on the other hand, affect pollinators including honeybees and bumblebees, particularly when used as a post-bloom spray on perennial trees and field crops.

Industrial pollution is among the important causes of global insect decline, and the fertilizer industry may account for 10% [4]. Light pollution can lead to the luring of moths to bulbs, and make insects fall prey to lizards, toads, birds, and other predators. This negatively affects insects that use their own body-produced light as signals for mating as in the case with fireflies. Mercury vapor, metal halide, and compact fluorescent bulbs induce a more negative impact on moths (sensitive to artificial light at night) than LED and sodium lamps [23]. However, the effect of artificial light on insect populations and declines remains to be elucidated. In their assessment of the drivers causing global insect decline, Sánchez-Bayo and Wyckhuys [4] reported that *Lepidoptera*, *Hymenoptera*, and *Coleoptera* (dung beetles) in terrestrial ecosystems and *Odonata*, *Plecoptera*, *Trichoptera*, and *Ephemeroptera* from aquatic taxa were more affected.

Insect biomass has been used as a proxy for measuring the biodiversity of insects; however, this index has its limitations [24]. Instead, they recommended robust measures of biodiversity trends based on metrics including traits-based phylogeny according to spatial and temporal changes. Additionally, Didham et al.

[25] emphasized the inclusion of data from long-term studies and diversity metrics in the measurement of insect decline. To reach a consensus on the global decline of insects, more long-term studies of biomass, abundance, and biodiversity are needed [26]. In tropic and subtropics, where the majority of insect diversities exist, there are few or no records of long-term data and checklists for most of the species as the case in a temperate region. Thus, many of the species may go extinct in the tropics without being noticed and in most cases before being identified and named. Due to the abovementioned reasons, the impact of global insect decline on the proper functioning of the ecosystem is yet to be quantified [27]. Therefore, long studies and compilation of records and checklists are urgently needed in the tropics and subtropics.

4. Differences between conventional and organic farming systems

In the organic farming system, natural biological processes such as the activities of soil microorganisms, nutrient cycling, and biocontrol agents are used in pest management to keep pest populations below the level that cause economic damage. On the other hand, tillage and cultivation practices are used to manage soil fertility and crop nutrients [28–31]. This is contrary to what happens in conventional farms, where synthetic chemicals including fertilizers, insecticides, and herbicides are commonly used in pest management. Pest management in organic farms is carried out by using mainly botanical and microbial pesticides that are either harmless or with a little adverse effect on the agroecosystem. Other options of pest control include crop rotation, mechanical cultivation, mulching, and flaming. Due to the use of benign pesticides and other environmentally friendly pest management measures, organic farms have a high diversity of arthropod species, on average, than conventional farms [30]. Organic agroecosystems differ from conventional ones by greater insect diversity [32], as indicated by the relevant indices, as well as the diversity of taxa and the number of individuals [12]. The largest number of phytophages was recorded in the organic fields of winter wheat, but in organic ecotones and adjacent protective forest shelterbelts, compared with the conventional ones, there were a larger share of predators and parasites. The similarity of organic field ecosystems and conventional forest belt by the Sørensen coefficient indicates the migration of phytophages from conventional fields to adjacent areas [11].

5. Impact of organic farming on faunal and floral biodiversity

Biodiversity encompasses different levels including species diversity, genetic diversity, and habitat and ecosystem diversity. It is essential for proper ecosystem functioning and critical processes such as pollination, reduction in soil erosion on arable land, decomposition of dung in pastures, and natural pest reduction in soil and on crops. Biodiversity is also essential for the stability and resilience of ecosystems [24, 33].

Species richness is higher in organic agriculture and pastures than conventional ones because chemical veterinary drugs do not contaminate them. Dung beetles provide an essential ecological function by degradation and recycling of dung, which add to soil fertility and quality in natural or organic pastures (**Figure 4**).

Dung beetles encompass three groups; the rollers (Scarabaeidae), tunneller (Geotrupidae and Scarabaeidae), and dwellers (Aphodiidae) [4]. Organic farming increases the richness and abundance of insects as compared with conventional farming. The number of insect orders, families, and individuals is greater under

Figure 4.
A sacred dung beetle contributing to the recycling of nutrients in pasturelands.

organic farming. This is supported by the meta-analysis of several published studies on the topic [6, 12, 34]. Moreover, biodiversity indices such as Shannon, Menhinick, Margalef, Berger-Parker, and Piclou confirmed the greater diversity of insects in the organic field of winter wheat. The number of predators and parasitoids was more than double in organic ecotones and forest shelters [11]. Insect species richness and abundance in organic farming were found to be 22 and 36% higher than conventional farming. Likewise, the species richness and abundance for spiders were 15 and 55%, respectively higher compared with conventional farming [12]. Organic farms provide alternative habitats for predator and parasitoid communities through hedges, which represent refugia and source of food (pollen and nectar) for the adults of many insect species (**Figure 5**). Marshall et al.

Figure 5.
Hedges around organic farms provide refugia for predators and parasitoids.

[35] confirmed this and indicated that many species of arable weeds support a large variety of insect species.

Schmidt et al. [36] reported higher spiders' densities of about 62% in organic farms than conventional farms. They also highlighted the impact of landscape diversification, which is common in organic farming on parasitoid wasps, ladybird beetles, and ground beetles.

6. The main practices on organic farms that promote higher insect biodiversity

Conventional, seminatural or organic and landscapes surrounding the farms as well as the farm size greatly influence the conservation of biodiversity [6]. The practices and crop husbandry measures in organic farms that influence biodiversity include no use of herbicides, forbidden of synthetic chemical pesticides, use of pure organic fertilizers, rotation with a leguminous crop, and heterogeneous farm structure [37]. All these practices increase arthropod diversity, particularly soil-dwelling insects. The organic farming system encourages natural processes such as decomposition of organic, usage of livestock dungs, and compost in which several species of insects can thrive. Saprophagous insects such as springtails (*Collembolla*) flourish well in organic farms than conventional ones. The use of cover crop mulching to increase soil fertility, maintain temperature, and conserve moisture enhances the presence of insects. Soil disturbance is to the minimum in organic farming; thus, soil microorganisms and arthropods can thrive well. In an organic farming system, the use of predators and parasitoids together with botanical or natural microbial insecticides has no deleterious effect on the arthropod communities. Honeybees, wild bees, and bumblebees were reported to have exploited the diversity of different flora in organic fields. Diversity of weeds, trees, and shrubs as well as hedges in organic farms encourages visitation of bees and other generalist pollinators [38].

7. Conclusions

The analysis of data on insect biodiversity revealed that organic farming strongly encourages the abundance and biodiversity of insects. Monitoring global insect decline based on biomass as the sole metric is not enough. Most of the studies on biodiversity were carried out in the temperate region, where long-term data exist. A few studies are available in tropical and subtropical regions where the majority of insects exist; therefore, no available data upon which trends of insect decline can be traced. Using robust methodology for monitoring decline in abundance and biodiversity as well as long-term studies, data are needed to reach a consensus on the main drivers of this decline. Organic farming and landscape heterogeneity can be adopted as farming systems that alleviate the loss of insects' biodiversity and decrease the rate of global insect decline.

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