Review article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2026) 8 (1) : 53-61

Abuses of pesticides ravage soil dwelling insects and soil health in Bangladesh

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Received: 22 December 2025, revised: 17 February 2026, accepted: 18 January 2026, DOI: https: //doi.org/10.59619/ej.8.1.7

Abstract

Agricultural production is increasing to meet the demands of the growing global population, which led to a parallel rise in chemical pesticide use. Global pesticide consumption in 2022 reached 3.7 million tons of active ingredients, representing a 4% increase from 2021, a 13% increase over the past decade, and nearly double since 1990. Insect pests such as crickets, cutworms, termites, white grubs, and cucumber beetles can severely reduce crop yield. Soil-dwelling insects like ants, dung beetles, ground beetles and collembolan springtails are vital for ecosystem functioning, enhancing bioturbation, soil health, nutrient cycling, decomposition, aeration, organic matter breakdown, fungal dispersion, and natural pest control. Without these hexapods, soil ecosystem services decline, negatively impacting plant growth and productivity. Farmers manage pest infestations using various pesticide classes, including organophosphates, pyrethroids, carbamates, organochlorines, neonicotinoids, and biological pesticides applying through seed treatment, spraying, soil application, drip irrigation, fogging, fumigation and post-harvest treatment. Many organophosphates, carbamates, and organochlorines are banned by the world health organization (WHO) due to their classification as highly hazardous pesticides. Despite widespread use, less than 0.1% of applied pesticides reach target pests, while 99.9% contaminate soil, water, and the environment. Nearly 50% of pesticides persist in soil or water due to their prolonged half-life, resulting detrimental effect on beneficial soil insects and a reduction in soil fertility. Continuous exposure of soil ecosystems to such pesticides threatens biodiversity and diminishes the capacity of soil to support healthy crop growth.

Keywords: Hazardous pesticides, pesticide use, agricultural productivity, soil-dwelling insects, soil health

Introduction

Agricultural production is escalating to meet the demands of the increasing population growth of the world. Over time, there has been a comparable rise in the use of chemical pesticides to protect crops from the attack of pests and diseases. Global consumption of pesticides in the year 2022 was 3.7 million tons of active ingredients, which was 4% higher with respect to the year 2021, 13% increase over a decade, and a doubling since 1990 (FAO 2024). Different soil-dwelling insect pests, such as crickets, cutworms, termites, white grubs, and cucumber beetles can severely infest plants and affects subsequent yield potential, but a greater number of hexapods such as springtails, ants, dung beetles, and ground beetles, are found in the soil as a vital component of the ecosystem and biodiversity (Thanuja *et al*. 2025). They greatly enhance bioturbation in soil ecosystems and contribute a significant role in soil health and nutrient cycling, decomposition, aeration, breaking down organic matter, spreading fungi, and pest control (Rupali *et al*. 2024, Culliney 2013). Lacking the activities of soil-dwelling insects, the ecosystem services will be less diverse, and plant growth and productivity may suffer.

Pest infestations in agricultural fields are managed in different countries using a variety of pesticide classes such as organophosphates, pyrethroids, carbamates, organochlorines, neonicotinoids, biological pesticides and others (Warner 2023). Seed treatment, spray application, soil application, drip irrigation, fogging and fumigation, and post-harvest treatments are some of the common methods of pesticide application. Organophosphates, carbamates, and organochlorines are banned as they are classified as highly hazardous pesticides by WHO in 2022. Due to extensive use of pesticides, mostly the banned and highly hazardous ones, by any means of application are threatening the soil-dwelling insects and soil fertility. However, indiscriminate application and wrong selection of insecticides not only affecting the soil health and biodiversity but also in the crop field by killing the beneficial insects including predator (Mollah *et al*. 2012), parasitoids (Mollah and Khatun, 2023) and non-target or minor insect pests like green stink bug (Mollah *et al*. 2017) and bean bug (Mollah *et al*. 2022). Unfortunately, less than 1% of pesticides used for pest control reach the target pest, and the rest 99% go to soil, water, and the environment. According to current estimates, 50% of all pesticides have a long half-life in soil or water (Quandahor *et al*. 2024). Because of the prolonged half-life of the pesticides in the soil, insects in cultivated fields have been contaminated and ravaged, and the capacity of the soils to support plants is diminishing. Pesticide exposure negatively affected soil invertebrates in over 70 % of analyzed cases, impacting earthworms, ants, beetles, nematodes, and other soil fauna critical to soil health and biodiversity where organophosphate and neonicotinoid insecticides were among the most harmful classes studied (Gunstone *et al*. 2021). Therefore, it is utmost necessary to know the effect of different pesticides on soil health, ecosystem as well as soil-dwelling insects.

Classification of pesticides

According to the World Health Organization (WHO 2020), there are five classes of pesticides: extremely hazardous, highly hazardous, moderately hazardous, slightly hazardous and unlikely to present acute hazard. The percentage of the pesticides under these categories are variable (Figure 1). Among the classes, the highest percentage is acquired by the class moderately hazardous (37%), followed by unlikely to present acute hazard (28%), slightly hazardous (22%). The proportion of highly hazardous and extremely hazardous is comparatively less which is 9% and 4%, respectively.

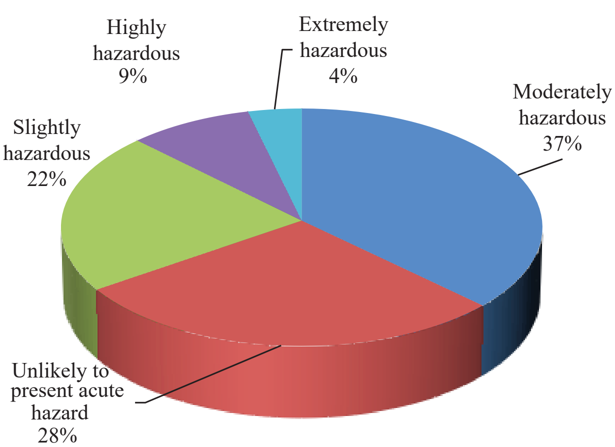

Figure 1. Pesticides classification and proportion of different classes according to WHO.

Consumption of pesticides in Bangladesh

The overall amounts of pesticides used in agriculture globally in 2022 were 3.70 million tons. In 2017, Bangladesh imported over 15,106 tons of active ingredients for the manufacture of 37,187 tons of pesticide products (Imran 2018). By 2023, it reached 39,000 metric tons of pesticide formulations. According to plant protection wing of Department of Agricultural Extension (DAE), currently there are 342 active ingredients, and 7887 formulated products are available in Bangladesh (till 87th PTAC). These pesticides include fungicides (21.65%), insecticides (46.25%), herbicides (15.87%), PHP (detailed) (14.54%), biopesticides (1.39%), and rodenticides (0.3%). According to Khatun *et al*. (2023), in vegetables such as tomato, brinjal, beans, cauliflower and many others pesticide contamination levels found above the safe threshold (MRL).

Not only in Bangladesh but also in other neighboring countries such as India and Myanmar the pesticides are consumed predominantly (Table 1). Insecticide consumption rate is greater in India (76%) than Myanmar (40%) and Bangladesh (46.25%). However, in Myanmar herbicide consumption rate is higher (50%) (Myanmar Plant Protection Division, 2024) than in Bangladesh (15.87%) and India (10%).

Category and number of formulations of registered pesticides in Bangladesh (81st PTAC approved)

Pesticide Technical Advisory Committee (PTAC) of Bangladesh approved many formulations of single and mixed active ingredients (Figure 2). The figure compares the number of formulations in five categories among these; insecticides and fungicides show significantly higher registrations for mixed active ingredients (94 and 70) compared to single active ingredients (66 and 33). In contrast, herbicides and public health pesticides have more single active ingredient registrations than mixed, while miticides remain the lowest in both types, with 5 single and 3 mixed active ingredients (DAE 2022).

Table 1. Consumption pattern of different pesticides in Bangladesh and neighboring countries

Country	Consumption (%)			
	Insecticide	Fungicide	Herbicide	Other
Bangladesh	46.3	21.7	15.9	0.5
India	76.0	13.0	10.0	1.0
Myanmar	40.0	10.0	50.0	0.0

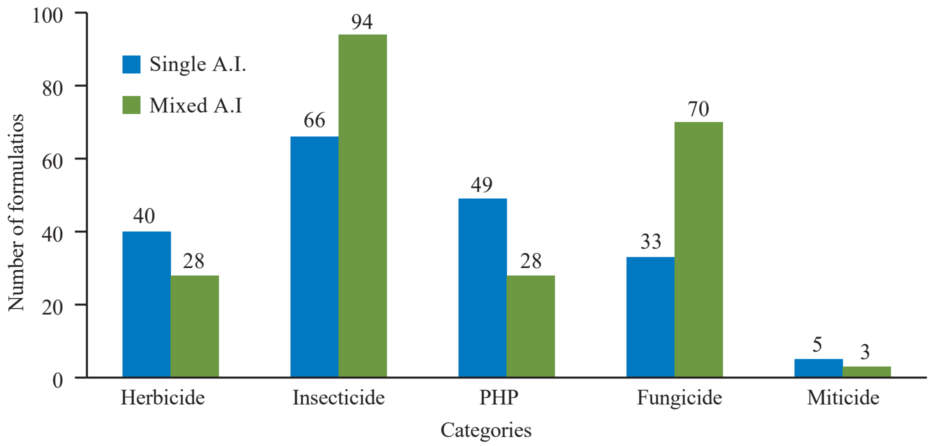

Figure 2. Number of formulations of registered pesticides in Bangladesh.

Formulation of registered bio-pesticides in Bangladesh (81st PTAC approved)

Figure 3 depicts the amount of formulation of bio-pesticides of Bangladesh according to their active ingredients whereas figure 4 exhibits the distribution of them in various sectors. There is a total of 20 formulations of bio-pesticides, where 16 are single active ingredients and 4 are mixed ingredients.

According to DAE (2022), the bio-pesticides are distributed among different agricultural sectors where majority of the bio-pesticides are used in production of horticultural crops (60%), followed by cash crop sector (28%), whereas only 12% are used in field crop production (Figure 4).

Registered insecticides formulation in agriculture sector (81st PTAC approved)

Figure 5 shows the distribution of insecticides registered for various crop sectors based on single and mixed active ingredients. The cash crop sector has the highest registrations, with 59 single active ingredients and 32 mixed active ingredients, followed by horticultural crops with 52 single active ingredients and 14 mixed active ingredients. Field crops have relatively fewer registrations than the other sectors and contain more mixed active ingredients (37) than single active ingredients (34) (DAE 2022).

Transport routes of pesticides

Unfortunately, a very negligible portion of applied pesticides reach the target pests, while most of them transport through various routes such as air, ground water etc. and eventually transferred to the soil ecosystem and threatens the existence of the soil-dwelling insects. Therefore, lack of such organisms affects soil health as well as plant development and growth. Figure 6 illustrates how pesticides are transported through various environmental pathways and their eventual disembarkation into the soil ecosystem. Only a small fraction of the applied pesticide (approximately 1%) affects the target pests whereas the majority (99%) of the pesticides are dispersed into the environment and other ecosystems. Pesticides by volatilization pollute the air and by leaching action

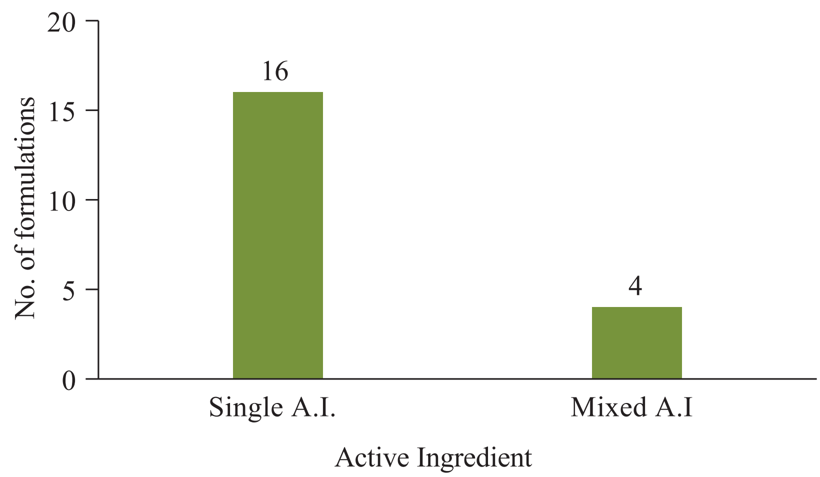

Figure 3. Number of formulations of bio-pesticides according to active ingredients.

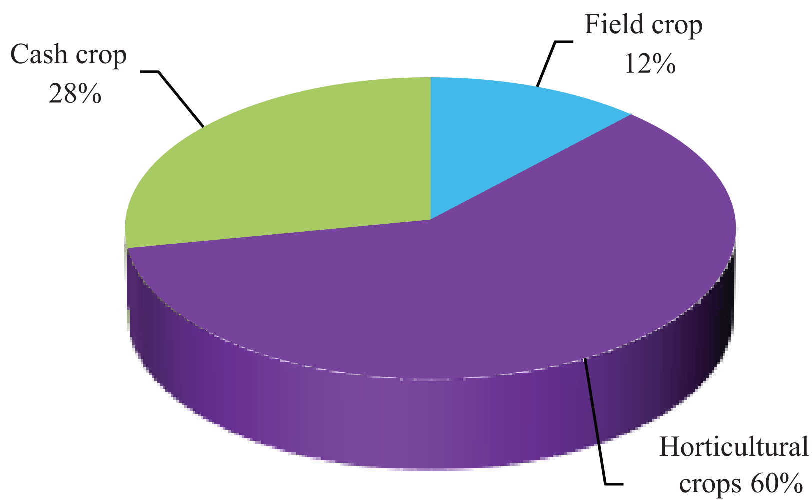

Figure 4. Bio-pesticides used in different crop sectors.

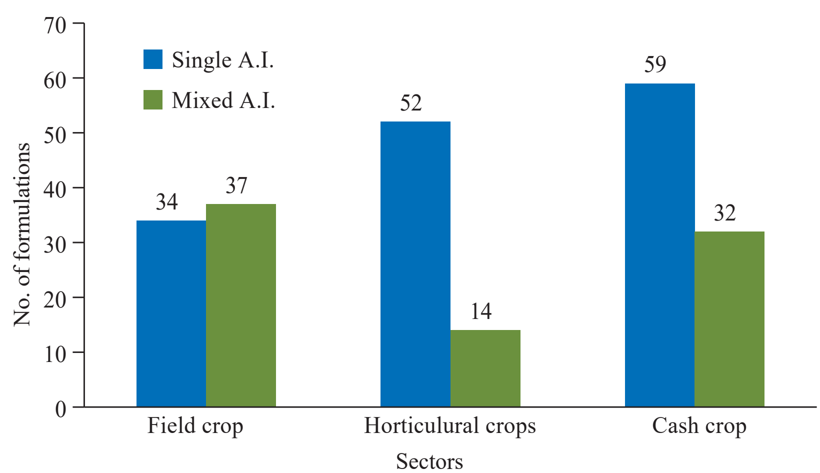

Figure 5. Number of registered insecticides formulation used in different crop sectors.

reach the ground water. Thereafter during application by drifting action, contamination of nearby crops, forests, water bodies, and beneficial organisms occurs (Geiger *et al*. 2010). These combined impacts lead to serious health risks for humans and degradation of ecosystems. When pesticides are dispersed, they can contaminate neighboring crops, which can then release harmful residues into the human body when consumed. The final deposition of pesticides in the soil disrupts the soil ecosystem by harming beneficial soil organisms, reducing fertility, and altering soil structure and nutrient cycles.

Hazards to soil dwelling insects and soil health

Insects that dwell in the soil are essential for preserving soil biodiversity, decomposition, aeration, bioturbation, releasing and immobilizing nutrients from soil organic matter (SOM), enhancing soil structure, and promoting plant growth. Moreover, some insect pests such as termite, mole cricket etc. are severely threatening to plants. Pesticides that are used for controlling these targeted pests eventually affect the non-targeted pests as well as soil health.

Soil dwelling insects contributing to bioturbation

Table 2 includes soil-dwelling insect and Collembolan contributing to bioturbation and their taxonomic positions. Ants, termites, dung beetles, and ground beetles belong to Formicidae, Termitidae, Scarabaeidae, and Carabidae families, respectively. Mole crickets are from Gryllotalpidae, cicadas from Cicadidae, and springtails from Collembola order. These hexapods play key roles in soil mixing and aeration.

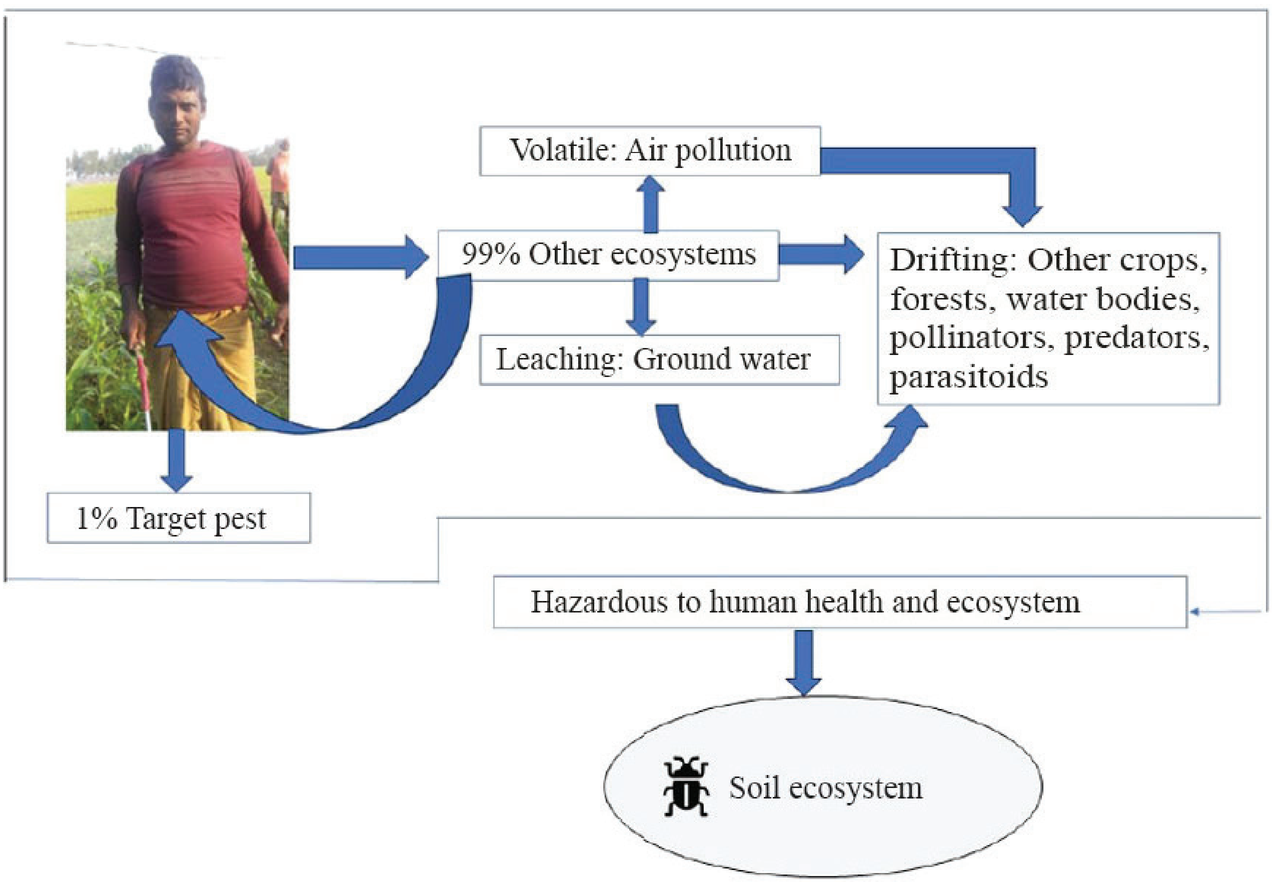

Figure 6. Transport routes and disembarkation of pesticides in soil ecosystem.

Table 2. List of soil dwelling hexapods with taxonomic informations contributing to bioturbation

Hexapods	Scientific name	Family name	Order name	Class name
Ants	*Formicidae sp.*	Formicidae	Hymenoptera	Insecta
Termite	*Odontotermes obesus*	Termitidae	Blattodea	
Dung beetle	*Scarabaeidae sp.*	Scarabaeidae	Coleoptera	
Mole cricket	*Gryllotalpa africana*	Gryllotalpidae	Orthoptera	
Cicadas	*Cicadidae sp.*	Cicadidae	Hemiptera	
Ground beetle	*Carabidae sp.*	Carabidae	Coleoptera	
Springtails	*Entomobrya nivalis*	Entomobryidae	Entomobryomorpha	Collembola

Soil dwelling insect pests of Bangladesh

There are pests such as mole crickets, black cutworms, common cutworms, field crickets, white grubs, rice root weevils, wireworms, stem flies, earwigs, termites etc. (Table 3) which affect various plant parts, including stems, roots, pods, tuber etc. (DAE 2019). Some of the major pests are capable of causing serious infestation rate (Table 4) such as cutworm is responsible for up to 74% of infestation; termite causes 50%; white grub 40-80% of infestation; potato tuber moth 24%; field cricket and mole cricket 14.4% and 11.30%, respectively (Nasif *et al*. 2018).

Table 3. Soil dwelling insect pests and damage caused by them in Bangladesh

Insect	Taxonomic position	Affected plant part
Mole cricket	*Gryllotalpa africana* (Orthoptera: Gryllotalpidae)	Seedling
White grub	*Heteronychus* sp. (Coleoptera: Scarabaeidae)	Root
Rice root weevil	*Hydronomidus molitor (*Coleoptera*:* Curculionidae)	Root
Wireworm	*Agriotes sp.*(Coleoptera*:* Elateridae)	Root
Black cutworm	*Agrotis ipsilon (*Lepidoptera: Noctuidae)	Seedling
Common cutworm	*Spodoptera liturua* (Lepidoptera: Noctuidae)	Seedling
Stem fly	*Ophiomyia phaseoli* (Diptera: Agromyzidae)	Seedling, stem
Ear wig	*Euborellia stali* (Dermaptera*:* Forficulidae)	Root, stem, pod
Termite	*Odontotermes obesus* (Isoptera: Termitidae)	Root, pod
Field cricket	*Brachytrypes portenosus* (Orthoptera: Gryllotalpidae)	Seedling
Rhinoceros beetle	*Oryctes rhinoceros* (Coleoptera: Dynastidae)	Root
Potato tuber moth	*Phthorimaea operculella* (Lepidoptera: Gelechiidae)	Tuber
Root feeder	*Myllocerus 11-pustulatus* (Coleoptera: Curculionidae)	Root
Fly	*Sciara rufithorax* (Diptera: Sciaridae)	Seedling
Onion fly	*Delia antiqua* (Diptera: Anthomyiidae)	Bulb, leaf
Black ant	*Componotus compressus* (Hymenoptera: Formicidae)	Root

Table 4. Major soil dwelling insect pest and their infestation level on crop plants

Insect	Crop	Infestation (%)
Cutworm	Maize, wheat, sugarcane, soybean, vegetables, horticultural crops	74
Termite	Rice, wheat, maize, jute, sugarcane, groundnut, vegetables, forest and plantation crops	50
White grub	Sugarcane, maize, potato	40-80
Potato tuber moth	Potato	24
Field cricket	vegetable and root crops	14.4
Mole cricket	Cereal crops, vegetable and root crops	11.30

Table 5. Proportion of declining and threatened species per taxa according to IUCN criteria

Insect Taxon	Declining (%)	Threatened (%)
Coleoptera	49	34
Diptera	25	0.7
Ephemeroptera	37	27
Hemiptera	8	n.a
Hymenoptera	46	44
Lepidoptera	53	34
Odonata	37	13
Orthoptera	49	n.a
Plecoptera	35	29
Trichoptera	68	63

Proportion of declining and threatened species per taxa according to IUCN criteria

According to IUCN (detailed) criteria, insect species per taxa are threatened and declining alarmingly (Table 5). Trichoptera has the highest percentage of both declining (68%) and threatened species (63%). Lepidoptera and Coleoptera also show high proportions of declining species (53% and 49%, respectively), with 34% of each taxon being threatened. Hymenoptera is notable for its high proportion of both declining (46%) and threatened (44%) species. Diptera and Hemiptera have the lowest percentages, with Diptera showing only 0.7% threatened species and Hemiptera having no available data (n.a.) for threatened status (Quandahor *et al*. 2024).

Conclusion

This review highlighted the classes, uses, and application routes of pesticides and their impacts on soil ecosystems and fertility. Moderately hazardous pesticides, which dominate global usage according to WHO, are being applied indiscriminately, degrading soil health as most residues ultimately reach the soil. In Bangladesh and neighboring countries, pesticide use is increasing at an alarming rate. Data from the 81st PTAC meeting indicate that insecticide formulations with mixed active ingredients are most prevalent, followed by fungicides, while herbicides, public health pesticides, and bio-pesticides also contribute to overall usage. Cash crops such as tea, cotton, jute, tobacco, and sugarcane receive the highest insecticide exposure, followed by horticultural and field crops. Only a small fraction of applied pesticides reaches target pests, while the majority disperses into soil, water, and air, posing serious risks to soil-dwelling insects. Reduced species richness and abundance caused by chemical residues threaten soil fertility and ecosystem services essential for nutrient cycling, decomposition, and plant growth, with reported declines in several taxa including Coleoptera, Lepidoptera, and Trichoptera

(IUCN). Promoting bio-pesticides and restricting hazardous chemical applications can help restore soil health, protect beneficial soil insects, and sustain long-term agricultural productivity. Responsible pesticide management is therefore crucial to ensure a safe ecosystem for soil fauna while maintaining soil fertility and crop yield.

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