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Review Article

The Loss Canopies, Damaged Soil: Evaluating the Interconnected Effects of Deforestation and Agroforestry Decline on Soil Health

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ABSTRACT

Deforestation and agroforestry losses have far-reaching impacts on soil quality. Canopy losses and degradation of a productive soil are serious threat to the ecosystem conservational practices worldwide. Our review paper covers a lot of aspects related to the soil i.e., soil erosion, unwanted alteration in productive fertile land that leads to desertification. A limited existence of practices related to agroforestry exaggerates these complications, leading to an abrupt decrease in soil biodiversity, soil nutrients and organic matter, carbon sequestration volumes that magnify soil pollution. There are numerous impressions that lead to soil morpho-physiological alterations, posing significant barriers to sustainable practices of land usage. The major objective of this review is to broadly comprehend decrease in forestation and agroforestry and their adverse impacts on soil characteristics by thoroughly reviewing the existing research on this aspect, thus giving valued insights for sustainable soil management.

Keywords: Loss Canopies, Damaged Soil, Deforestation, Soil Health.

INTRODUCTION

Environment characteristics which are crucial for preserving the stability of the natural resources that guarantee societal socio-economic progress, badly suffer from anthropogenic activities (Cui et al., 2021). Soil that dwell the plant required nutrients is an essential tool to reserve for sustaining the ecosystem functions (Dollinger & Jose, 2018). The drop in soil quality characteristics is a major universal concern that diminishes the intricacy of agricultural ecosystem (Alyokhin et al., 2020). Woody perennials fruit trees in cropping scheme can produce food while boosting soil and organism health (Eddy & Yang, 2022). A key component of sustainable and multifunctional development in the environment is to grow forest (Bončina et al., 2019). The movement of carbon, water, and energy between canopies and the atmosphere is just one of the many ecological processes that are influenced by the forests (Beland et al., 2019). The major ecological services provided by forests include fertilization of the soil, agricultural pollination process purifying water, quality of air control, and aesthetic and psychological benefits.



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However, because they had substantial land holdings for agricultural purposes and tree cover, the higher-income groups is now going to believe that soil preservation, soil fertility, and pest and disease management are crucial for crop production (Ahammad et al., 2019).

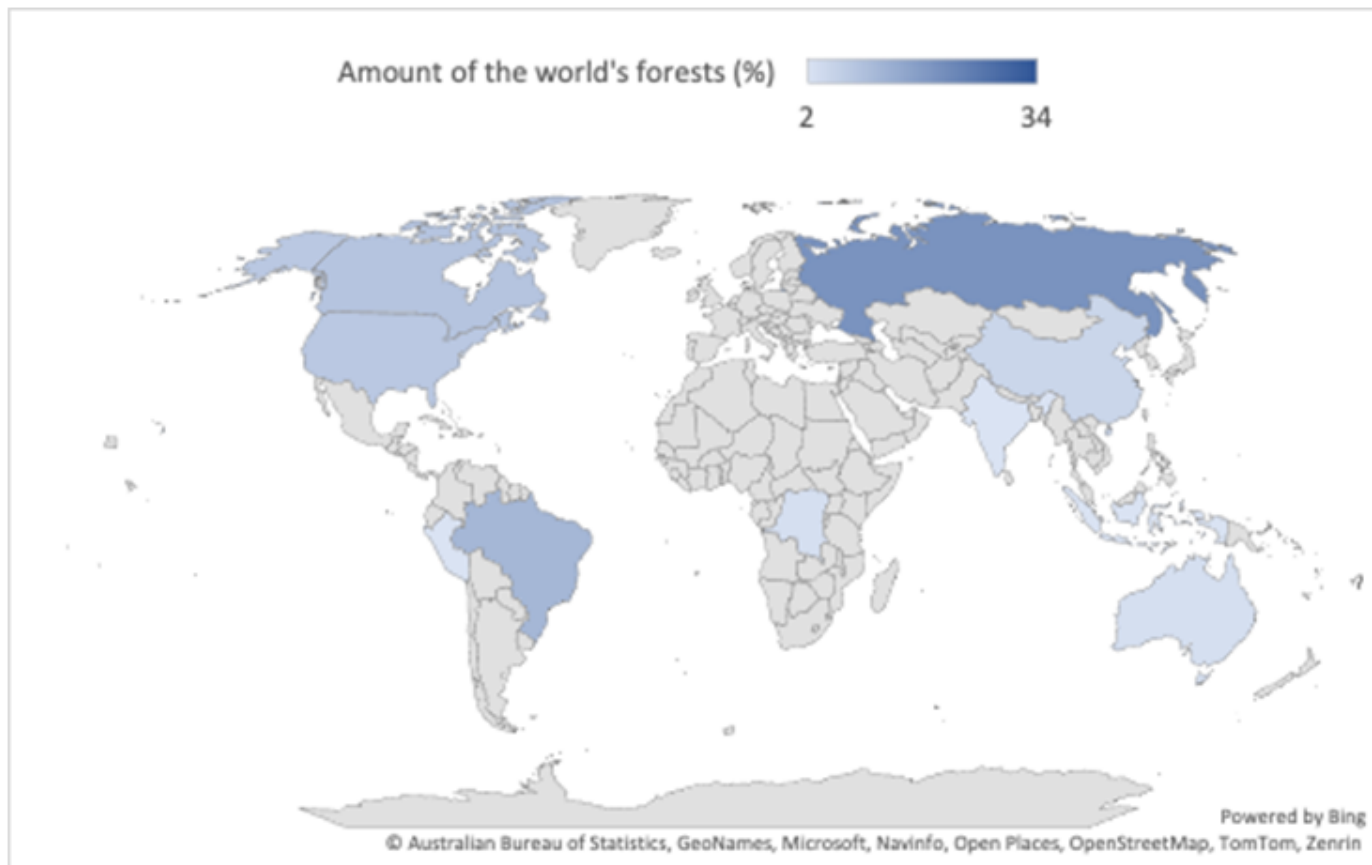


Figure 1. The percent of the world's forests (% across various regions).
Source: ("The State of the World's Forests 2020," 2020).

The rate of deforestation has accelerated globally (Sakadzo & Nyasha, 2021). Eighty percent of the carbon contained in the top mineral soil is lost as a result of deforestation and intensive farming (Merino et al., 2023). Soil characteristics, such as the amount of carbon and nitrogen in the soil, have suffered, and soil microbial activity has decreased. Enzymes needed for many soil processes or activities, such as nutrient mineralization, nutrient cycling, decomposition, and organic matter creation, are provided by soil microorganisms (Sakadzo & Nyasha, 2021). Growing evidence suggests that the soil is an ecosystem made up of several interdependent components that influence one another. When all these components are present and functioning (i.e., when the soil is healthy), human health also improves (Brevik et al., 2020).

Table 1. illustrates how anthropogenic activities cause forests to disappear over time.

The period	Area of forest loss
2000	92000000 hectares
2005	89000000 hectares
2010	83000000 hectares
2015	72000000 hectares
2020	78000000 hectares

Source: (Hannah Ritchie, 2021).

For scientists and farmers alike, maintaining and improving soils' physical, chemical, and biological characteristics while enhancing the functioning of agroecosystems is a problem (Castellini et al., 2021).

Soil functioning has been negatively impacted by the destruction of some trees (Sakadzo & Nyasha, 2021). Leading to the decline of biodiversity and growing harm to ecosystems (Fernandes et al., 2023). The primary determinants of soil health are the variety and activity of soil microorganisms (Tahat et al., 2020). Key insect-mediated ecosystem services and functions, such as soil and freshwater functions (nutrient cycling, soil formation, decomposition, and water purification), biological pest control, pollination services, and food web support, could be at risk due to insect decline globally. These services and functions are essential to ecosystem functioning, human health, and human survival (Van der Sluijs et al., 2013). It is generally accepted that microorganisms coexist closely with trees in forests (Terhonen et al., 2019).

A deep Concern is developing about, how the world's population, which is predicted to approach 10 billion by 2050, will be fed? by the escalating demands for nutritious, sustainable meals (Milbank, 2023). Thus, maintaining healthy soils is essential to ensuring global food production (Rinot et al., 2019). Desertification, biodiversity loss, aggregate disturbance, and loss of organic matter and nutrients are all results of human activity. Ensuring soil best usage and performance is critical as the focus shifts to planting new trees, improving degraded areas with organic supplements, and revitalizing plants, soil dwelling organisms, and microorganisms (Kv et al., 2019). Reforestation of the area can improve the overall quality of the soil (López-Vicente & Wu, 2019). Various approaches in agroforestry can be utilized to lessen soil erosion, enhancing carbon sequestration and nitrogen fixation (N), maintaining favorable soil pH, all of which are considered as the true examples of environmentally friendly services (Muchane et al., 2020). Altering forest land to cultivated agricultural land has antagonistic effect on the physico-chemical soil properties. Thus, it is vital to preserve forests (Davari et al., 2020, Hisano et al., 2018).

The major purpose of this inclusive review study is to widely evaluate the complex interaction between soil properties and forest loss and also investigating the associations between desertification, deforestation, nutrient reduction and organic matter loss, uncontrolled carbon dioxide release in the atmosphere, and soil erosion in order to create some valuable understandings for scientists related to conserving environmental resources, land managers, as well as policymakers.

THE IMPACT OF FORESTS AND AGROFORESTRY DECLINE ON THE HEALTH OF THE SOIL

"Planetary health" is actually the way in which human actions change the environment creation and functioning, thereby positively affecting human well-being. Agroforestry, tree management works alongside crops and livestock, climate change, hydrology, biodiversity and biochemistry (Rosenstock et al., 2019). Global climate alterations are significantly affected by changes in forest cover because changes in surface biogeochemical and biophysical properties affecting it (Boysen et al., 2020). The entire ecosystem is impacted by these consequences, which go beyond biological systems to include soil, water, and air quality as well as geochemical processes. (Vicente-Serrano et al., 2020). There are significant effects on local public health and agricultural output when the rates of deforestation in Earth's tropical rainforests increase (Zeppetello et al., 2020). Climate change threatens the sustainability of agriculture and ecosystems by increasing uncertainty and complexity (Dubey et al., 2019a). Forest loss is the main danger at the moment (Gomes et al., 2019).

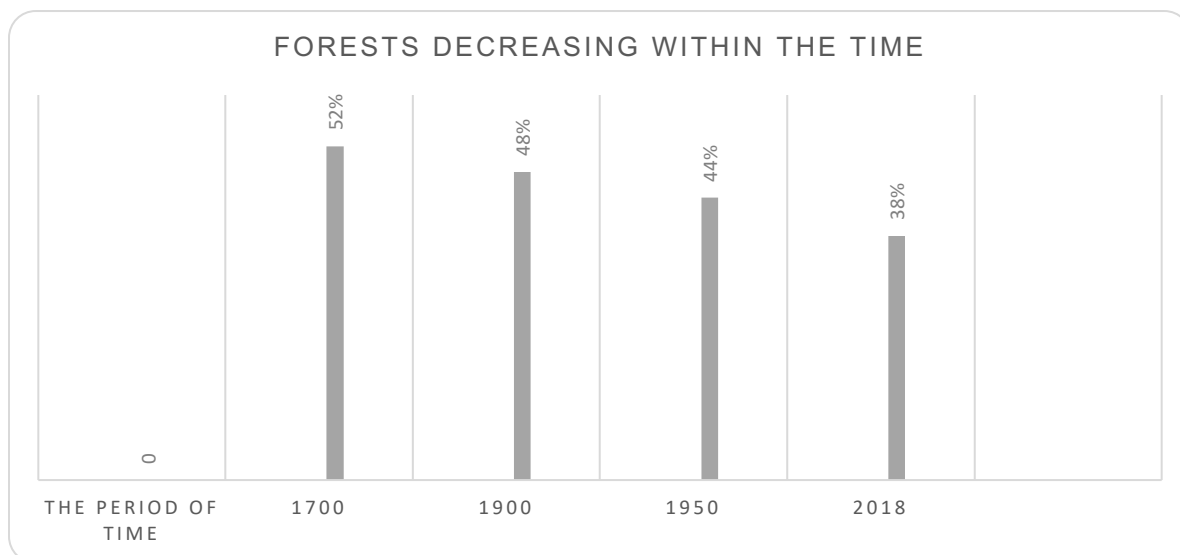


Figure 2. illustrates how anthropogenic activities cause forests to disappear over time.

Source: (Hannah Ritchie, 2021).

Erosion of Soil

Deforestation, a primary factor in land-use change, is regarded as the biggest danger to the richness of the natural world and may have permanent effects on the ecosystem (Ayoubi et al., 2021). Food production is seriously threatened by one of the major agricultural issues, which is the erosion of land (Bekele, 2019). One of the primary factors causing soil degradation worldwide is soil erosion, which has a significant influence on yields from agriculture, the biodiversity of soils, biogeochemical cycles, and ultimately human nutrition (Guerra et al., 2020). Excessive soil erosion is widely acknowledged as a serious environmental (Hancock et al., 2020). Because of their connection to humankind, soils are an invaluable resource (Fierer et al., 2021). Sustaining soil health is essential for agricultural sustainability and is a major indicator of agro-ecosystem production (Dubey et al., 2019b). Climate change and increased human activities are causing extreme rains to occur more frequently and with greater intensity. Rainfall variations will raise the likelihood and unpredictability of water erosion. (Duan et al., 2020).

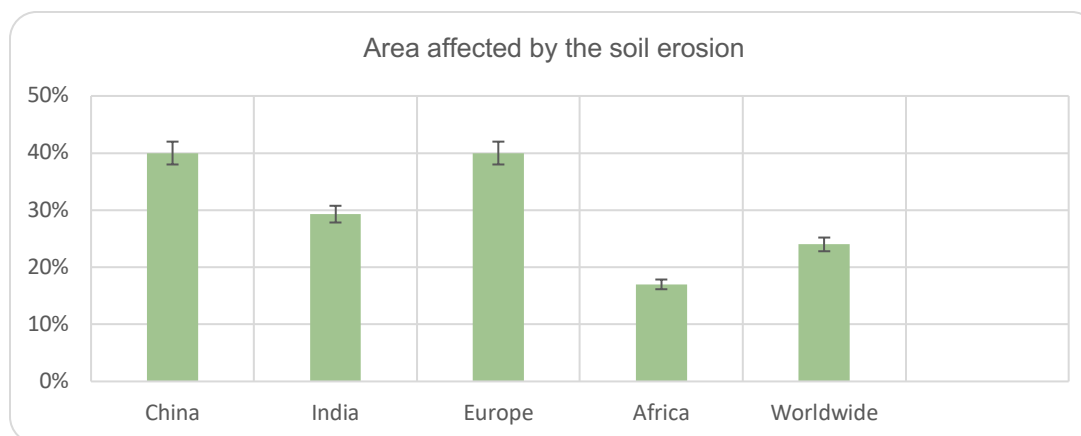


Figure 3. The following graph demonstrates how soil erosion is a severe concern
Source: (Delang, 2018; Barman, 2021; Borrelli et al., 2021)

We find that changes in land cover, especially deforestation, are contributing to an increasing tendency of soil erosion in the area (Tukura & Akalu, 2010). In a variety of landscapes and degrees of human disturbance, vegetation regrowth is a viable tactic to reduce the danger of soil loss (Teng et al., 2019). The primary way that plant cover or biomass controls soil erosion (Cerdà et al., 2021). Soil erosion may be managed by keeping a layer of live plants and debris on the ground. Raindrop impact that leads to soil erosion is lessened when there is a layer of litter covering the ground. As a result, trees are crucial for controlling erosion. (Sakadzo & Nyasha, 2021b).

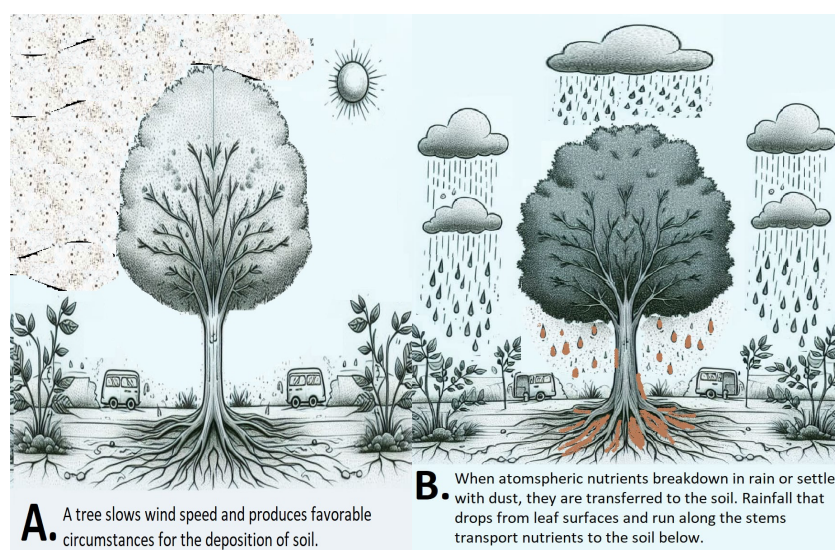


Figure 4. A tree's presence lowers wind speed and improves the environment for dust deposition. When dust or rain dissolves atmospheric nutrients, they are transferred to the soil. Nutrients are carried to the ground by rainwater that trickles off leaves and runs down their branches. (Sakadzo & Nyasha, 2021b).

Agroforestry systems help minimize soil deterioration, lessen soil and nutrient erosion, and cushion the effects of rainfall (Fahad et al., 2022).

Organic Matter Loss and Depletion of Nutrients

Soil organic matter level is critical for maintaining soil characteristics (Amoakwah et al., 2022). Changes in practices in manipulating soil resources can affect levels of SOC (soil organic carbon) that is important for regulating a sustainable ecosystem (Baldassini & Paruelo, 2020). The land utilization shifts from forest to low-input agricultural practices altered the soil health levels regarding SOC and other inorganic minerals. These adaptations are also noticeable in the general decrease in the reserves soil exchangeable magnesium (de Blécourt et al., 2019). Above-ground soil carbon has been reduced in the forest areas due to re-adjustments in land use. (Andrea Osinaga et al., 2018).

Root exudates have a pronounced effect on soil organic matter mineralization and the resulting nutrients taken up by the plants (Meier et al., 2020). Above and below soil surface characteristics are linked to the plant roots, as they transfer nutrients and regulate the carbon in terrestrial ecosystem (Li et al., 2021).

Fine roots (2 mm in thickness) are crucial in nutrient cycling, symbiotic association development, and efficient resource utilization in forests (Fortier et al., 2019). Thus, roots key role in forest is to regulate bio-geochemical cycle. Tree take up nutrients from greater depth and help recycle nutrients by preventing leaching inorganic nutrients applied to the crops, thus nutrient use efficiency (NUE) is improved and environmental pollution is potentially decreased (Sileshi, 2020). Litter fall from trees in the forest is indispensable for maintaining nutrient balance in forests (Giweta, 2020). It plays a critical role in the bio-chemical cycling within global environment (Irina et al., 2019). Plant litter as an organic matter is converted into inorganic soil form by the activities of microorganisms and grazing animals (Prescott & Vesterdal, 2021).

Variations in Microbial Communities

Complex exchanges between living organisms and inorganic elements control overall soil characteristics and establish intricate soil ecosystem (Hermans et al., 2020). Soil dwelling arthropods can be used as a tool to assess soil physical as well as chemical properties (Menta & Remelli, 2020). The population and the type of the soil microbes are the driving force to govern various biochemical processes within soil (Navarrete et al., 2023). Deforestation causes damage to their habitat (Bodo et al., 2021). Cutting of trees rationally alter soil microbial communities within soil by changing their organization and nutrient cycling (Díaz-Vallejo et al., 2021).

Soil Temperature Rise

One of the biggest risks to mankind in the first few decades of the twenty-first century is the issue of deforestation (Szkoła Finansów I Prawa W Bielsku-Białej & Naukowe, 2021). Local climate and temperature can be impacted by changes in land use and deforestation (Alves de Oliveira et al., 2021). In terrestrial ecosystems, soil temperature is crucial to many physical, biological, and chemical processes (Feng et al., 2019). The temperature of soil is influenced by environmental variables (Onwuka, 2016). The loss of forests causes temperatures to rise both locally and globally (Ellwanger et al., 2020). Deforestation has already led to significant climate warming exposure (Wolff et al., 2021). Predictions are that drylands will become more arid and saline as a result of droughts and rising global temperatures (Dantas et al., 2020). The forecast is that many regions of the planet will experience more severe droughts continuing until the conclusion of the next century (Vicente-Serrano et al., 2020). Due to the lack of vegetation, drylands often suffer from rapid soil erosion, land degradation and desertification (Hu et al., 2021).

The forests have higher humidity and lower temperatures (Meijide et al., 2018). Plants have the ability to provide shade through transpiration (Manickathan et al., 2018). Trees have a known effect on temperature, water accessibility and climate, while also improving the environment (Njora & Yilmaz, 2022). Controlling soil fertility, water absorption, and retention, as well as soil temperature, can increase crop growth and productivity (Rayne & Aula, 2020).

Soil Salinity

The quality of the soil may be negatively impacted by the growing tendency of natural forests being converted to farms (Davari et al., 2020b). The equilibrium between evapotranspiration and rainfall is altered by deforestation, which increases seepage and percolation of water. Low-lying areas and foot slopes become salinized as a result of saline seepage water (Miura & Subhasaram, 1991). According to research conducted locally, deforestation alters the soil-water balance, speeds up groundwater rise, and mobilizes water-soluble salts to the surface, which has an impact on crop yield and plant development (Maertens et al., 2022).

A significant worldwide agricultural problem that jeopardizes sustainable development objectives for nutrition, agriculture, food security, and resource conservation is soil salinization (Sahab et al., 2021). Due to marked decreases in soil organic carbon, total phosphorus, hydraulic conductivity, mean weight diameter, geometric mean diameter, and

aggregate stability, as well as increases in soil pH, EC, BD, and K-factor, the conversion of scarce natural forest into dry farming for the production of food, fodder, and fiber has seriously harmed soil quality (Davari et al., 2020b). Soil salinization is a grave concern for soil fertility (Hammam & Mohamed, 2020).

A key element in managing and reducing dryland salinization in both rain-fed farms and natural environments is plant salt tolerance (Perri et al., 2018). The creation of forestry-related methods, such as silvopasture, agroforestry, reforestation, and afforestation, to help salt-affected soils recover (Stavi et al., 2021).

Direct CO₂ Emissions Loss of Carbon from the Soil

The greatest terrestrial carbon sink is soil, which has two or three times as much carbon as the atmosphere does (Ramesh et al., 2019). Forest soils contain over half of the total organic carbon (C) in terrestrial ecosystems (Mayer et al., 2020). An essential ecological function is provided by soils, which store more carbon (C) underground than both plants and the atmosphere combined (Shao et al., 2019). Deforestation can have biophysical implications that increase carbon losses (Li et al., 2022). However, it appears that the carbon sink is decreasing due to things like deforestation (Gatti et al., 2021).

Because they sequester carbon, forest ecosystems are essential for reducing greenhouse gas emissions (Hisano et al., 2018). The goals of greater carbon storage and biodiversity may be compromised by this strategy for forest development since plantations frequently displace more carbon-rich or biodiverse land covers (Heilmayr, 2020). Even though it has the potential to be a significant sector for lowering global GHG emissions (van der Gaast et al., 2018). Forest land lowers CO₂ emissions, preserves SOC, and stops land degradation (Davari et al., 2020b).

Table 2. illustrates how carbon emissions are caused by deforestation. (Source: Pendrill et al., 2019).

Region or Nation	Deforestation for food production is connected to tons of CO ₂ emissions per person.	Region or Nation	Deforestation for food production is connected to tons of CO ₂ emissions per person.	Region or Nation	Deforestation for food production is connected to tons of CO ₂ emissions per person.
Australia	0.52 t	Croatia	0.12 t	Germany	0.51 t
Austria	0.35 t	Cyprus	0.23 t	Greece	0.24 t
Belgium	0.97 t	Czechia	0.20 t	Hungary	0.11 t
Brazil	2.71 t	Denmark	0.50 t	India	0.08 t
Bulgaria	0.09 t	Estonia	0.39 t	Indonesia	1.24 t
Canada	0.36 t	Finland	0.39 t	Ireland	0.46 t
China	0.14 t	France	0.42 t	Italy	0.43t

Impacting the Soil's Ability to Retain Water

Practices for managing forests have a significant impact on controlling the soil's capacity to store water (Wang et al., 2021). Deforestation may result in less stable and available water (Mompremier et al., 2022). As the amount of deforestation rose, the proportion of sand has increased, bulk density has grown, soil particle density has dropped, clay has decreased, and soil moisture has decreased (Bhuyan & Laskar, 2020). Farm trees increase infiltration and have a beneficial influence on hydrologic processes due to their impacts on litter fall and canopy (Fahad et al., 2022). Reforestation might increase agriculture yield by securing reliable water supplies (Mompremier et al., 2022).

Improved water management in the soil is a result of advances in passive forest restoration, which have created favorable circumstances for water infiltration into the soil as demonstrated by greater initial infiltration rates and decreased soil repellency (Pereira et al., 2022).

Increase Soil Pollution

Deforestation, pollution, and climate change all have detrimental effects (Wigand et al., 2022). The cornerstone of human health is healthy soil. To grow crops, provide food, and maintain population levels, healthy soil is essential. Its main objective is to preserve the variety of ecosystems and important biological functions (Münzel et al., 2023). Farmers have used a number of pesticides in an attempt to increase agricultural production (Al-Ani et al., 2019). The misuse of these substances has led to significant issues like soil pollution, which persist in the ecosystem (Raffa & Chiampo, 2021a). Toxic elements within pesticides and fertilizers adversely affect the environment as well as human health (Raffa & Chiampo, 2021b).

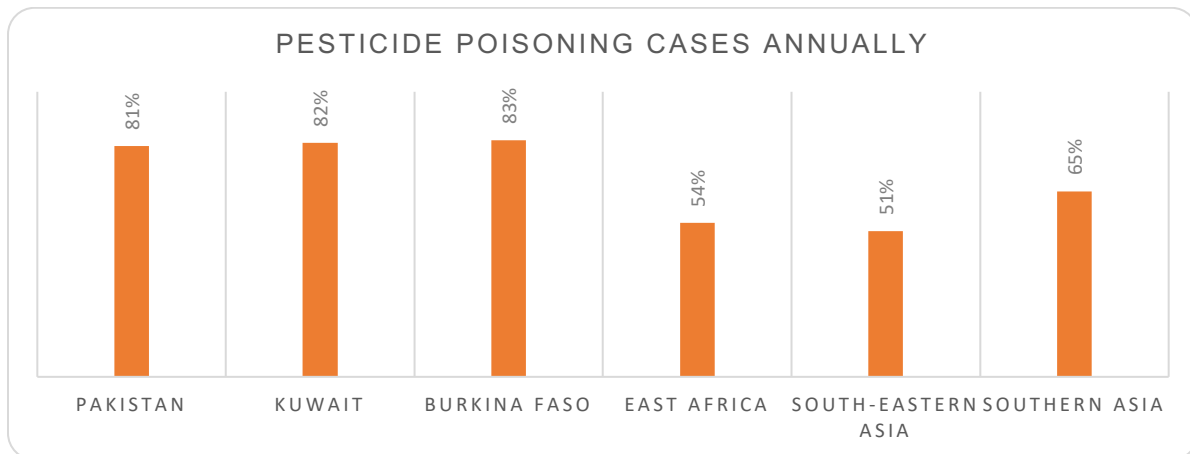


Figure 5. Pesticide poisoning cases annually (Tracked from: Boedeker et al., 2020).

The residues of pesticides have direct as well as indirect adverse effect on soil physical, chemical and biological properties (Alengebawy et al., 2021). The contaminants that are left in the soil cause a noticeable decrease in soil beneficial microorganism population and diversity (Münzel et al., 2023). Soil protection from xenobiotic toxins is critical for keeping sustainable and protective environment (Krishna Gautam, 2023). Phytoremediation rather than the use of traditional physical methods and chemicals is considered as an environmental friendly as well as an economical approach for protecting environment from pollutants (Suman et al., 2018; de Souza et al., 2019; Aghili & Golzary, 2023).



Figure 6. Trees have deep roots that absorb pesticides and contaminate the soil protecting its health

The ability of soil microorganisms to detoxify pollutants is reduced by cutting forests (Aryeh Feinberg, 2024). Phytoremediation is thus considered to have a vital role as a plant-mediated remediation method (Priya et al., 2023).

Converting the Soil to Desertification:

Terrestrial surface appearances are progressively being impacted by conversion in land cover (Hu et al., 2021). Deforestation and forest degradation initiate a sequence of alterations in the ecosystem (Rahul Kumar, 2022). Due to its reduction in the provision of ecosystem services, desertification is one of the main environmental issues that mankind is now facing (Vieira et al., 2021).

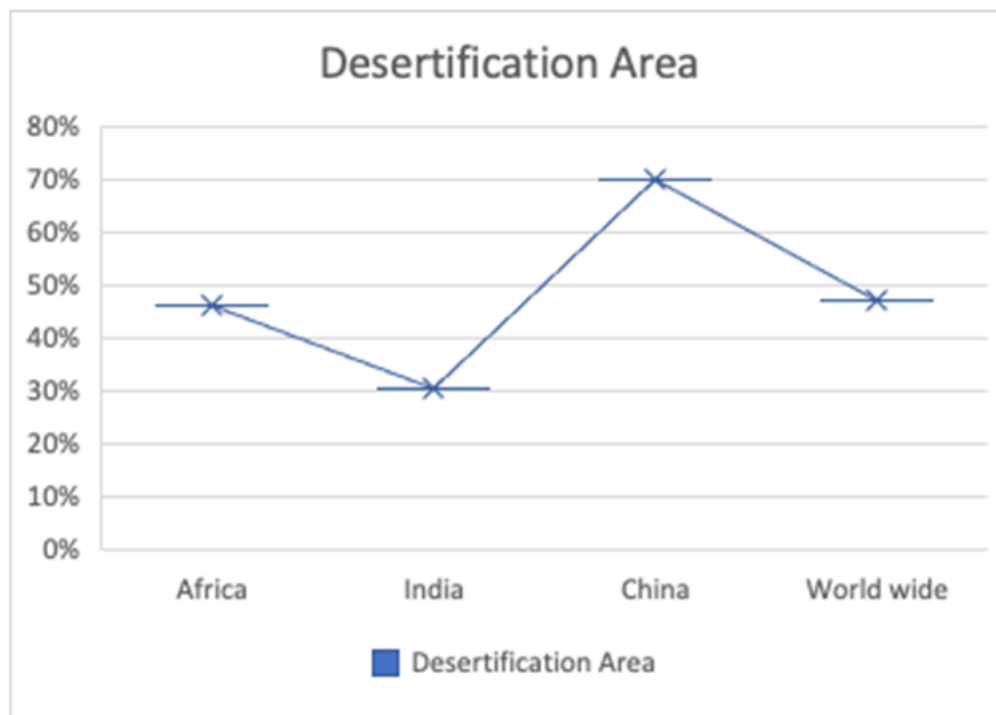


Figure 7. shows how desertification is a serious problem.

Figure 7. shows how desertification is a serious problem. (Source: Kalyan et al., 2021; Reich, 2019; Cuo et al., 2020; Abdel Rahman, 2023). Mankind is familiar with deserts (Sivakumar, 2007). Tree cover is diminishing, but bare soil area is expanding (Flores et al., 2020).

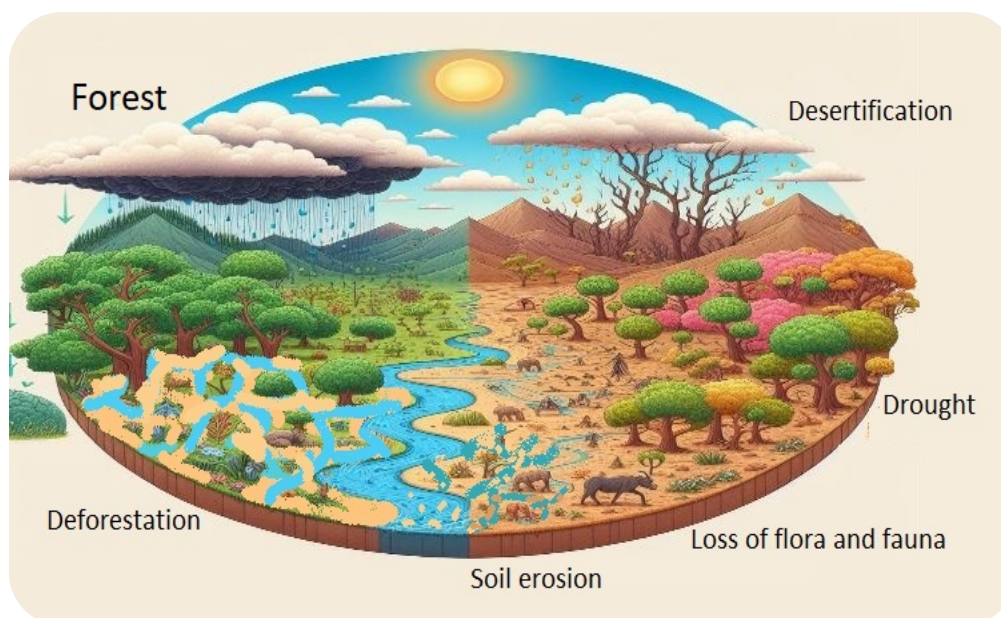


Figure 8. Desertification is the degrading process by which a productive land transforms into a desert by losing its vegetation and biodiversity. This can be caused by droughts and deforestation (Patel, 2021).

To avoid the spread of desertification, the earth's heat must be decreased by lowering environmental imbalances (Patel, 2021). Agroforestry is a type of sustainable agriculture; the current threat to agroforestry is a shift in agroforestry landforms to a less sustainable form (Priyadi et al., 2023). Agricultural forestry may restore soil-based ecosystem services in degraded soil and provide a potential avenue for intensification to make agriculture more sustainable because of its nutrient pumping and cycling, litter fall, microclimate impacts, and influence on the soil biota. (Fahad et al., 2022).

Alter the Fertility and Qualities of Soil

Demand for agricultural land, food, and fuel has resulted in rampant deforestation throughout the world. This has resulted in the loss of some woods, which has had a negative impact on soil function (Sakadzo & Nyasha, 2021b). Forest resources are critical to the existence of the world as a whole (Nosrati & Collins, 2019). Conversion of forest to dryland farming has detrimental effects on soil physical and chemical qualities (Davari et al., 2020b). Deforestation-related changes persist for decades after forest removal and have a significant impact on soil processes such as nutrient storage and recycling, carbon storage and greenhouse gas emissions, erosion resistance and water storage, drainage and filtering (Veldkamp et al., 2020). Deforestation causes dramatic changes in dynamic soil characteristics, degrading most soil functions (Veldkamp et al., 2020).

Converting forest areas to grazing fields may cause changes in soil fertility indicators (pH, organic matter content, moisture, density, soil aeration, and temperature), leading to changes in soil microbial diversity and biomass composition (Melo et al., 2021). Forest loss caused a decline in soil quality (Zeraatpisheh et al., 2020). Cropping between forest trees is strongly suggested in order to maintain natural resources such as forest trees and soil (Davari et al., 2020b). By influencing the microclimate, including trees with crops through appropriate species selection and management practices can improve soil biological, chemical and physical properties as well as soil structure in these areas. which are suffering from degradation (Fahad et al., 2022).

CONCLUSION

The implications of deforestation and the decline of agroforestry on soil health are complex, with far-reaching effects. Our review has highlighted important consequences for various elements of soil health, such as soil erosion, changes in microbial populations, temperature and salinity increases, carbon dioxide emissions, water retention capacity, pollution, desertification, and changes in fertility and characteristics.

The ability of soils to support ecosystems and biodiversity is compromised by these impacts, putting global food security, water reserves, and climate regulations at risk. A comprehensive approach that should be consisted of integrating environmental conservation techniques, sustainable land management strategies, and legal procedures for promoting reforestation, agroforestry, and soil reclamation programs is required to address these challenges.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this research.

COMPETING OF INTEREST

The authors declare no competing interests.

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