

Note 2

# Biocontrol

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# Note 2: Biocontrol

## Summary

### Type of nature loss this practice addresses

- ✓ Pollution
- ✓ Land use change
- ✓ Soil degradation
- ✓ Invasive Species

### Type of agriculture this practice is most relevant for

- ✓ Smallholder farms on forest frontiers
- ✓ Agrochemical intensive monoculture
- ✓ Water extractive farming
- ✓ Intensive livestock systems

### Investment bundle

Biocontrol is a key component of alternative pest management, delivering optimal results when integrated with broader sustainable practices such as Integrated Pest Management (IPM) and organic farming.

## Introduction

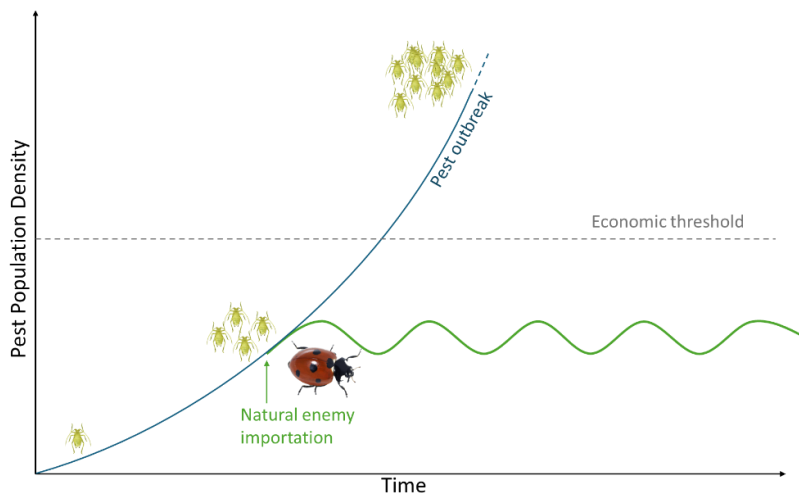
Worldwide, the estimated pesticide use in agriculture is 2.7 million tons (Mt) of active ingredients (FAOSTAT). Despite their accessibility and efficacy, chemical pesticides raise numerous environmental concerns. Chemical pesticides can pollute ecosystems by contaminating soil, air, and freshwater through various pathways, including volatilization [1], spray drift [2], runoff from fields [3], and improper product management [4], like improper disposal of empty containers or incorrect dosage. This contamination can have detrimental effects on aquatic ecosystems [5], harm animals [6], and pose risks to human health through contaminated drinking water sources [7]. The second major concern is the undesired impacts on biodiversity: The use of chemical pesticides is frequently linked to a decrease in populations of non-target species [8], [9], [10], and can also lead to the development of resistance by target species [11], [12], further unbalancing the equilibrium of species populations. Moreover, resistance to pesticides induces the use of alternative and often more potent chemical products, further perpetuating the cycle of environmental harm.

Biological pest control, also called biocontrol, directly addresses the environmental issues caused by the widespread use of conventional chemical pesticides, enhances nature-like processes and minimizes environmental burdens, biodiversity losses and risks to human health. Biocontrol refers to a diverse set of nature-based practices and strategies to pest control using natural enemies. Contrary to the use of pesticides, which aim to directly eliminate harmful organisms, biocontrol relies largely on interspecies predation and parasitism, mediated by active human management, to contain pest populations within an acceptable level. It preserves biodiversity in the ecosystem, creating an equilibrium between pests and antagonists that is favorable to the latter and, ultimately, to the farmers. Biocontrol can also be applied using microbial pathogens and repellents. This type of biocontrol has become more prevalent in recent years with the advancement of microbiology.

Biocontrol constitutes a toolkit for alternative pest management, often adopted as part of Integrated Pest Management (IPM) approaches [13] and organic agriculture systems [14]. Pairing biocontrol with organic agriculture and/or IPM enables a more functional implementation of these systems-based production approaches, helping to achieve the

various benefits these methods offer, which range from improving and preserving biodiversity, to enhancing market positioning of agricultural commodities produced.

There are three basic biocontrol strategies: importation, augmentation, and conservation. Importation involves the new introduction of a pest's natural enemies in an environment where the natural enemy is absent. Augmentation involves the additional release of a pest's natural enemy to increase its population in an environment in which it naturally belongs. Conservation consists in promoting all the practices aimed at favoring the presence of a natural enemy already established in the area. The importation strategy is presented in Figure 1.



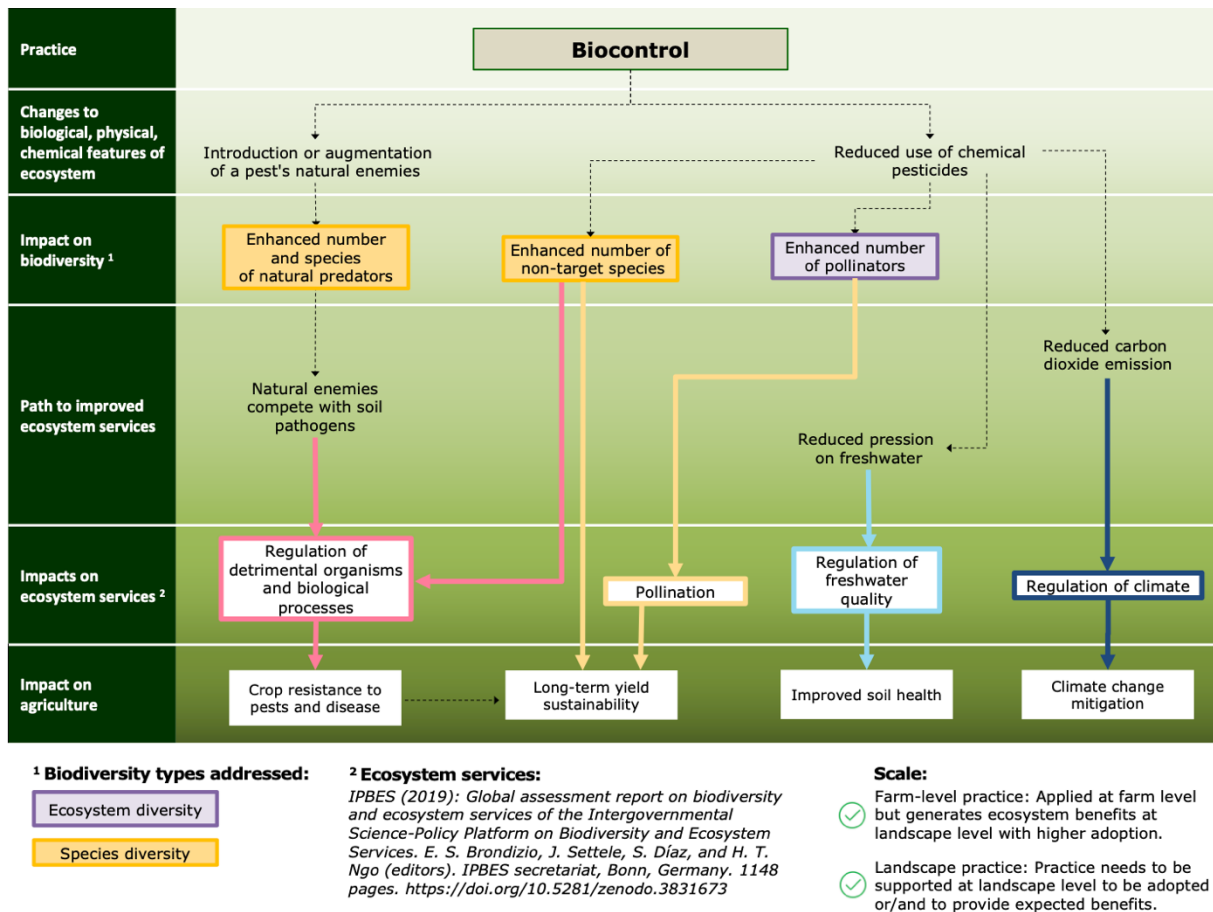
**Figure 1.** Rationale of the Biocontrol importation strategy. To control pest populations (blue curve), a pest's natural enemy is introduced in the area. Ideally, the pest and the natural enemy population will find an equilibrium favorable to farmers (green horizontal curved line). Otherwise, the population of unwanted pests will continue to increase (blue curve segment above the introduction of natural enemies).

Source: Authors

## Pathways to Reduced Nature Loss

### Assessment of impacts

The paragraphs below describe the pathways through which biocontrol affects biodiversity and the subsequent pathways through which it impacts ecosystem services that support agriculture. These pathways are summarized in Figure 2.



**Figure 2.** Pathways through which biocontrol contributes to reduced nature losses

Source: Authors

Biocontrol can contribute significantly to biodiversity enhancements and to provisioning and regulation services generated by the agroecosystem. First, augmentation and the introduction of natural pest enemies increases species diversity. By promoting beneficial organisms and natural pest regulation mechanisms, biocontrol fosters a more resilient and adaptable system that can better withstand perturbations [15], [16]. This resilience translates into reduced risk of pest and disease outbreaks, since the pest and disease control service, already provided by the natural agroecosystem, is preserved and enhanced. Thus, as a pest control practice, biocontrol enhances the supply of provisioning services by preventing crop losses [17], [18] and improving long-term sustainability of crop yields.

Different supporting ecosystem services are improved. For example, there is also the possibility of using pollinators to operate biocontrol, enhancing the agroecosystem's pollination services, like in the reported case of using Syrphids species to control in-field aphid populations [19].

A second pathway through which biocontrol can affect biodiversity is the use reduction, or avoidance altogether of chemical pesticides. This can help preserve the habitat of numerous species with a positive impact on the agroecosystem's fauna [20], [21], [22]. Reducing or avoiding chemical pesticides also helps regulate the chemical condition of freshwater and atmosphere, significantly reducing the risk of water and air pollution. Biocontrol also regulates greenhouse gases by preventing emissions linked to pesticide production, transportation, and spread [23], [24].

Biological control has been successfully applied across different agricultural contexts, in a variety of production systems, and with different organisms involved. Here are some examples of successful biological control actions:

- Ladybugs and aphids [25], [26], [27]: This is a classic example of biocontrol through pest predation. Ladybugs are natural predators of aphids, consuming large quantities of these pests. Farmers can introduce ladybugs into their fields or create habitats within their farms to attract them naturally. They are frequently applied to strawberry production [28].
- Wasps and Lepidoptera larvae [29], [30]: Various species of wasps are used for biological control, acting as parasitoids on the larvae of butterflies and moths. These wasps lay their eggs inside the larvae, and the developing wasp larvae feed on the host, ultimately killing it. This approach is particularly effective against specific moth species targeting crops like cotton [29].
- *Bacillus thuringiensis* and Lepidoptera larvae [31], [32]: This example utilizes a naturally occurring soil bacterium, *Bacillus thuringiensis*, which produces toxins lethal to specific pests. *Bacillus thuringiensis* can be applied as a spray or incorporated into genetically modified crops (Bt crops) that express the toxin directly, offering protection against harmful caterpillars [33].

## Barriers to adoption

Biocontrol is a promising tool that can be incorporated into sustainable pest management. However, its effectiveness requires the adoption from a large number of farmers, alongside appropriate management and coordination at landscape level, because the habitat of many of the organisms involved extends to spatial scales beyond a single farm or plot [34]. Nonetheless, adoption of biocontrol faces several barriers and limitations that restrict its widespread implementation and diffusion. First, the affordability of pesticides frequently undermines the economic feasibility of biocontrol. In-field application of this practice often fails to reach the necessary efficacy [19], [35]. Insects used as biocontrol agents may fail to establish themselves in the desired environment for a combination of reasons involving hyperparasitism (the insect is prey to other insects) and other competition behaviors [34]. As a result, biocontrol is often referred to as a knowledge-intensive approach [14]. It often requires a good understanding of the ecological dynamics involved, including the biology of both the pest and the natural enemy. Therefore, farmers must be adequately trained and informed to implement biocontrol strategies effectively. This may become more problematic in countries with insufficient agricultural extension services [36].

Stringent regulatory policy frameworks concerning use of biocontrol agents have also been reported as a barrier to a wider spread of the practice [37], [38].

Additional constraints to a wider adoption of this practice include farmers' risk attitudes and perceptions. Specifically, farmers' high-risk aversion prevents them from moving beyond business-as-usual practices, and thus holds back the adoption rate [39]. Moreover, the underdevelopment of the biocontrol industry, and of the marketing of biocontrol products, compared to the chemicals industry, results in lack of awareness and further discourages farmers from implementing the practice [39].

## Key knowledge and evidence gaps

There is some evidence that gender may affect adoption of biocontrol, as demonstrated by a study in Pakistan which revealed that women exhibited higher willingness to adopt relative to men [40]. More evidence is needed to render this finding useful in developing strategies aimed at promoting the practice of biocontrol. For instance, implementing targeted training

programs for women, or focusing efforts in regions where women have a more active role in farm management could improve the expected outcome. The literature also indicates the need for more frequent economic assessments showing the benefits of the practice [41]. These assessments would be beneficial for promoting targeted interventions for a wider implementation of biocontrol.

## Conclusions

Climate change projections indicate a potential rise in the frequency of pesticide application, increasing environmental risks and biodiversity losses [42], [43]. Those risks are even higher in developing countries due to the application of products that are banned in other countries [44] and the use of inappropriate, or damaged spraying equipment [4]. Biocontrol offers a compelling alternative to conventional chemical pesticides, promoting a healthier environment, responsible resource management and biodiversity conservation. However, promoting the implementation of biocontrol requires (i) the mobilization of public stakeholders to increase farmers' awareness of the benefits of the practice; and (ii) stronger extension services and their closer collaboration with farmers to ensure proper landscape management can bring about the expected positive outcomes [38]. This highlights the potential benefit of investments to enhance the biocontrol implementation, ensuring its accessibility for farmers and overall effectiveness as a pest management practice. In summary, while biocontrol shows great potential for pest control, it is important to acknowledge its limitations and work toward creating a supportive environment for its adoption.

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# CGIAR Nature Notes

This note is part of a series of 15 publications on sustainable agricultural practices to mitigate agriculture-driven nature loss, particularly biodiversity. Sustainable agriculture practices are defined as technologies or approaches that mitigate selected types of nature loss or enhance positive impacts on nature, are economically viable, support livelihoods, and include diverse smallholders. The note examines agricultural drivers of biodiversity loss, impacts on ecosystem services and consequences for agriculture.

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