SCIENCE FOR A FOOD-SECURE FUTURE

Note 6

Mechanical soil and water conservation

December 2025

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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
Mechanical soil and water conservation practices belong to the set of climate-smart agriculture (CSA) farming methods and should be promoted as a part of interventions targeting CSA.

Introduction

In semi-arid areas, where water scarcity and poor soil condition pose significant threats to agricultural production and to the livelihood of individual smallholders and communities, water and soil management are critical for food/water security. Limited renewable freshwater and erratic rainfall patterns in those areas restrict the reliance on irrigation, making water conservation strategies more pressing and necessary [1].

Moreover, implementing advanced irrigation systems may be challenging due to limited resources and a lack of technical expertise [2]. For smallholder farmers, the adoption of irrigation systems, such as drip irrigation, is limited by further constraints such as high costs, limited access to finance, lack of technical support, and may not be suitable for all local conditions and cropping systems [3]. Under these constraints, promoting water and soil conservation strategies practices as part of a broader water management package to increase agricultural productivity at the farm level becomes crucial for ensuring sustainable agricultural production [4], [5].

These practices aim to minimize soil degradation, enhance water retention, and improve overall land productivity. The practices falling under these broad categories are numerous and context-specific, often very similar but with different local names. Among those, water harvesting practices and runoff limitation practices stand out as some of the most effective methods [6]. Water harvesting practices collect and store rainwater to provide water for human, animal, or crop use [7]. The water thus collected can either be utilized immediately or stored in ponds or cisterns for subsequent utilization. Runoff limitation practices consist of mechanical means, usually made of stones, soil, and plants, that prevent runoff of water and soil due to excessive inclination of the land and to rainstorms generating transient excess of water.

Overview of Water Harvesting Practices

Semi Circular Bunds: Also known as demi-lunes [8], this water harvesting practice involves excavating half-moon-shaped basins in the soil. The concave area within the demi-lune is a catchment for water flowing down the slope from higher ground. The design of demi-lunes varies based on factors such as topography, climate, and vegetation requirements. In arid conditions, the bunds are constructed larger and feature spillways to accommodate excess water. Conversely, in regions with higher precipitation, multiple bunds of smaller radiuses are built per hectare to manage water flow effectively.

Tied ridges: The term refers to small basins utilized for planting seeds of both annual and perennial crops [9]. The pits are typically provided with amendments like mulch, manure, or nutrient-rich soil to enhance soil fertility and water retention capacity. Additionally, tied ridges protect the seeds and soil organic matter from water runoff. This practice is used under various names in different countries - i.e., *Chololo pits* in Tanzania, *Zaï pits* in Burkina Faso, *Tassa* in Niger.

Enarenados: Also known as "*arenados*", this is commonly practiced in the Canary Islands (ES) [10]. It involves the construction of semi-circular or crescent-shaped stone walls, the "*enarenados,*" around individual plantings or small plots of land. These stone walls create microclimates, acting as windbreaks and shielding plants from excessive heat and moisture loss due to evaporation. Additionally, the stone walls serve to trap moisture from fog and dew.

Overview of Runoff Limitation Practices

Terracing: An ancient method for farming on hills and sloped lands aimed at soil conservation. The technique was already used before the 3rd millennium BC in the Yemen Highlands [11] and today is practiced worldwide. It involves constructing platforms to form step-like structures along the slope. Additionally, the flat surfaces provide more efficient and productive farming areas on steep terrain. “Fanya juu” is a variation of the method from Kenya [12].

Stone Lines: These are arrangements of stones placed in line along contours, varying in size, following the slope orthogonally [13]. They enhance infiltration and retain sediment while making water and nutrients accessible for crops. Plants, such as vetiver grass (*Chrysopogon zizanioides*), are sometimes used to stabilize the stone lines, reduce water runoff and soil erosion, and create terraces [14].

Grassed Waterways: Vegetated channels designed to carry runoff from fields to nearby water bodies [15]. They are planted with grass or other vegetation to stabilize the soil, filter sediment, and reduce erosion.

Both water harvesting practices and runoff limitation practices are part of the climate-smart agriculture set of farming methods [16]. Climate-smart agriculture uses adaptation methods to mitigate the impacts of climate change, aims to increase agricultural productivity, and reduce greenhouse gas emissions from agriculture.

Pathways to Reduced Nature Loss

Assessment of impacts

The paragraphs below describe the pathways through which mechanical soil and water conservation practices affect biodiversity and the subsequent pathways through which they impact ecosystem services that support agriculture. These pathways are summarized in Figure 1.

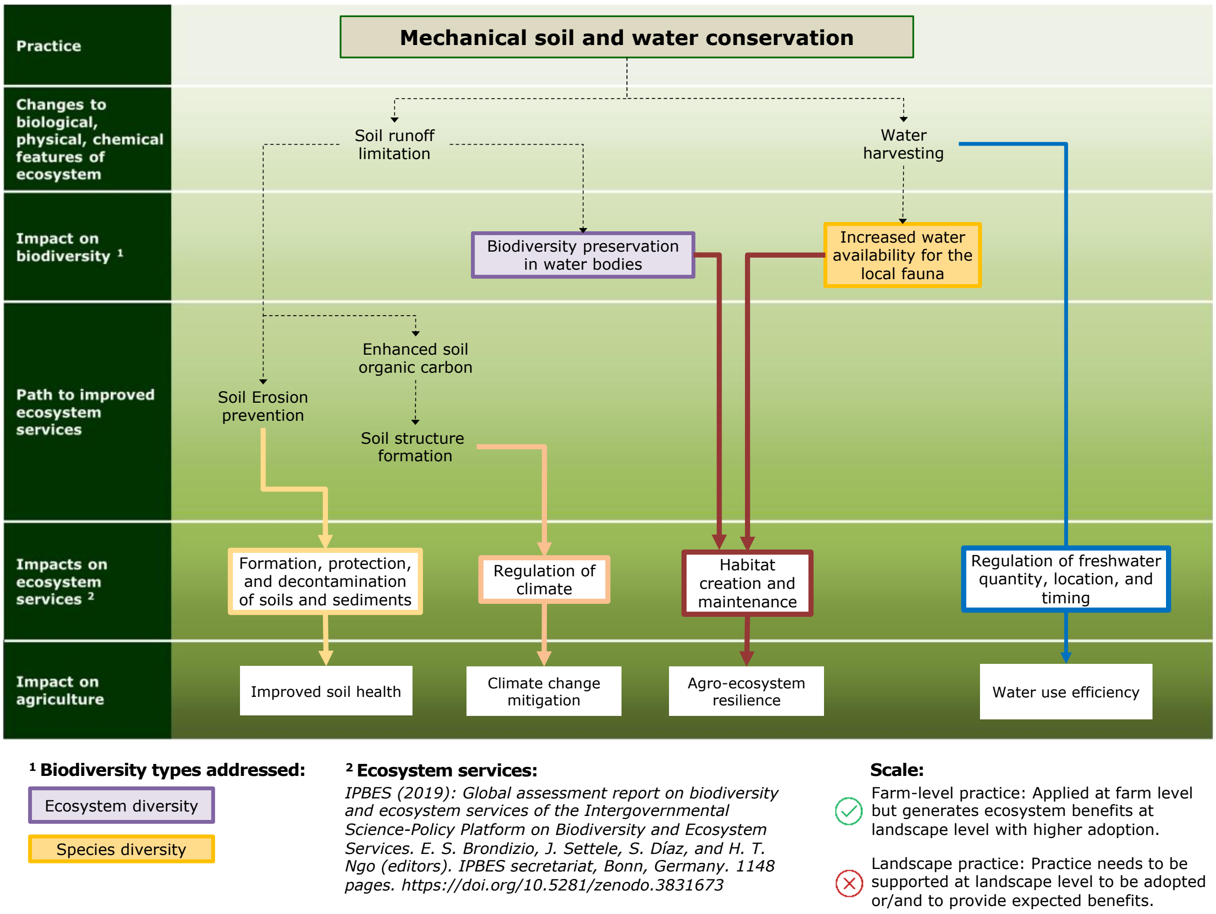

Figure 1. *Pathways through which mechanical soil and water conservation practices contribute to reduced nature losses*

Source: Authors

Water and soil conservation practices encompass various environmental benefits functional to agricultural sustainability and ecosystem health. The primary impacts of these practices are reducing soil runoff and enhanced water harvesting capacity [17]. Soil runoff accelerates soil organic matter degradation, reducing the amount of carbon stocked into the soil, thus reducing the climate mitigation service provided by the soil carbon sink. Limiting soil runoff also prevents soil erosion which has multiple beneficial consequences for agricultural production and the environment. Soil erosion lowers overall soil quality by reducing the topsoil depth, depleting nutrients, and reducing water availability for plants, provoking a reduction of soil fertility and, ultimately, a potential yield decrease. Additionally, soil erosion can also cause freshwater pollution by carrying sediments within water bodies [18].

The impact of the practices on soil erosion shows significant variability, being affected by the different climatic, topographic, and management systems where the practices are applied [19]. In a field trial, stone lines reduced runoff by 73% [17]. Terrace farming has even been found to reduce soil erosion by up to 90% [19].

Water provision is the result of harvesting systems capturing and storing rainwater and air humidity, increasing water availability for agricultural purposes. Collecting water runoff ensures a reliable supply of water during dry periods, thereby enhancing water security and supporting crop irrigation, livestock watering, and household use. Besides water provisioning, those techniques have the potential to enhance biodiversity. Studies demonstrated that birds and arthropods benefit from the augmented water availability in semi-arid areas [20], [21].

Barriers to adoption

Several factors affect uptake of soil and water conservation practices. One important factor is land tenure and land rights– evidence from Rwanda, participants in a land registration program were twice as likely to use bunds, terraces, and check dams [22]. Land tenure insecurity in Malawi was shown to have a negative effect on soil conservation [23]. In Uganda, knowledge of land rights increased soil conservation [24]. Evidence from Sub-Saharan Africa reveals that training farmers and raising awareness about potential positive economic and environmental impacts are the most important factors driving adoption of water conservation practices [25]. Moreover, these factors have been found to exert a greater influence on adoption than financial, or liquidity constraints that farmers may be facing [26]. Similar results are also reported in Europe (Italy) where adoption of water and soil conservation practices is driven mainly by the policy emphasis on environmental protection, rather than water scarcity. Yet, even under such an institutional setting, communication of potential productivity benefits, and raising overall awareness of farmers have been found to be key adoption determinants [27]. Gender also appears to play a role in the adoption of water conservation practices, since the labor-intensive and time-consuming nature of mechanical soil and water conservation practices may prevent female-led farms to adopt those practices [28], as may lack of land rights.

These results suggest that promoting water conservation practices should pay attention to land tenure issues and then provide knowledge, primarily target the mobilization of extension services and other actors who are able to inform farmers and influence their behavior, either through formal means (e.g., trainings) [26], or informally (e.g., social networks and co-learning) [28]. Mechanisms to help put the knowledge into use can then be considered (e.g., providing credit or materials).

Key knowledge and evidence gaps

Although evidence has demonstrated the impact of water and soil conservation practices, some knowledge gaps exist, including how traditional water and soil conservation practices can be better integrated with modern agricultural technologies and other farm practices [29]. Second, while evidence suggests that training and awareness raising have a positive effect on adoption, the mechanism through which this occurs is still not well understood. For example, it is still not clear why farmer schools may be more effective in promoting adoption, compared to cash transfers that alleviate liquidity constraints [26]. More research is needed to generate behavioral science evidence to understand the underlying adoption mechanisms [30]. Moreover, there is also lack of evidence on the role of gender and land tenure security in affecting water and soil conservation [31]. Such evidence is crucial for policy makers to better understand the role of the tools at their disposal which can provide the appropriate nudge to farmers' behavior and promote adoption of conservation practices [32]. Finally, much of the literature focuses on short- or medium- term effects of soil and water conservation practices, often promoted and adopted as a response to an existing or expected drought or other unfavorable environmental conditions (e.g., soil erosion). However, there is very limited data on the long-term impacts (benefits or potential drawbacks) of these conservation practices on soil health, water availability, and overall ecosystem resilience, with even more limited evidence regarding their long-term socio-economic impacts [33].

Conclusions

In conclusion, water and soil conservation practices play a crucial role in mitigating the impacts of water scarcity and poor soil conditions in semi-arid regions, where agricultural production and livelihoods are at risk. They are most needed in the farming contexts of smallholder farmers, where the high costs and knowledge needed by classical irrigation investments are challenging. These practices not only contribute to food and water provisioning, strengthening food security, but also help in climate mitigation and biodiversity enhancement. Better understanding the long-term impacts of conservation practices, particularly when they are integrated with modern technologies, remains a priority that needs to be addressed to inform decision-making and sustainable agricultural development.

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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.

The 15 notes were developed to support preparation of the World Bank report Rooted: Agriculture Rooted in Biodiversity. We are grateful for the financial support of the World Bank Group in preparing this note. The World Bank Group is not responsible for the content or accuracy of this note. The work was supported by and benefited from the CGIAR Nature-Positive Solutions Initiative and Multifunctional Landscapes Science Program.

Suggested citation: Antonio Paparella, Athanasios Petsakos, Kristin Davis, Chun Song, and Eleonora De Falcis. 2025. Mechanical soil and water conservation. Note 6. Sustainable Management Practices to Mitigate Agriculture Driven Nature Loss. International Food Policy Research Institute and the Alliance for Bioversity International and CIAT.

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