The Threats on Soil; The Alarming Effects of Agriculture

Pak Hei Chevy Chan, Lene Gramstad, Ho Fai Lau, Mathias Ringkjøb, and Lena Winderen

Introduction

Soil is the foundation for plant life on the planet. It's a complex material, consisting of minerals, organic matter from decomposed biomatter, water, air, and millions of microorganisms (*Soil Management*, n.d.). Without soil, it would be impossible to sustain life on land (Berhe, 2019). Its structure and composition helps it hold moisture, support root systems, and transport nutrients, which are all essential for plant growth (Vries & Hines, 2020). Humans mostly use soil for agriculture, which is highly necessary to sustain our large population (Vries & Hines, 2020).

The composition of soil changes over time, through biological, chemical, and physical processes. Rocks being weathered changes the mineral composition, nutrients leaking in or out changes the nutrient composition, and a change in plant species growth has several nutrient and pH effects (Needelman, 2013). Consequently, human activities like land use and crop cultivation can impact soil composition (Dror et al., 2022). Accelerated change due to human activities can greatly affect native species and their future survival (Needelman, 2013; Dror et al., 2022).

In Norway, 3.5% of the total land mass is suitable for agriculture, all of it being utilized, amounting to 11 billion square meters (*Arealbarometer*, 2024). More than half of the agricultural land is used to feed farm animals, while the rest is used to feed us humans (*Arealbarometer*, 2024). When cultivating a crop field, typically only one plant species is used, to ensure maximum effectiveness (Balogh, 2021). Moreover, high-intensity agriculture commonly utilizes fertilizers and pesticides (Onissiphorou, 2022). Consequently, this practice of limited biodiversity and chemical application has detrimental effects on the soil-dwelling microorganisms in cultivated fields.

High-intensity Agriculture Effects on Microorganisms

Microorganisms are vital for the plants to survive in the soil. A teaspoon of soil can contain up to one billion microorganisms (Herring, 2010). When the organisms eat and use oxygen, they release carbon dioxide and nutrients important for plant growth (Vries & Hines, 2020). They break down organic matter, making nutrients from the dead organisms usable (Vries & Hines, 2020). Additionally, they improve the structure of the soil and consequently water availability for the plant (Vries & Hines, 2020).

Research indicates that soil in agricultural land harbors significantly less biodiversity among microorganisms compared to natural land (Burton et al., 2022; Tsiafouli et al., 2015). In one of the studies, it was concluded that there was around a 26% less abundancy of biodiversity in cropland vs primary vegetation (Burton et al., 2022). Another study showed organisms fueled by plant roots to be most affected, likely due to tilling of the soil affecting the plant roots existing in the soil (Tsiafouli et al., 2015).

Furthermore, the same study showed that in the natural grasslands soil respiration was higher, when compared to intensive agriculture (Tsiafouli et al., 2015). Soil respiration is defined as the amount of CO2 released from the soil (*Soil respiration*, 2014). In practical terms, this is all the microorganisms in the soil eating and releasing waste, one of which includes carbon dioxide. Another waste material released by some microorganisms is nitrogen, which is one of the most important elements for plant growth (Ohyama, 2010).

The study also revealed that the flow of nitrogen in and out of the soil was higher in intensive agricultural land, which at first glance may seem like a positive effect (Tsiafouli et al., 2015). However, fewer arbuscular mycorrhizal fungi were observed in the agricultural land, which is a fungus that helps the plant absorb the nitrogen in the soil (Tsiafouli et al., 2015). This resulted in less nitrogen being absorbed by the plant, instead being released into the water and transported away. Nitrogen is essential for plants to survive and plays a crucial role in various plant systems, including leaves, structural components, and roots (Buchholz & Brune, 2022). It constitutes a vital component of chlorophyll in leaves, which is necessary for photosynthesis in plants (Buchholz & Brune, 2022). The findings highlight the intricate balance between nitrogen dynamics, soil microbial communities, and plant nutrient uptake, emphasizing the importance of considering ecological complexities in agricultural management practices.

The Impact of Monoculture

Monoculture is the practice of only growing a single crop type in a field and is very common in intensive agriculture (Petruzzello, 2024). This approach yields significant efficiency benefits, facilitating the utilization of large-scale machinery for both planting and harvesting operations. (Balogh, 2021). However, covering a large area with only one plant species increases the vulnerability to pests and diseases (Balogh, 2021). The area lacks other plant species that could limit the spread or animal species that could hunt and suppress the pests (Balogh, 2021). In the event of a pest, it would spread rapidly through the monoculture crop field and could potentially cause significant harm.

This heightened risk of pests and diseases leads to a larger use of pesticides (Balogh, 2021). After years of growing the same crop in a field, the soil will become exhausted of certain nutrients and will need additional fertilizers (Balogh, 2021). Repeatedly planting the same crop in an area also decreases the variety of microorganisms (Kogut, 2020). This affects the soil's ability to create favorable conditions and provide all the essential nutrients to the growing plants (Kogut, 2020, Cherlinka, 2022).

Additionally, monoculture has a negative effect on the structure of the soil (Kogut, 2020). The lack of diversity in roots limits the soil's ability to trap moisture and prevent soil erosion, leading to the migration of nutrients away from the area of the field (Kogut, 2020). The root system's inability to trap moisture leads to a significant loss of water, which needs to be countered by artificial watering (Kogut, 2020). This in turn leads to more nutrients being washed away, as well as local lakes and rivers being overused in order to meet the heightened demand for water (Kogut, 2020).

Monoculture, with its impacts on soil composition, often necessitates heavy reliance on chemical additives and artificial irrigation (Balogh, 2021; Kogut, 2020). Consequently, this practice tends to contribute more to environmental pollution and soil degradation compared to the alternative low-intensity diverse agricultural practices (Kogut, 2020).

The Use of Agricultural Chemicals

Multiple chemicals are used in agriculture, to kill pests, prevent diseases and increase production (Onissiphorou, 2022). The main ones used are pesticides and fertilizers. Pesticides cover a wide range of chemicals, used to kill pests, insects, fungi, and other organisms (Aktar et al., 2009). The chemicals used as pesticides need to target and kill specific organisms while not being harmful to humans. Fertilizers are either natural or artificial chemical substances that improve the growth and productivity of agricultural crops (Stewart, 2024).

The benefits of agricultural chemicals are clear; they can massively increase productivity and guarantee more and better products. Food grain production in India quadrupled over a span of 50 years (Aktar et al., 2009). The production went from 50 million tons produced in 1948 to 198 million tons by the end of 1996 (Aktar et al., 2009). This remarkable increase occurred while utilizing the same amount of area which shows how effective our agricultural practices have become. The result was not only due to pesticide and fertilizer use but also using a high-yield variety of seed and advanced irrigation technologies (Aktar et al., 2009).

Pesticides have been shown to contaminate the soil, water, turf, and other vegetation (Aktar et al., 2009). While the pesticides should be as specific as possible, they may be toxic to other organisms than target organisms, such as birds, fish, non-target plants, and beneficial insects and microorganisms (Aktar et al., 2009). Persistency and movement of the pesticides and their products in the soil depend on the water solubility, soil-sorption constant, pH of the soil, and amount of organic matter in the soil (Aktar et al., 2009). The adsorption of pesticides and their products is enhanced by high organic matter content in the soil, and for ionizable pesticides, by lower soil pH levels (Aktar et al., 2009; Andreu & Picó, 2004). Despite bans on many hydrophobic, persistent, and bio-accumulative pesticides like DDT, residues of these chemicals persist in the soil (Aktar et al., 2009).

Heavy treatment with pesticides affects the community of beneficial soil microorganisms, harming it (Aktar et al., 2009). An example is common herbicides, a pesticide used to control weeds and undesirable vegetation (*Herbicide*, 2024). They affect the process where the microorganisms transform atmospheric nitrogen into nitrates, which is essential for plants, as they cannot use the atmospheric nitrogen or transform it into nitrates themselves (Aktar et al., 2009). Glyphosate, an herbicide, inhibits the growth and activity of these free-living nitrogen-fixing bacteria, exemplifying how herbicides can disrupt and harm soil microorganism populations (Santos & Flores, 1995).

Agricultural chemicals not only harm microorganisms but also have adverse effects on earthworms. These chemicals can diminish the worm population, negatively impacting the soil's health (Balogh, 2021). Earthworms play a crucial role in soil health as they digest plant debris and soil, which in turn increases nutrient availability (Lines-Kelly, 1993). Additionally, their burrowing activity helps to aerate and loosen the soil, leading to improved drainage (Lines-Kelly, 1993). Understanding these intricate connections between soil organisms and agricultural practices is vital, especially in the context of monoculture farming.

Conclusion

High-intensity agriculture offers certain advantages, such as its ability to utilize less land area than other agricultural methods. However, it is evident that this approach also entails significant drawbacks. The agricultural practice leads to less biodiversity, due to both the monoculture with only one crop type in a large area and chemicals added in the form of fertilizers and pesticides. While transitioning agricultural practices to a more environmentally friendly approach may require more land, it could also be essential for maintaining soil health. It's challenging to predict the long-term consequences of soil biodiversity loss, and although it's possible to introduce microorganisms from another area, there's no guarantee that this will fully restore biodiversity in the affected area. Given the uncertainties surrounding the effects of biodiversity loss, it's crucial to proceed cautiously in determining future actions. In the worst-case scenario, the soil could be rendered unusable if the loss of microorganism types reaches a point where the soil can no longer sustain plant growth.

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