Note 1

Minimum tillage

December 2025

Note 1: Minimum tillage

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

Investment bundle

As a practice belonging to the conservation agriculture production paradigm, the effectiveness of minimum tillage is increased when applied together with crop rotation and soil organic cover (e.g., green manure). It can also present synergies when combined with Integrated Pest management (IPM)

Introduction

Soil tillage represents a key agricultural management practice for crop production, serving multiple purposes. Primarily, it is used to control weeds and increase the soil organic matter mineralization rates, making nutrients more available to plants. Other potential benefits are improved soil aeration and water filtration. However, extensive use of tillage has proven unsustainable for soil maintenance and climate regulation. Deep plowing and other cultivation practices lead to soil degradation by increasing susceptibility to erosion [1], soil runoff [2], and by reducing microbial diversity and activity [3].

Minimum tillage and no-tillage (also known as zero-tillage) address these problems by reducing soil cultivation to a minimum, or entirely avoiding it, thus promoting less disruptive and potentially more sustainable agricultural management. Specifically, no-tillage eliminates traditional plowing practices with the use of direct seeding. To be effective, direct seeding is preceded by other land preparation practices, including chemical or mechanical weed control (e.g., slashing), removal of the previous crop residues, or cover crops to create a mulch layer. Crop residues are retained entirely, or at a suitable level to ensure complete soil coverage. Seeding is then done directly through the mulch layer or through narrow slits for seed placement. Occasionally, direct seeding can be done just before harvesting the previous crop. This practice, known as relay cropping, is used to reduce weed emergence during the period the land would otherwise lie fallow. Finally, direct seeding can be also done jointly with fertilizer and amendment applications. Minimum tillage is also promoted as a method to reduce air pollution, for instance in India, where previously farmers used to burn rice straw but now apply direct seeding on cut crop residues which are spread as mulch.

Minimum tillage is one of the most widely adopted sustainable practices for its beneficial outputs and applicability to a diverse range of agriculture types and contexts. It is also a key building block of the conservation agriculture approach [4]. Conservation agriculture was developed to prevent soil erosion and degradation and consists of three practices: minimum tillage, soil organic cover and crop rotation [5]. These practices, when applied as a bundle, promote agrobiodiversity enhancements which provide agronomic weed control strategies and reduce the dependence on chemical herbicides.

Pathways to Reduced Nature Loss

Assessment of impacts

The paragraphs below describe the pathways through which minimum tillage affects biodiversity and the subsequent pathways through which it impacts ecosystem services that support agriculture. These pathways are summarized in Figure 1.

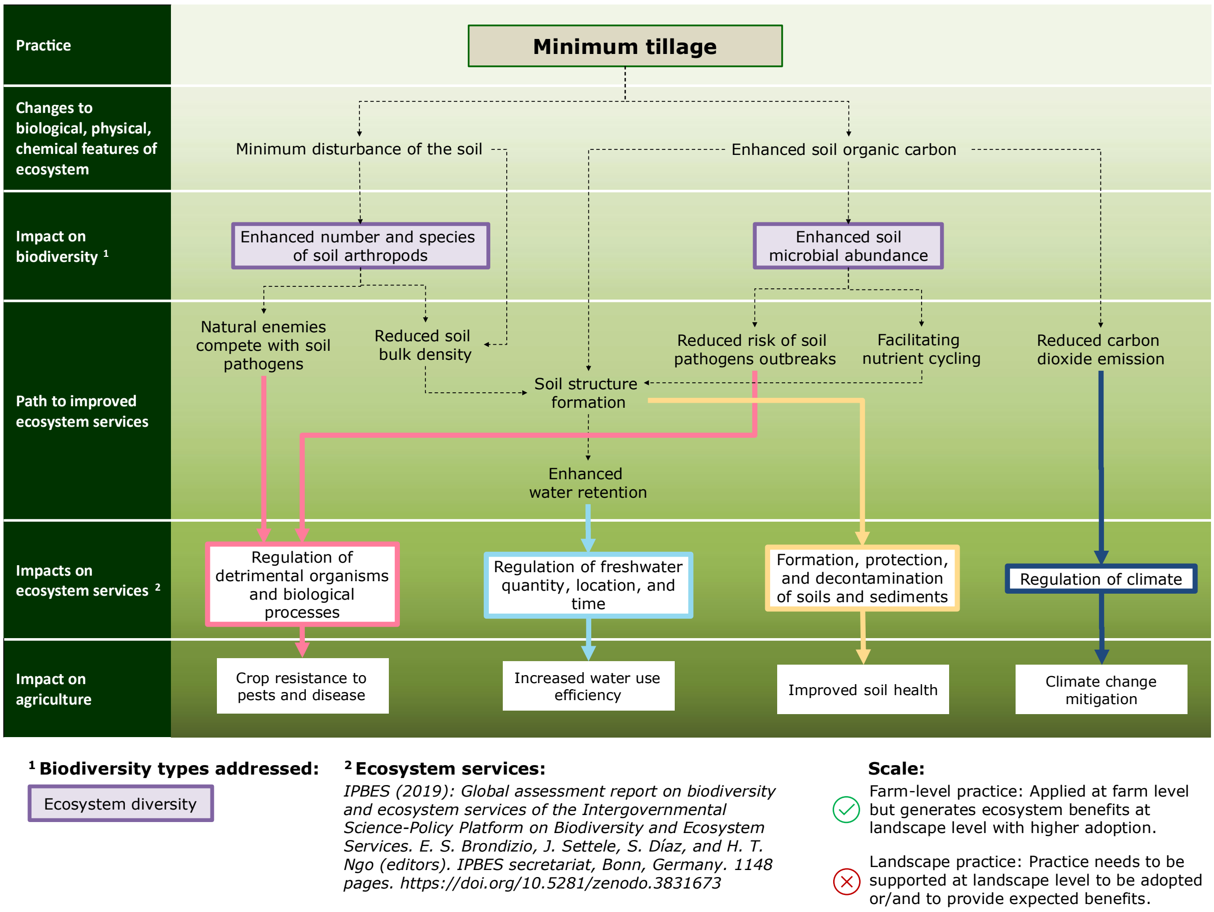


Figure 1. *Pathways through which minimum tillage contributes to reduced nature losses*

Source: Authors

The positive impacts of the practice are numerous and span from long-term yield stability and enhanced economic sustainability, with some studies showing increased profits and yields and decreased costs, to environmental benefits like reduction of fossil fuel combustion, biodiversity conservation, and carbon dioxide sequestration.

Avoiding or minimizing soil disturbance and soil compaction helps create a favorable environment for a diverse range of soil organisms, including beneficial microbes, fungi, and invertebrates. Hence, a complex food web that competes with soil pathogens is fostered [6], leading to high crop resistance to pests and diseases [7]. Minimum tillage also preserves earthworm populations [8] which contribute to the formation of stable soil aggregates by mining the soil and mixing organic matter with soil inorganic components, enhancing the overall soil structure.

Minimum tillage affects the soil's physical properties [9] by reducing soil bulk density, resulting in better water filtration and water retention and reducing evaporation and soil erosion losses [10]. Hence, numerous studies advocate for replacing conventional tillage methods with conservation tillage practices, like no-tillage, to enhance soil water retention and maximize water use efficiency.

Scientific literature also supports the effect of minimum tillage on increasing soil organic carbon [11], [12], which increases soil microbial abundance. This is a second pathway through which minimum tillage increases resilience against pest and disease outbreaks, since specific microbial communities can act as biological control agents that suppress pathogens. For example, beneficial fungi arbuscular mycorrhizae benefit from undisturbed soils, forming symbiotic relationships with plant roots. These fungi outcompete harmful pathogens and promote nutrient uptake by symbiotic plants [13]. Moreover, soil microbial abundance enhance the soil suppressiveness capacity. In suppressive soils, a diverse and abundant community of beneficial microorganisms outcompetes soil-borne pathogens for resources like space, nutrients, and water, thereby inhibiting pathogen growth and reducing the likelihood of disease outbreaks. For the above reasons, minimum tillage is often considered to present synergies with Integrated Pest management (IPM) approaches [14].

Increasing soil biodiversity can also enhance agricultural productivity by facilitating nutrient cycling. This is achieved by retaining crop residues on the soil surface, promoting the activity of decomposers. These organisms break down organic matter, speeding up the release of essential nutrients.

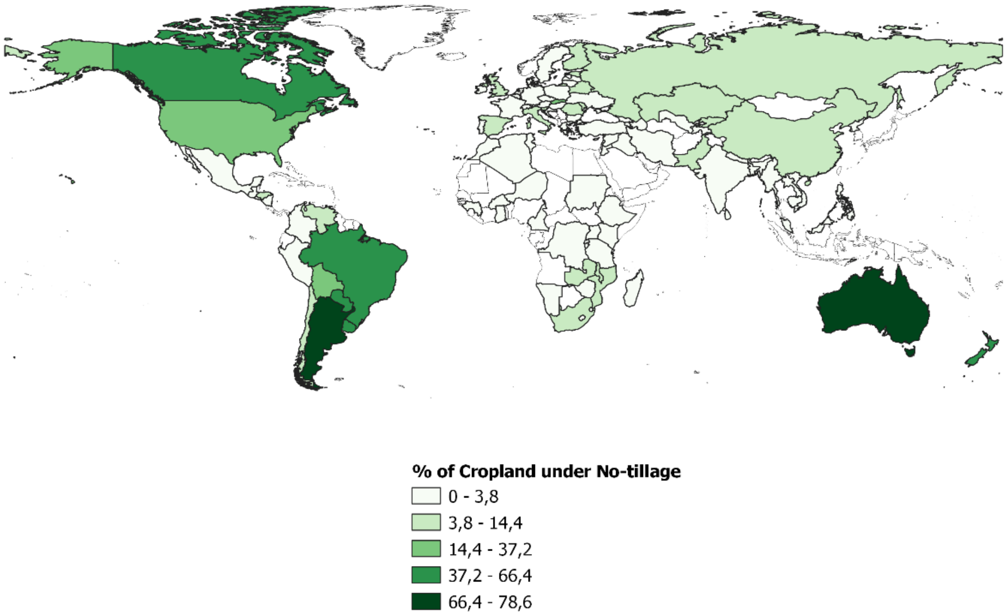
Chemical soil properties, and overall soil health, are also affected by this practice; minimum tillage prevents the decrease in soil organic carbon and nitrogen caused by traditional plowing. For this reason, organic carbon and nitrogen, which are important for plant health, are found in higher concentrations in soils under no-tillage management [15]. Improved soil organic carbon functions as carbon storage, mitigating the effects of climate change by reducing the greenhouse gases in the atmosphere [16].

Barriers to adoption

Despite the demonstrated environmental benefits, minimum tillage also has limitations. First, it may cause yield reductions in situations where agricultural environments involve cold springs, sub-optimal soil temperatures, and poorly drained, heavy-textured soils [17]. Since the practice is often used in monoculture systems and combined with chemical weeding, extensive use of herbicides could offset the beneficial effects of the practice by potentially limiting agrobiodiversity and causing the selection of herbicide-resistant weeds [18]. Herbicide (ab)use can be moderated by applying minimum tillage along with other agricultural practices like crop rotation [19], another practice belonging to the conservation agriculture paradigm (Note #13 on Crop Rotation). An alternative to the minimum tillage herbicide system can be found in the use of cover crops (see Note #4 on Green Manure) with the drawback of more difficult weed control [20].

The adoption of minimum tillage is worldwide (Figure 2) and constantly increasing [21], with the highest adoption rate in South American countries [4], followed by Australia and New Zealand. The high adoption rate of minimum tillage in these countries suggests that the technological barriers to adoption are not too constraining, and that the practice is found to be economically sustainable and suited for the local conditions [22]. High adoption can also be explained by the fact that minimum tillage can be applied to various crop types and to different farm sizes, and it is a popular practice for some of the most cultivated crops, like maize and soybeans. For example, the no-till soybeans system does not significantly decrease yield [23] and helps reduce costs, resulting in an economically convenient practice [24].

Figure 2. *Minimum-tillage diffusion worldwide– by country*



Source data: Cropland: [FAOSTAT](); No-tillage area: [25]; Administrative Boundaries: World Administrative Boundaries - Countries and Territories — Opendatasoft

However, the distribution of adoption of no-tillage globally is uneven, and some countries have not widely adopted the practice despite its potential benefits. African countries have the lowest percentage of adoption overall due to technical and environmental constraints. Technical barriers such as access to herbicides and appropriate seeding equipment, needed for an easy application of the practice, is a constraint for low-income and small-size landholders. Minimum tillage may be of particular interest for countries where water management is critical. In Kenya, for example, minimum tillage in conjunction with organic mulching has been proven to increase the amount of water stored in the soil and improve soil drainage [26]. Difficulties in weed management are also considered a constraint to scaling out of minimum tillage practices, particularly in South Asia, and when combined with limited labor availability, eventually leads to more dependence on herbicides [27].

Moreover, for economic reasons, some farmers may prefer using the soil coverage biomass for other purposes, like fuel sources. Lower adoption rates can occur in low-income countries where no incentives or relevant policies are in place and farmers are less aware of the benefits of minimum tillage [25]. However, thanks to the recognized environmental benefits, support from governments and institutions is becoming more frequent. For example, the African Conservation Tillage Network, in partnership with FAO and national governments, is improving farmers' access to training and innovative farming equipment, promoting conservation agriculture and minimum tillage practices.

Barriers to adoption may also include cultural reasons, as shown by a household survey from the Philippines in which all respondents considered tillage to be a necessary farm practice, since it is traditionally linked to the role of man as a farmer [28]. Similar findings have been reported in Sub-Saharan Africa where minimum tillage has been found to be the least preferred practice among all conservation agriculture practices, because it contradicts the traditional approach to land cultivation [29].

Key knowledge and evidence gaps

While the environmental benefits of minimum tillage are well documented, the social and gender impacts are less understood. Existing literature is inconclusive about how the practice can alter the labor distribution among men and women in the household; in the absence of labor availability constraints, there is not enough evidence to suggest that minimum tillage adds more labor burden to women relative to men, since findings from different regions are contradictory [27].

Conclusions

Overall, minimum tillage is a practice that can promote sustainability, both economically and environmentally. It improves soil biodiversity, enhancing soil quality, and contributes to climate change mitigation. These biodiversity gains also lead to enhanced economic results. However, it may not be a universal solution since it is usually combined with increased use of herbicides and sometimes associated with monocropping. To avoid those drawbacks, efforts should be made to promote this practice in combination with IPM but also with other conservation agriculture practices like crop rotation and cover crops. Hence, technical support is needed to foster the optimal use of minimum tillage, particularly in areas where mechanization is limited, or in semi-arid areas, where the potential benefits of this practice are the highest.

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Sustainable Practice 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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