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Review Article

Beetles (Coleoptera) in agricultural landscapes: contribution, challenges and conservation

Iqra Bibi, Iman Zafar, Muhammad Sikander, Sana Fatima, Syeda Ambreen Fatima, Humna Farooq, Iram Asad, Salwa Anoosh, Rabia Afzal, Sheeza Sakhawat, Aniza Iftikhar, Suleman Hussain Shah, Mubashar Hussain
Department of Zoology, The University of Gujrat, Punjab, Pakistan.

ABSTRACT

Agricultural landscape refers to the areas of land that are primarily used for agricultural activities and farming. Beetles (Order: Coleoptera) are one of the most diverse and ecologically important groups inhabiting agrarian landscapes. Coleoptera represents about 200 recognized families and 400,000 described species. Diverse feeding habits such as herbivory, predation, scavenging, decomposition, fungivory, and parasitism enable them to occupy a wide range of habitats and reduce competition. Consequently, contribute immensely to agricultural landscapes by providing numerous ecological services like pest control, pollination, decomposition and nutrient cycling, soil aeration and structure improvement, seed dispersal, fungal spore dispersal, nutrient recycling, habitat engineering (e.g., dung burial), and serving as food for other wildlife. Habitat loss and fragmentation, use of pesticides, agricultural intensification, soil disturbance, loss of floral resources and shelter, climate change, invasive species, light pollution and noise, overgrazing and land degradation, lack of awareness and conservation efforts are key challenges to the diversity of beetles in agroecosystems. Conservation of beetle populations requires integrated approaches, including preserving natural habitats, implementing agro ecological practices, and reducing chemical inputs. This review highlights the ecological functions of beetles in agroecosystems, examines their threats, and discusses strategies to promote their conservation, emphasizing their importance in fostering resilient and productive agricultural systems.

Keywords: Insect conservation; beetles; management; biodiversity; coleoptera; ecological roles.

Correspondence
Iqra Bibi
iqrasharif27@gmail.com

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INTRODUCTION

Overview of Their Diversity and Roles

The researchers estimate the diversity of insects to range from 5.5 to 7 million taxa (Stork, 2018). Class Insecta, with 1.070 million (over 80% of all arthropods) described species, is the most successful group of arthropods and animals (Zhang, 2013). The order Coleoptera (beetles and weevils) is the largest taxon, comprising about 400,000 described species that inhabit the entire accessible terrestrial environment (Zhang, 2011).

Importance of Coleoptera in Agroecosystems

The agricultural lands benefit from beetles that fulfil pollination, decompose organic matter, serve as predators, herbivores, and help to maintain crop cultivation and ecological stability of the soil. Three main groups of beneficial beetles in the families Coccinellidae (lady beetles), Carabidae (ground beetles), and Scarabaeidae (dung beetles) function as critical elements for sustainable farming by managing pests while processing nutrients and decomposing organic materials (Hussain et al., 2020; Kulkarni et al., 2015). Beetles, which play crucial roles in ecosystems, are facing increasing challenges because of modern agricultural methods. Habitat excessive use of farm inputs such as pesticides and monoculture are major threats to coleopteran insects (Hussain et al., 2024). Major groups of beetles include dung beetles (Scarabaeidae), ground beetles (Carabidae), and ladybird beetles (Coccinellidae), which are key taxa providing ecosystem services in agricultural landscapes (Kundoo & Khan, 2017; Noureen et al., 2021). Ladybird beetles are important predators of many insects like aphids, scale insects, whiteflies, and mealybugs. These beetles act as natural enemies of pests and regulate pest populations of many insects (Kundoo & Khan, 2017). Many beetles feed on animal feces and are excellent decomposers, like carrion beetles (Silphidae), rove beetles (Staphylinidae), dung beetles (Scarabaeidae and Geotrupidae), termites (Termitidae), and flesh flies (Sarcophagidae). These beetles not only decompose the dung to release nutrients but also help to improve soil structure and texture (Lamont, 2009; Yadav et al., 2023). These beetles contribute significantly to soil enrichment, improved soil structure, pathogen control, and fertilizer alternatives that reduce reliance on synthetic fertilizers by enhancing natural nutrient cycles (Byk & Piętka, 2018; Davis et al., 2004; Hussain et al., 2020; Tiede et al., 2022). A schematic overview of the various ecological services of beetles has been presented to highlight the significance of beetles (Figure 1). We have also summarized various ecological services provided by beetles (Table 1), threats and challenges faced by beetles in agricultural landscapes (Table 2), and approaches for the conservation of beetles in agroecosystems (Table 3).

Table 1. Various ecological services provided by beetles.

Role	Contributions	Examples	Citations
Ecological Roles	Insects are critical to pollination, decomposition, soil health, pest control, and food chains	Dung beetles (decomposition) Ladybird beetles (pest control)	(Verma et al., 2023)
Pollination	About 75% of all food crops depend on animal pollination, mostly insects	Pollinating beetles, e.g., Ladybird beetles	(Thapa, 2006)
Nutrient Recycling	Insects break down organic matter, recycle nutrients, and maintain soil fertility	Dung beetles	(Culliney, 2013)
Pest Control	Natural predators and parasitoids help manage crop pests and reduce chemical use	Ladybird beetles, Ground beetles & Stag beetles	(Ballal & Verghese, 2015)
Food Web Links	Insects serve as prey for birds, amphibians, reptiles, mammals, and fish	Beetles (for birds, mammals, fish)	(Schoenly, 1990)
Decline Trends	Global insect populations are declining by 1–2% per year, signaling ecosystem distress	Beetles (various species globally, e.g., European stag beetles)	(Wilson & Fox, 2021)
Drivers of Decline	Habitat loss, intensive agriculture, pesticides, climate change, pollution, invasive species, and light pollution	Ground Beetles	(Brain & Anderson, 2020)

Ecological Contributions of Beetles

Pollination services

Beetle pollination (cantharophily) has not been extensively studied and well established like other insect groups, such as bees and butterflies (Sivadasan & Sabu, 1989). Beetles are one of the oldest groups of insects, providing pollination service since the early Cretaceous period (145 to 66 million years ago). Beetles have played a crucial role in the diversity and evolution of flowering plants (Peris et al., 2025; Wang et al., 2013). Beetles such as Chrysomelidae and Scarabaeidae are major families among the beetles that have developed interactions with angiosperms and provided them with pollination services (Muinde & Katumo, 2024; Thien et al., 2009). Cantharidae, Coccinellidae, and Meloidae have been reported as pollinators of crops and natural vegetation in protected areas (Hussain et al., 2023).

Natural pest control

Predatory beetles within the Carabidae and Coccinellidae families deliver important ecological pest control services to the environment. The ground-dwelling predators *Pterostichus melanarius* belong to the carabid beetle family, which preys upon soil insects, including caterpillars and slugs, and insect larvae. At night, these beetles emerge to play an essential role in pest control across the soil surface (Busch, 2016). The seven-spotted lady beetle, along with many other coccinellid beetles, serves as an effective predator that controls aphids, whiteflies, and scale insects. These two beetle groups are widely used in integrated pest management because of their targeted and efficient strategies. Each coccinellid insect can eat up to 400 aphids every day, thereby protecting wheat, maize, and vegetable fields. The activities of these beetles minimize the need for chemical pesticides, which enables sustainable agricultural practices. Natural habitats, including hedgerows and flower strips, promote the growth of these beetle populations (Pervez et al., 2020).

Table 2. Threats and challenges faced by beetles in agricultural landscapes.

Threats	Reasons	Examples
Habitat Loss and Fragmentation	Deforestation for urbanization, agriculture, factories, etc., is leading to the decline of beetles, especially flightless species.	Central New South Wales, Australia – 90% woodland cleared; beetles declined due to habitat loss (Driscoll & Weir, 2005)
Pollution and Agrochemicals	Agrochemical runoff pollutes soil and water, affecting beetles like rove beetles, ground beetles, tiger beetles, etc. Highly sensitive beetles show early signs of decline.	19% of tiger beetles are at risk of extinction; agrochemicals harm freshwater beetles (Bean *et al.*, 2013; Tudi *et al.*, 2021)
Climate Change	Rising temperatures due to human activities affect beetle populations, especially in high-altitude regions. Habitat-specific beetles cannot adapt to temperature shifts.	Tropical beetles like weevils and leaf beetles at higher altitudes in Brazil are highly vulnerable (García-Robledo *et al.*, 2016; Harvey *et al.*, 2023)
Monoculture	Growing single crops limits insect biodiversity and food sources, causing specialized beetles like the Tansy beetle to decline.	Tansy beetle declined due to monoculture and reduced Tansy plants (Gassmann *et al.*, 2010; Liu *et al.*, 2018)
Overexploitation	Excessive resource use leads to biodiversity loss and beetle extinction. Removal of beetle habitats and competition reduces survival.	The American burying beetle is endangered due to overexploitation of small animal carcasses (McMurry *et al.*, 2023; Rosser & Mainka, 2002)

Decomposition and nutrient cycling (e.g., Dung beetles)

The decomposition process and nutrient cycling depend heavily on dung beetles because they break down animal waste while returning invaluable soil nutrients. Through their burial and digestive processes, the beetles enhance fast organic breakdown, which leads to better soil quality and nutrition levels (Shah & Shah, 2022). Dung beetles contribute to increased accessibility of nutrients, including nitrogen, phosphorus and carbon, for plants. *Onthophagus gazella*, along with Scarabaeus sacer, effectively bury dung, which leads to pasture nutrient enrichment. Through their activities, these beetles lower parasite counts and eliminate fly breeding sites, which provides additional health benefits to livestock. The burial of dung increases airflow to the soil while diminishing waterlogging, which enables crop health improvement. These beetles maintain healthy productive soils in temperate alongside tropical ecosystems. The ecological process performed by dung beetles enables farmers to minimize their dependency on chemical fertilizer usage while practicing sustainable farming methods. Thus, dung beetles are key decomposers that link animal waste to soil fertility and ecosystem health (Slade et al., 2016).

Soil aeration and health

Anthropogenic activities, which trigger habitat loss, affect the diversity and abundance of beetles (Nasir et al., 2016). The challenges become worse when combined with climate change alongside land-use conversion because they cause habitat changes affecting beetle life cycles and ecological relationships (Hussain et al., 2020; Noureen et al., 2021). The creation of sustainable conservation strategies requires the comprehension of the interactions of beetles in agroecosystems. We explored the contributions and challenges faced by beetles in agricultural landscapes to assess current knowledge gaps and future directions of the research.

Beetle Diversity in Agricultural Landscapes

Habitat types and beetle assemblages

The variety of habitat types alongside beetle communities significantly influences the distribution of beetles throughout agricultural zones. Habitats which include crop fields, field margins, hedgerows, and fallow lands create different

Table 3. Strategies and approaches for the conservation of beetles in agroecosystems.

Strategy/Approach	Description	Benefits	Limitations	Examples
Habitat Restoration & Recreation	Restoring natural habitats (meadows, grasslands, deadwood) to support beetle populations.	Supports diverse beetle species; restores degraded areas.	Requires long-term commitment and funding.	Restoration of saproxylic beetle habitats in Europe; native plant reforestation (Bažok *et al.*, 2021; Shuey, 2013)
Integrated Pest Management (IPM)	Use of multiple pest control methods, cultural, biological, mechanical, with minimal chemical application.	Reduces beetle mortality from chemicals; promotes sustainable pest control.	It may require more labor and knowledge from farmers.	IPM for Colorado potato beetle using microbial pesticides and natural predators (Bažok *et al.*, 2021; Tiwari, 2024)
Cultivation of Native Plants	Planting native vegetation to provide food and habitat for beetles and other beneficial insects.	Enhances beetle reproduction, pollination, and natural pest control.	Native species availability may be region-specific.	Wildflowers and milkweed for North American beetles; mango and fig trees in tropics (Bali & Kaleka, 2021)
Polyculture Farming	Growing multiple crop species together to increase habitat diversity and ecological balance.	Supports a wide range of beetles and natural enemies; improves crop yield.	May be less economically optimized than monocultures.	Intercropping with flowering plants like marigold attracts beneficial beetles (Quinto *et al.*, 2021)
Legislation and Policy	Creating environmental laws and incentive programs to promote sustainable agriculture and protect endangered species and habitats.	Provides long-term protection; enforces conservation action.	Implementation can vary across regions; political will may be lacking.	EU Environment Directive for stag beetle; U.S. Farm Bill supporting beetle-friendly agriculture (New & New, 2010)
Single-Species Conservation	Focused efforts on conserving a specific endangered or iconic beetle species through research, captive breeding, and awareness.	Generates public interest; can act as a flagship for broader conservation.	Neglects broader ecosystems; resource-intensive.	Stag beetle conservation using captive breeding and habitat protection (Méndez & Thomaes, 2021)

ecological resources combined with varied microclimates that sustain separate beetle populations (Thomas et al., 2002). The predatory nature of Carabidae beetles leads them to establish themselves best in open fields, but Chrysomelidae leaf beetles succeed primarily in vegetated margins that contain their host plants. The decayed wood environment of hedgerows functions as a refuge space for beetles that require dead wood. The Scarabaeidae taxonomic group uses pasture regions for their activities while promoting nutrient recycling. The distribution of beetle species, both in number and diversity, is affected directly by the diversity of habitats present (Woodcock et al., 2010). Influence of crop type and management practices. Seasonal and spatial changes in the environment affect beetle diversity throughout agricultural environments due to their impact on resource availability and habitat suitability. The population of beetles experiences periodic changes across the seasons because dung beetles (Scarabaeidae) reach their highest activity levels during the monsoon season, which provides ideal conditions of moisture and increased dung availability (Thomas et al., 2002). Ground beetle populations (Carabidae) experience higher abundance levels during cooler months' periods attributed to favorable temperature conditions of the soil. The space-based variations between upland and lowland fields alongside cultivated plots against field margins generate habitat diversity, which attracts multiple beetle species. Beetles of the family (Chrysomelidae) show a preference for bordered field areas, while members of the family (Nitidulidae) typically occupy fruit plantation zones. Structures of beetle communities in agricultural areas develop from various temporal movements and spatial locations (Holland et al., 2009).

Seasonal and spatial dynamics

The patterns of availability of resources along with habitat conditions differ across times and spaces to significantly impact beetle species diversity in agricultural landscapes. Populations of dung beetles (Scarabaeidae) reach their highest levels during the monsoon because the weather conditions, along with an abundance of dung, create optimal conditions for them. The population of ground beetles (Carabidae) peaks during cooler seasons because of preferred soil temperature conditions (Thomas et al., 2002). Different ecological zones connected by landscape features like upland fields versus lowlands and cultivated land areas relative to field boundaries lead to habitat diversity that allows the existence of multiple beetle populations. Leaf beetles prefer vegetated field edges as their habitat, but sap beetles frequently choose fruit-growing areas for habitat. Structures of beetle communities in agricultural areas develop from various temporal movements and spatial locations (Rather et al., 2021).

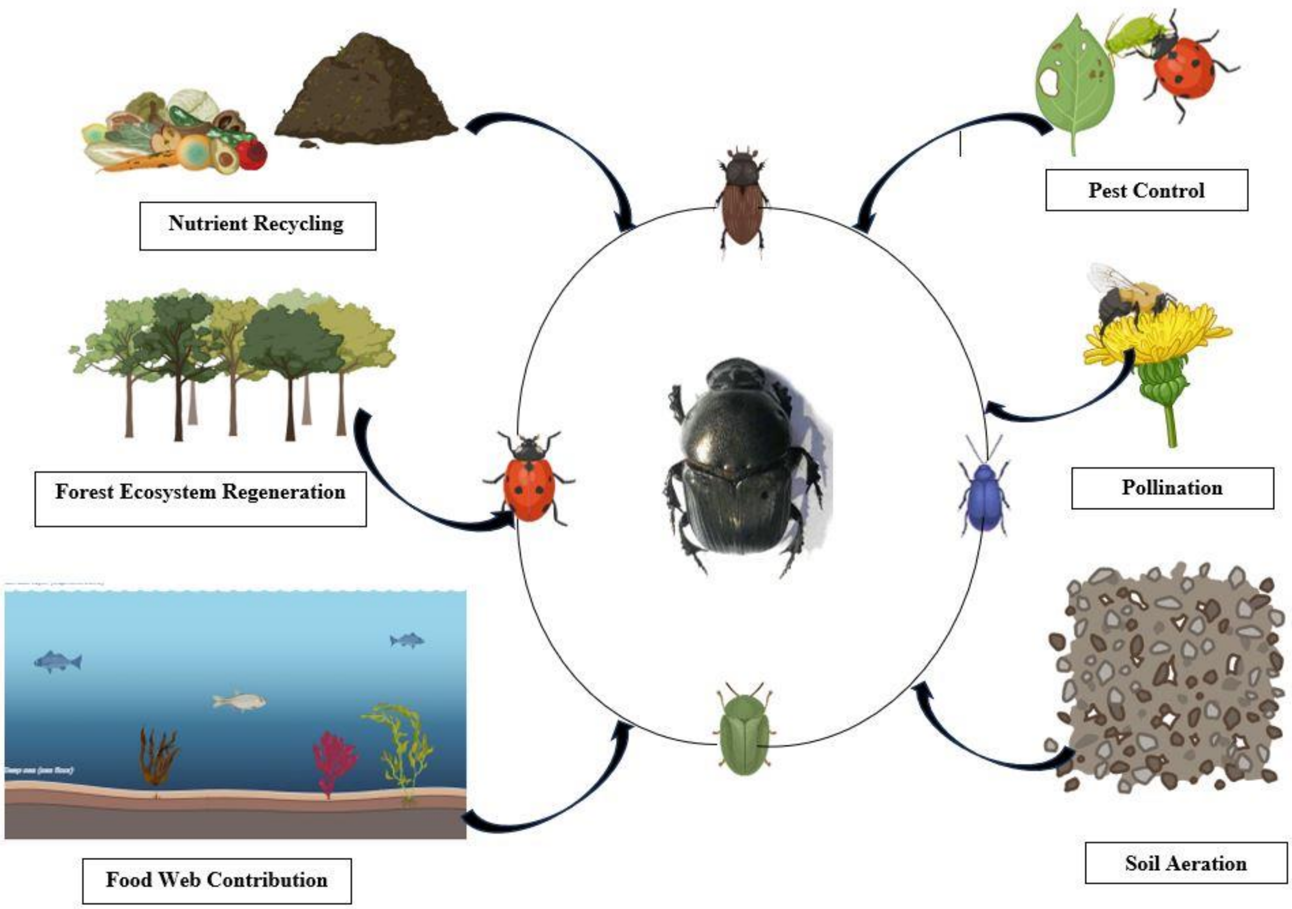

Figure 1. Schematic overview of the various ecological services of beetles.

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Challenges and Threats

Habitat fragmentation and loss

Results of anthropogenic activities adversely affect the natural habitat and cause the destruction and fragmentation of the natural habitat. These activities include the cutting and removal of trees and forests on a large scale to make new factories, roads and some recreational points for entertainment, etc. Due to these activities insect orders including Coleoptera, Lepidoptera, and Hymenoptera are under great threat of habitat loss (Dar et al., 2021). An experiment was performed in Central New South Wales, Australia, where 90% of the mallee woodland has been cleared for agriculture. At each of three 100-km2 locations, researchers sampled beetles in 10 sites and found that due to the loss of habitat beetles are under threat of decline mostly those which are flightless. Dung beetles also explain that habitat loss is the reason of beetles decline as these are sensitive to the dung of mammals for their survival (Driscoll & Weir, 2005).

Pesticide use and chemical exposure

Usage of agrochemicals to get more and more crop yield mostly nitrogen containing components are also a major cause for insect’s biodiversity loss because these are added in soil and due to nitrification water soluble nitrates leak in to soil surface and cause danger to insect population. Mostly soil-dwelling insects including beetles (rove beetles, ground beetles and Japanese beetles) which help in nutrient cycling are at more risk of decline. Through rain these chemicals entered in water bodies and also harm the freshwater insects and also Coleopteran (crawling water beetles, trout-stream beetles and burrowing water beetles. In this way, these agrochemicals are the main reason for the decline (Tudi et al., 2021).

Monoculture and landscape homogenization

Cultivation of only one type of crop on a large scale to get more and more production leads to loss of food for many other species including insects because different insects feed on different types of plants because of food shortage insects move toward extinction. The only one or two types of insects feeding on this type of crop will survive and becomes the pest of this crop and result in its yield loss. For monoculture crop productions many pesticides and insecticides are used on a large scale which also affect the insect’s population (Liu et al., 2018).

Climate change and its effects on beetle populations

No doubt climate is changing day by day, which is imparting negative effects on ecosystem. Mostly human activities like automobiles, industrial effluents, air conditioners, urbanization and several other factors are increasing the temperature on this planet. According to a study, the earth temperature is increasing by 1.1 oC and it may increase by 3 to 4 oC until end of 21st century. In this way, climate change is responsible for the extinction of many insect species (Harvey et al., 2023). An international team of scientists has noted that Climate change is responsible for extinction of many tropical high-altitude beetles. Research by the University of York, the Federal University of Rio de Janeiro (UFRJ) and the Federal University of Goiás has shown that two plant-eating beetle groups – weevils and leaf beetles are remarkably in danger due to climate change. The researchers observed several insect groups at different altitudes in the Brazilian Atlantic Rainforest, a region well known for its high diversity of plant and animal species. They found that at higher altitudes groups of herbivorous beetles are mostly present. This places these species in more danger of disappearance as they have no place to go when the climate becomes warmer (García-Robledo et al., 2016).

Conservation Strategies and Management

Landscape-level approaches

Habitat loss and fragmentation result in the decline of many insect species in agricultural landscapes. The conservation of insects is necessary for the survival of humans on this planet (Kawahara et al., 2021). There is a difficulty in conserving insects in agricultural landscapes because there are many factors which make it difficult; therefore, the recreation and restoration of habitat in landscapes with open meadows and grasslands provide a wide range of food and habitat to variety of insects and we conserve them in this way (Shuey, 2013). For example, in Europe, retuning deadwood and limiting logging in vital regions have proven effective ways to restore forests for saproxylic beetles, which are dependent on decaying wood. In a similar vein, beetles can flourish in degraded habitats when native plants are planted again (Bažok et al., 2021).

Integrated pest management (IPM)

Pesticide usage is the chemical way to control pests, but it also harms the beneficial organisms also especially insects, which act as biological control agents of some pests and also help in pollination. IPM refers to the usage of different ways to control insects, not only chemicals, because chemical usage eradicates insects, not controls them, but we have to control them, not to eradicate (Tiwari, 2024). This integrated pest management involves practicing cultural, mechanical, biological, and physical control first. Then, if required chemical control can be used to manage pest populations. By following this pattern, we can conserve insect's diversity easily (Kogan & Lattin, 1993). IPM techniques like crop rotation, microbial pesticides such as (*Bacillus thuringiensis*), natural predators and sparing insecticide applications are used to manage the Colorado potato beetle. This preserves the ecosystem while successfully reducing pests (Bažok et al., 2021).

Policies and farmer awareness

Local State and Government should make policies and laws to conserve biodiversity and arrange programs to aware people about the importance of insects in agriculture. Besides this, the government should make hard and fast rules for selling and using pesticides, agrochemicals within limits. Local States have to make laws to check the fuel quality used in vehicles, industrial effluents removal without treatment which cause air and water pollution and are responsible for insect decline (New, 2012). For instance, environments vital to endangered insects such as the European Union's Environmental Directive protects the stag beetle (*Lucanus cervus*). Land usage and logging are controlled to preserve the vital ecosystem. On the other hand, government initiatives such as the U.S. Farm Bill provide incentives for sustainable agricultural methods that promote the development of habitats that are beetle-friendly through less tillage and cover crops (Hipólito et al., 2021).

CONCLUSION

In agroecosystems, the well-documented ecological roles of beetles indicate their immense contribution to sustainability. However, many areas that need to be studied may be identified to address the gaps in understanding population dynamics, interspecific interactions, and responses to modern agricultural pressures. The studies on the impact of climate change, land-use transformation, and pesticide exposure on beetle communities are limited and focused on specific species, and many beetle taxa remain understudied. Exploring the diversity of native beetles in agroecosystems. Ecological monitoring of populations under varying agricultural intensities and climate conditions. Coleopterans provide key ecological services for the stability and sustainability of the ecosystem. Biological interactions such as pollination, predation, and parasitism provide insight into the maintenance of food chains and food webs. Other major services include nutrient recycling, decomposition of waste material, soil aeration, etc. Bridging these gaps will be instrumental in fostering resilient and ecologically balanced farming landscapes where beetles continue to thrive and support sustainable food systems.

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All authors have equal contributions.

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The authors declare that there is no conflict of interest.

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REFERENCES

Bali, G. P. K., & Kaleka, A. S. (2021). Potential reasons for insect decline. In Global Decline of Insects. Intech Open. https://doi.org/10.5772/intechopen.100065

Ballal, C. R., & Verghese, A. (2015). Role of parasitoids and predators in the management of insect pests. New Horizons in Insect Science: Towards Sustainable Pest Management, 307-326. https://doi.org/10.1007/978-81-322-2089-3_28

Bažok, R., O'Keeffe, J., Jurada, I., Drmić, Z., Kadoić Balaško, M., & Čačija, M. (2021). Low-dose insecticide combinations for Colorado potato beetle control. Agriculture, 11(12), 1181. https://doi.org/10.3390/agriculture11121181

Bean, D., Dudley, T., & Hultine, K. (2013). Bring on the beetles. Tamarix: a case study of ecological change in the American West, 377. https://doi.org/10.1093/acprof:osobl/9780199898206.003.0022

Brain, R. A., & Anderson, J. C. (2020). Anthropogenic factors affecting wildlife species status outcomes: why the fixation on pesticides? Environmental Science and Pollution Research, 1-24. https://doi.org/10.1007/s11356-020-08980-1

Busch, A. K. (2016). Life History of *Pterostichus melanarius* (Coleoptera: Carabidae) and its importance for biological control in field crops. Master of Science. MPhil Thesis. Penn State University.

Byk, A., & Piętka, J. (2018). Dung beetles and their role in the nature. Edukacja Biologiczna i Środowiskowa.17-26 https://doi.org/10.24131/3247.180103

Culliney, T. W. (2013). Role of arthropods in maintaining soil fertility. Agriculture, 3(4), 629-659. https://doi.org/10.3390/agriculture3040629

Dar, S. A., Ansari, M. J., Al Naggar, Y., Hassan, S., Nighat, S., Zehra, S. B., Rashid, R., Hassan, M., & Hussain, B. (2021). Causes and reasons of insect decline and the way forward. In Global Decline of Insects. Intech Open. https://doi.org/10.1201/9781032620312

Davis, A. L., Scholtz, C. H., Dooley, P. W., Bham, N., & Kryger, U. (2004). Scarabaeine dung beetles as indicators of biodiversity, habitat transformation and pest control chemicals in agro-ecosystems. South African Journal of Science, 100(9), 415-424. https://doi.org/10.1111/een.12950

Driscoll, D. A., & Weir, T. (2005). Beetle responses to habitat fragmentation depend on ecological traits, habitat condition, and remnant size. Conservation Biology, 19(1), 182-194. https://doi.org/10.1111/j.1523-1739.2005.00586.x

García-Robledo, C., Kuprewicz, E. K., Staines, C. L., Erwin, T. L., & Kress, W. J. (2016). Limited tolerance by insects to high temperatures across tropical elevational gradients and the implications of global warming for extinction. Proceedings of the National Academy of Sciences, 113(3), 680-685. https://doi.org/10.1073/pnas.1507681113

Gassmann, A., Schwann, A., Mosyakin, A., Wolf, V., Jović, J., & Toševski, I. (2010). Biological control of common tansy, *Tanacetum vulgare*. Annual Report. https://doi.org/10.1079/9781780642574.0378

Harvey, J. A., Tougeron, K., Gols, R., Heinen, R., Abarca, M., Abram, P. K., Basset, Y., Berg, M., Boggs, C., & Brodeur, J. (2023). Scientists' warning on climate change and insects. Ecological monographs, 93(1), e1553. https://doi.org/10.1002/ecm.1553

Hipólito, J., Coutinho, J., Mahlmann, T., Santana, T. B. R., & Magnusson, W. E. (2021). Legislation and pollination: Recommendations for policymakers and scientists. Perspectives in Ecology and Conservation, 19(1), 1-9. https://doi.org/10.1016/j.pecon.2021.01.003

Holland, J., Birkett, T., & Southway, S. (2009). Contrasting the farm-scale spatio-temporal dynamics of boundary and field overwintering predatory beetles in arable crops. Biocontrol, 54, 19-33. https://doi.org/10.1007/s10526-008-9152-2

Hussain, M., Liaqat, H., Malik, M. F., Aftab, K., Batool, M., Iqbal, R., & Liaqat, S. (2023). Distribution patterns of insect pollinator assemblages at Deva Vatala National Park, Bhimber, Azad Jammu and Kashmir. Pakistan Journal of Zoology, 2023, 1-7. https://doi.org/10.17582/journal.pjz/20221004171007

Hussain, M., Nazir, T., & Malik, M. F. (2024). Community Structure of Ladybird Beetles (Coccinellidae: Coleoptera) Alongside the Chenab River at Wazirabad, Gujranwala, Punjab, Pakistan. Pakistan Journal of Zoology, 56(3), 1041. https://doi.org/https://dx.doi.org/10.17582/journal.pjz/20180520120529

Hussain, M., Younas, M., Malik, M. F., Umar, M., Kanwal, M., & Batool, M. (2020). Spatio-temporal diversity of dung beetles in selected locales of Sialkot, Punjab, Pakistan. Punjab University Journal of Zoology, 35(1), 35-42. https://doi.org/https://dx.doi.org/10.17582/journal.pujz/2020.35.1.35.42

Kawahara, A. Y., Reeves, L. E., Barber, J. R., & Black, S. H. (2021). Eight simple actions that individuals can take to save insects from global declines. Proceedings of the National Academy of Sciences, 118(2), e2002547117. https://doi.org/10.1073/pnas.2002547117

Kogan, M., & Lattin, J. D. (1993). Insect conservation and pest management. Biodiversity & Conservation, 2, 242-257. https://doi.org/10.1007/BF00056671

Kulkarni, S. S., Dosdall, L. M., & Willenborg, C. J. (2015). The role of ground beetles (Coleoptera: Carabidae) in weed seed consumption: a review. Weed Science, 63(2), 355-376. https://doi.org/10.1016/j.agee.2025.109551

Kundoo, A. A., & Khan, A. A. (2017). Coccinellids as biological control agents of soft bodied insects: A review. Journal of Entomology and Zoology Studies, 5(5), 1362-1373.

Lamont, W. J. (2009). Overview of the use of high tunnels worldwide. HortTechnology, 19(1), 25-29. https://doi.org/10.21273/HORTSCI.19.1.25

Liu, C. L. C., Kuchma, O., & Krutovsky, K. V. (2018). Mixed-species versus monocultures in plantation forestry: Development, benefits, ecosystem services and perspectives for the future. Global Ecology and conservation, 15, e00419. https://doi.org/10.1016/j.gecco.2018.e00419

McMurry, R. S., Cavallaro, M. C., Shufran, A., & Hoback, W. W. (2023). Establishing age-based color changes for the american burying beetle, Nicrophorus americanus Olivier, with implications for conservation efforts. Insects, 14(11), 844. https://doi.org/10.3390/insects14110844

Méndez, M., & Thomaes, A. (2021). Biology and conservation of the European stag beetle: recent advances and lessons learned. Insect Conservation and Diversity, 14(3), 271-284. https://doi.org/10.1111/icad.12465

Muinde, J., & Katumo, D. M. (2024). Beyond bees and butterflies: the role of beetles in pollination system. Journal for Nature Conservation, 77, 126523. https://doi.org/10.1016/j.jnc.2023.126523

Nasir, A., Hussain, M., Fatima, S., Noureen, N., & Ghazanfar, M. (2016). New faunal records of dung beetles from district Sialkot, Punjab, Pakistan. Journal of Biodiversity and Environmental Sciences, 9(2), 122-128.

New, T. R. (2012). Introduction to insect conservation, an emerging discipline. In Insect conservation: past, present and prospects (pp. 1-17). Springer. https://doi.org/10.1007/978-94-007-2963-6_19

New, T. R., & New, T. R. (2010). Beetles in conservation. Springer. https://doi.org/10.1007/978-3-031-49255-6

Noureen, N., Hussain, M., Malik, M. F., Umar, M., Abbas, Z., & Munaward, S. (2021). Habitat types effect on diversity, distribution and abundance of dung beetles. Pakistan Journal of Scientific and Industrial Research Series B: Biological Sciences, 64(3), 217-224. https://doi.org/10.52763/PJSIR.BIOL.SCI.64.3.2021.217.224

Peris, D., Ollerton, J., Sauquet, H., Hidalgo, O., Peñalver, E., Magrach, A., Álvarez-Parra, S., Peña-Kairath, C., Condamine, F. L., & Delclòs, X. (2025). Evolutionary implications of a deep-time perspective on insect pollination. Biological Reviews. https://doi.org/10.1111/brv.70008

Pervez, A., Omkar, & Harsur, M. M. (2020). Coccinellids on crops: Nature's gift for farmers. Innovative Pest Management Approaches for the 21st Century: Harnessing Automated Unmanned Technologies, 429-460. https://doi.org/10.1007/978-981-15-0794-6_21

Quinto, J., Martínez-Falcón, A. P., Murillo-Pacheco, J. I., Abdala-Roberts, L., & Parra-Tabla, V. (2021). Diversity patterns of tropical epigeal beetle assemblages associated with monoculture and polyculture plantations with big-leaf mahogany. Neotropical Entomology, 50(4), 551-561. https://doi.org/10.1007/s13744-021-00870-6

Rather, B. A., Mir, M. M., Iqbal, U., & Mir, S. A. (2021). Integrated pest management of stone fruits. Production Technology of Stone Fruits, 397-422. https://doi.org/10.1007/978-981-15-8920-1_15

Rosser, A. M., & Mainka, S. A. (2002). Overexploitation and species extinctions. Conservation Biology, 16(3), 584-586. https://doi.org/10.1046/j.1523-1739.2002.01635.x

Schoenly, K. (1990). The predators of insects. Ecological Entomology, 15(3), 333-345. https://doi.org/10.3157/061.141.0110

Shah, N. A., & Shah, N. (2022). Ecological benefits of scarab beetles (Coleoptera: Scarabaeidae) on nutrient cycles: a review article. Advances in Biochemistry and Biotechnology, 7(1), 1-6. https://doi.org/10.29011/2574-7258.010109

Shuey, J. A. (2013). Habitat re-creation (ecological restoration) as a strategy for conserving insect communities in highly fragmented landscapes. Insects, 4(4), 761-780. https://doi.org/10.3390/insects4040761

Sivadasan, M., & Sabu, T. (1989). Beetle–pollination–cantharophily–in Amorphophallus bobenackeri (Araceae). Aroideana, 12(1-4), 32-37.

Slade, E. M., Riutta, T., Roslin, T., & Tuomisto, H. L. (2016). The role of dung beetles in reducing greenhouse gas emissions from cattle farming. Scientific reports, 6(1), 18140. https://doi.org/10.1038/srep18140

Stork, N. E. (2018). How many species of insects and other terrestrial arthropods are there on Earth? Annual review of entomology, 63(1), 31-45. https://doi.org/10.1146/annurev-ento-020117-043348

Thapa, R. (2006). Honeybees and other insect pollinators of cultivated plants: a review. Journal of the Institute of Agriculture and Animal Science, 27, 1-23. https://doi.org/10.3390/ijerph18031112

Thien, L. B., Bernhardt, P., Devall, M. S., Chen, Z. d., Luo, Y. b., Fan, J. H., Yuan, L. C., & Williams, J. H. (2009). Pollination biology of basal angiosperms (ANITA grade). American Journal of Botany, 96(1), 166-182. https://doi.org/10.3732/ajb.0800016

Thomas, C. G., Holland, J. M., & Brown, N. J. (2002). The spatial distribution of carabid beetles in agricultural landscapes. The agroecology of carabid beetles, 305-344.

Tiede, J., Iuliano, B., & Gratton, C. (2022). Agriculturally intensified landscapes are associated with reduced body condition of lady beetles. Landscape Ecology, 37(7), 1921-1936. https://doi.org/10.1007/s10980-022-01458-0

Tiwari, A. K. (2024). Insect Pests in Agriculture Identifying and Overcoming Challenges through IPM. Archives of Current Research International, 24(3), 124-130. https://doi.org/10.9734/acri/2024/v24i3651

Tudi, M., Daniel Ruan, H., Wang, L., Lyu, J., Sadler, R., Connell, D., Chu, C., & Phung, D. T. (2021). Agriculture development, pesticide application and its impact on the environment. International journal of environmental research and public health, 18(3), 1112. https://doi.org/10.3390/ijerph18031112

Verma, R. C., Waseem, M. A., Sharma, N., Bharathi, K., Singh, S., Anto Rashwin, A., Pandey, S., & Singh, B. (2023). The role of insects in ecosystems, an in-depth review of entomological research. International Journal of Environment and Climate Change, 13(10), 4340-4348. https://doi.org/10.9734/ijecc/2023/v13i103110

Wang, B., Zhang, H., & Jarzembowski, E. A. (2013). Early Cretaceous angiosperms and beetle evolution. Frontiers in Plant Science, 4, 360. https://doi.org/10.3389/fpls.2013.00360

Wilson, R. J., & Fox, R. (2021). Insect responses to global change offer signposts for biodiversity and conservation. Ecological Entomology, 46(4), 699-717. https://doi.org/10.1111/een.12970

Woodcock, B., Redhead, J., Vanbergen, A., Hulmes, L., Hulmes, S., Peyton, J., Nowakowski, M., Pywell, R., & Heard, M. (2010). Impact of habitat type and landscape structure on biomass, species richness and functional diversity of ground beetles. Agriculture, Ecosystems & Environment, 139(1-2), 181-186. https://doi.org/https://doi.org/10.1016/j.agee.2010.07.018

Yadav, M., Kumawat, N., Meena, P., Prajapat, R., & Meena, S. (2023). Ecological role of dung beetles (Coleoptera: Scarabaeidae) and their diversity in India. Flora Fauna, 29. 349-355. https://doi.org/10.33451/florafauna.v29i2pp.

Zhang, Z.-Q. (2011). Animal Biodiversity: An Introduction to Higher-Level Classification and Taxonomic Richness. Zootaxa, 3148, 7-12. https://doi.org/10.11646/zootaxa.3148.1.3

Zhang, Z.-Q. (2013). Phylum Arthropoda. In: Zhang, Z.-Q. (Ed.) Animal Biodiversity: An Outline of Higher-level Classification and Survey of Taxonomic Richness (Addenda 2013). Zootaxa, 3703(1), 17-26. https://doi.org/https://doi.org/10.11646/zootaxa.3703.1.6