

## Note 9

# Sustainable manure management

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# Note 9: Sustainable manure management

## 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

Sustainable manure management can play a key role in the circular economy transition by converting organic matter from agri-food systems into energy through biogas plants. Investors in this practice could also consider waste to animal feed for enhance circular bioeconomy effects. While the initial investments in certain infrastructure may be significant, the potential for a transformative impact on the entire system is substantial.

## Introduction

Manure is any excrement and urine of farmed animals and is considered a resource or waste, depending on where and how much is produced, and how it is used. It is an essential source of nutrients for plants, and it has been used for fertilizing soil and enhancing crop production since the advent of agriculture [1]. It reduces the reliance on chemical fertilizers in situations where they can be hard to find (or to afford) and in contexts like organic agriculture, where chemical fertilizers are avoided for ethical or policy reasons. Manure production worldwide is increasing [2] due to the growing demand for meat and animal-based products [3]. This trend raises concerns about the potential threat to ecosystems posed by manure, since several factors can contribute to environmental pollution hazards [4]. Manure contains high levels of nutrients like nitrogen and phosphorus. When manure is applied to soil in excessive amounts, or during periods of heavy rainfall, these nutrients can enter nearby water bodies through the processes of leaching and runoff [5]. High levels of nitrates in water bodies can lead to excessive and rapid growth of algae, causing oxygen depletion and eutrophication [6]. This process can lead to the death of fish and other aquatic organisms that depend on oxygen to survive, ultimately resulting in habitat degradation and loss of biodiversity [7]. In fact, untreated manure spread onto soils is generally considered the principal cause of eutrophication [8], [9] and of nitrate freshwater pollution from agricultural sources [10]. [7]

Another source of pollution is ammonia volatilization. Ammonia is the main nitrate component in manure and is a greenhouse gas. When manure is spread, especially under warm and humid conditions, ammonia is not consumed quickly enough by soil microbiota and volatilizes into the atmosphere, contributing to climate change [11]. Potential pollution can also occur through soil contamination by harmful pathogens, like viruses and bacteria [12]. These pathogens can be transported through runoff or leaching into water bodies, posing risks to human health and ecosystems. Finally, manure may contain heavy metals, which can originate from the diet of the animals [13]. When manure is applied to the soil, these heavy metals can accumulate over time, leading to soil pollution [14]. All these environmental risks

are even more serious in intensive livestock landscapes, where more manure is spread onto limited land.

To avoid the negative impacts of manure use and to promote sustainable agricultural production systems, farmers have no choice but to adopt some system of manure management. Sustainable manure management practices can be of different scales and address different pollution risks. Among the various manure management strategies, manure anaerobic digestion for biogas production [15], [16], [17] and manure composting [18] emerge as promising and effective tools. While the first implies industrial technologies for producing energy from unused manure, the second refers to a treatment which makes manure easy to apply to the soil and can also be promoted in contexts where the lack of infrastructure may constrain high-technology initiatives.

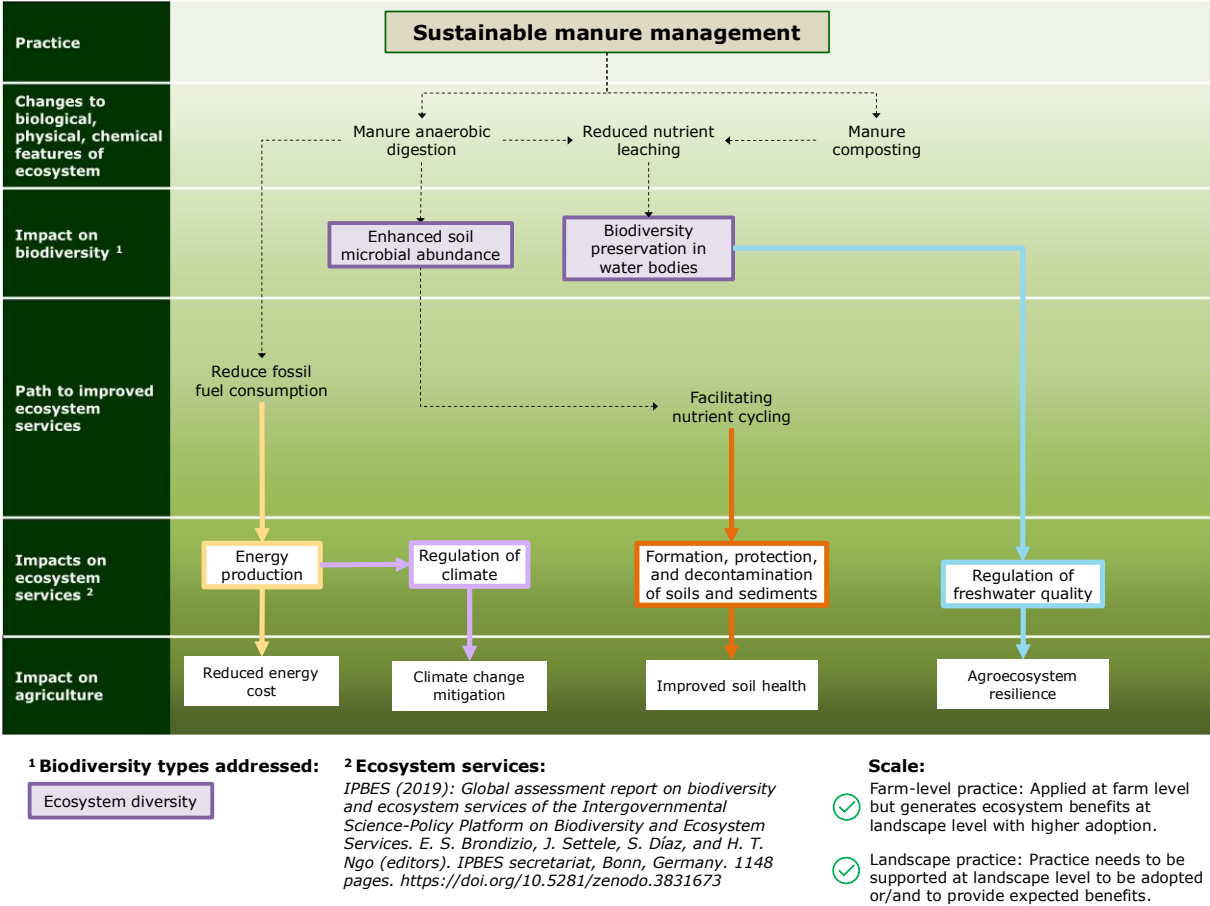
Biogas production from manure is an industrial process that aims to produce energy by transforming the manure's organic content into biogas via anaerobic digestion, carried out by specific bacteria [1]. Biogas is a mixture of principally methane and other gases that can be burned, producing heat and energy. The byproduct of the process is a digestate that can be used to fertilize soils and whose physiochemical characteristics are less dangerous for the environment [19]. The process can also be complemented with nitrogen sequestration, leading to a low nitrate digestate [20].

An alternative management practice, aimed at lowering the environmental risks from manure use, is manure stabilization via composting. Manure composting is a controlled decomposition process where microorganisms break down organic matter into a stable, humus-like material called compost [21]. In this process, manure is usually mixed with other organic materials, such as straw, to provide a balanced carbon-to-nitrogen ratio and ensure proper aeration. The organic pile is periodically turned or aerated to provide oxygen to the microorganisms and facilitate decomposition. As the organic matter decomposes, heat is generated, which helps kill pathogens and weed seeds present in the manure [22]. The resulting compost is a nutrient-rich soil amendment that improves soil structure, moisture retention, and nutrient availability when applied to agricultural fields [23].

# Pathways to Reduced Nature Loss

## Assessment of impacts

The paragraphs below describe the pathways through which sustainable manure management 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 sustainable manure management contributes to reduced nature losses

Source: Authors

Composting and biogas production are two sustainable methods capable of mitigating different environmental impacts of improper manure management. However, the magnitude of these environmental benefits depends on the strategy and the context in which the methods are applied.

The main environmental benefit of the anaerobic digestion is that the produced biogas can be used as a renewable energy source for heating and electricity generation [24], which reduces dependence on fossil fuels, reduces greenhouse gas emissions generated by fossil fuel consumption, and therefore contributes to climate change mitigation and to energy. Furthermore, biogas production helps manage pathogens [24], [25], improving soil and water quality. The anaerobic conditions under which biogas is produced devitalize weed seed and fly larvae, facilitating pest control. The treatment process shows efficacy in devitalizing *Brucella* bacteria, thereby reducing the risk of brucellosis transmission. The resulting digestate from biogas production can be utilized as a nutrient-rich biofertilizer, completing the nutrient cycling loop, reducing the need for chemical fertilizers, and promoting soil health. Moreover, if combined with nitrogen sequestration systems, anaerobic digestion reduces the pressure on water bodies of nutrient runoff [26].

Manure composting also offers several environmental advantages. Firstly, by avoiding anaerobic conditions, composting prevents the emission of greenhouse gases, like methane and nitrous oxide which produced in traditional manure storage systems [27]. Additionally, composting stabilizes nutrients in the manure, reducing the risk of nutrient leaching and eutrophication of water bodies [28], thus preserving biodiversity in water bodies. The resulting compost acts as a soil conditioner, improving soil health and fertility while reducing the need for synthetic fertilizers [29].

Both methods described above make use of the manure from livestock to produce higher-value products (i.e., energy, digestate, and compost). For this reason, scaling them out is an example of the sustainable production paradigm of the circular economy [30], [31].

## Barriers to adoption

Despite the many potential benefits, widespread adoption of sustainable manure management practices faces significant barriers. Correct implementation requires substantial investments for appropriate facilities and a high degree of expertise and coordination among farmers and other public and private stakeholders across a diverse set of activities—generation, collection, treatment, storage, transport, and end use application (biogas production or use as fertilizer) [32]. All these activities for both composting and biogas production are considered labor-intensive, which means that farms in regions facing labor availability constraints are less likely to adopt sustainable manure management practices [33], [34]. Some authors have also claimed that allocating time to sustainably manage manure is beyond the interest of most animal producers, who are primarily concerned with the economic performance and management of their farm [32]. This appears to be linked to the perceived lack of environmental awareness which has often been found to affect adoption [34], even in European Union countries where the implementation of strategies for manure management (or waste management in general) is imposed by legislation [35].

The two management strategies described above are applicable at different scales and are therefore subject to additional specific adoption barriers which are related to the end use product of their underlying processes. Hence, composting is a practice that can be adopted at farm level, but adoption is highly dependent on farmers' perceptions about the use and affordability of organic fertilizers in general, as opposed to chemical fertilizers. Although

recent volatility in chemical fertilizer prices due to global food supply chain crises (COVID-19 and the Russian invasion of Ukraine) strengthens the economic argument for manure as an alternative to chemical fertilizers, and therefore for composting, the economic incentive to adopt composting has generally been limited because of the high costs associated with manure treatment [32], [36]. Nevertheless, several studies have shown that appropriate subsidies can make composting economically viable for farmers, thus authors advocate for similar economic incentives to boost adoption of the practice [33], [34], [35]. Finally, adoption may be affected by gender norms, like in the case of Malawi, where social perceptions about gender labor division did not allow women to have a meaningful role in manure composting [33].

The production of biogas from manure is a strategy typically undertaken at the community level or above, since it requires facilities which are often beyond the capacity of any single farmer to construct, operate, and maintain. However, there are cases where biogas production is also promoted as a farm practice, for example in Switzerland [37]. Although some authors consider biogas production at farm level to also be a viable energy solution for developing countries [38], [39], others highlight the role of high investment and maintenance cost, and the lack of expertise as important adoption barriers in the developing world [40]. An additional technical constraint that may render farm biogas production unattractive for individual farms is that low temperatures affect the biogas fermentation process during winter and therefore limit the plant's capacity to produce biogas exactly when the farmers need it the most [41]. In the case of community or regional biogas plants, production depends on the existence of a well-developed and profitable biogas market. This condition can prove problematic even for developed countries like the United States [42]. It also requires a constant supply of manure, which is inherently linked to the existence of adequate transportation infrastructure, combined with careful planning of the plant location to minimize transportation costs, and ensure the buy-in from farmers [41].

## Key knowledge and evidence gaps

Because FAP interventions are natural/human/social capital intensive, it is important to keep in mind that the outcomes of such interventions hinge critically upon the quality of the untapped potential in the natural resource base, expert knowledge thereof, and upon the available social capital that can be leveraged to realize the potential. Outcomes are especially sensitive to deficiencies in expert knowledge. An assessment of the US pollinator habitat conservation program, for example, found that wildflower strips were effective in delivering ecosystem services only on farms with 25-55% natural habitat cover [26], which is substantially larger than similar threshold values originally proposed for the EU [27]. These results imply that the investments for promoting FAP must account for the specificities and peculiarities of each landscape and the farms operating in it. This is why socio-economic agricultural research for development is one of the key steps in the FAP approach enumerated in the previous section. Each FAP intervention must be carefully tailored to its specific agroecological and socio-economic context.

## Conclusions

Sustainable manure management practices, such as biogas production from anaerobic digestion and manure composting, offer promising solutions to mitigate the environmental risks associated with improper manure handling. These methods provide several environmental benefits, including reduced greenhouse gas emissions, improved soil and water quality, and enhanced soil fertility. However, the increasing meat consumption and manure production level at a global scale raises the need to promote widespread adoption of those practices. Policymaking institutions play a fundamental role and should consider providing financial incentives and technical support to farmers. Additionally, efforts should be

made to inform stakeholders about the environmental and economic advantages of sustainable manure management. Furthermore, research and development efforts should focus on optimizing these technologies, making them more cost-effective, and adapting them to different agricultural contexts and scales.

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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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