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AGROFORESTRY AS A CONTRAPTION FOR CONTROLLING SOIL EROSION AND IMPROVING SOIL HEALTH: A REVIEW

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ABSTRACT

Agroforestry is the land use planning where woody perennial crops, shrubs fodders are combined with agricultural field crops along with livestock. In terms of protection agroforestry reduces soil erosion, surface runoff and nutrients loss. In terms of amelioration it improves soil structure, nutrient status, addition of organic matter, maintain proper pH and controlling pest and diseases. Agroforestry increases infiltration, carbon sequestration rate and N, P, K, content in soil which is available for current season crops. Production of food, fuel, fodder, wood along with livestock is seen here under environmental influence. According to different studies agroforestry has more internal restoration potential than mono-cropping. Species with deep roots increase water intake from deeper layers in soil and reduces less water loss through percolation. Soil microbial activities are higher in case of agroforestry system due to presence of trees, incorporation of organic matter, root exudates, and litter fall. It shelters epigenic organisms under a particular climate, buffering action, soil water content. During climate variability especially in drought years presence of trees on farmland can minimize the frequency of crop failure. Agroforestry is the environment friendly approach where cost of cultivation is reduced by applying inorganic fertilizers less frequently.

KEY WORDS: Agroforestry, Microclimate upliftment, Soil erosion, Soil pollution etc.

INTRODUCTION

To fulfill the food requirement of increasing human population soil makes a very important role here, in agriculture. The rapid continuation of these degraded land areas causing due to inappropriate soil conservation measures (Pena *et al.*, 2020). This countless soil erosion resulting in reduced agricultural productivity, carbon sequestration potential and making negative impact on natural resources (Lizaga *et al.*, 2020). Loss of crop productivity and soil productivity; siltation of reservoirs; environmental pollution; and deterioration in forest area are some of the major outcomes of soil erosion (Jinger and Kakade, 2019). Wind erosion is provoked by deep ploughing of sandy soils, mainly drawn by tractors which detaches the unstable clods present in the soil and exterminates the natural vegetation leaving the soil to fatal wind action. Approximately 35 to 40 % of the

rainfall is lost as runoff causing 5334 million tonnes of soil loss and 5.4 to 8.4 million tonnes of nutrient losses every year (Pratap *et al.*, 2020). Tillage operations followed by crop management practices can reduce runoff losses but increase soil erosion rates on the other hand, planting trees and agroforestry system can arrest rain-water, thereby creating a good impact on runoff process, and consequently the soil loss (Ali *et al.*, 2016). This system is also linking the tree and non-tree parts of the system together. Main components of agroforestry are – perennial trees or shrubs, livestock or Pastures, interaction with environment (climatic factors, soil conditions & landforms). It gives productive as well as service function. In productive function 3Fs (Fruit, fodder and fuel wood) are important along with woods growing for construction purpose, fibers, medicines, resins & gums thus enhancing economic value of the system (Kumar *et al.*, 2020).

Agroforestry helping in improving soil through climatic upliftment

Addition of organic matter through Nitrogen cycling by adding leaf litter thus increasing long term soil nitrogen content. More efficiently Nitrogen cycling resulting in withdrawing of nitrogen from deep soil layers to maize root zones through tree roots (Augustine *et al.*, 2007). Phosphorus and Potassium availability is more in agroforestry than monocropping system (Nath *et al.*, 2015). Agroforestry increases soil moisture content, carbon sequestration rates and soil N, P, K content which are available for current season crops. Which creates sustainability for upcoming years by reduced the use of inorganic fertilizer (Surki *et al.*, 2020). While incorporating Nitrogen fixing green manuring crop residues in the soil, it enhances soil Organic matter, cation-exchange capacity, total nitrogen content, bulk density, moisture content and infiltration rates (Narendra *et al.*, 2008). Adopting Agroforestry practices than traditional agri-practices increase Soil organic carbon stock levels upto 40% at 0-30 cm, and 34% at 0-100 cm soil depth (Sirohi *et al.*, 2022).

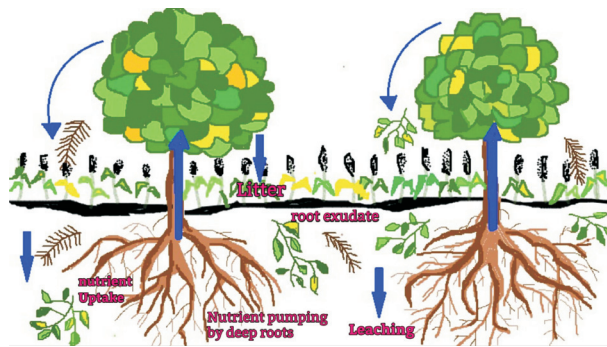


Fig 1. Nutrient cycling and pumping in an agroforestry system

Management of Agroforestry system for improving soil

Trees can hold more dust than shrubs because of their dense canopies. So, Soil below tree is more nutrient enriched than shrub. Trees are always preferred more than shrubs for soil improvement. Agro-forestry system can increase soil organic content but not an enough sustainable approach because it doesn't provide enough soil cover to reduce soil erosion. Also thinning, mulching, trimming all these cultural operations are also performed (Sarmiento-Soler *et al.*, 2019). Including species with different root depths, some shade tolerant species below the canopies of foundational

trees, nitrogen fixing species which can fix atmospheric nitrogen and improves soil nitrogen thus enhances resource-use-efficiency (Eddy *et al.*, 2022). Species with deep roots increase water intake from deeper layers in soil and reduces less water loss through percolation. Species choice should be done based on the locality and climatic conditions for getting higher soil carbon mass rates (Douglas *et al.*, 2020). A study on agroforestry system suggested that *F. albida* and *P. reticulatum* are important tree species for planting in natural regeneration parklands, managed by the farmers for improving resource use efficiency, production-use-efficiency than other trees (Diallo *et al.*, 2019). Trees plays so many roles in agroforestry system which are determines by different factors like- rooting depth and size, type of soil, rainfall pattern and intensity, dry season severeness (Padovan *et al.*, 2018).

Nutrient management and application of fertilizers

Application of proper fertilizer combination both organic and inorganic improves soil mineralization process and increase available nitrogen content. It has been reported that the application of Farmyard manure + recommended dose of NPK promotes mineralization of Carbon in *Terminalia sp.* based agroforestry system in Himalayan region (Kumar *et al.*, 2020). Integrated application of farmyard manure, Azotobacter and Phosphate solubilizing bacteria on *Capsicum frutescens* under a rubber estate proves to be improving soil physical as well as chemical characters under an agroforestry service (Kannur *et al.*, 2020). Application of well-decomposed FYM 20 mg/ha/year is useful to solve the problems related to P limitations (Zake *et al.*, 2015). Farming systems should be included with livestock. Improvement of soil properties depend on several factors – crown characteristics, tree age, phytochemical structure of litter and its nutrient content, rate of root conversion. *F. albida* and *P. reticulatum* has low tannins in their leaves so decomposes quickly (Temitope *et al.*, 2016). When soil My-corrhizae and P contents are completely taken in account, nutrient management would be done effectively (Zhu *et al.*, 2022). Agroforestry systems can bring several benefits such as protecting soil erosion, producing bioenergy, fixing carbon, creating tree-diverse agricultural landscapes, and offering sustainable land management techniques. These systems also provide natural pest control and habitat for biological diversity. The farmers in the country need to understand the potential and

expertise of agroforestry and work towards making it economically and environmentally viable for global farmers (Singh *et al.*, 2021).

Impact of Agroforestry on soil biota

Combination of trees along with agricultural crops influences microbes inside the soil. Micro-organism population has an indirectly effect on plant growth by enhancing soil fertility (Li *et al.*, 2020). More functional microbes are present in soil in case of agroforestry system compare to mono-cropping which results in increase in soil fertility biologically. Soil microbial activities are higher in case of agroforestry systems due to presence of trees, more organic matter incorporation, root substance, varied litter quality. Presence of earthworms, nematodes, fungus, termites, ants and some insects play an important role in nutrient cycling, soil aggregate formation and improving soil structure (Marsden *et al.*, 2020). Litter accumulation and root substances are the sources of sugars, amino acids other organic constituents (Beule *et al.*, 2022). Agroforestry improves soil micro-climate compared to mono-cropping by sheltering epigenic organisms under a particular climate, buffering action, soil water content. *P. Reticulatum* increases activities of different micro-organisms through organic matter addition in the soil and nutrient mineralization. Nitrogen fixation by *Bradyrhizobium* and *Mesorhizobium* promoted by trees under agroforestry system than monocropping of trees (Beule *et al.*, 2021). Pathotrophic fungi are those who are destroying the host tree by stealing nutrients from host cell. Male Poplar tree (*Populus deltoids*) has higher potential in improving soil biota under varied co-occurrence of bacteria present in the soil (Zhu *et al.*, 2022).

Soil Pollution diminishing ability of Agroforestry

Repeated application of pesticides and fertilizers is the source of surface and ground water pollution causing soil quality degradation (Pavlidis *et al.*, 2020). Crops having high root length and density can uptake nutrients leached in deeper soil layers and can make use of these nutrient and water during dry spell periods. Agroforestry decreases the frequent application of chemicals leading to advance mineralization, rectifies soil, water quality (Dawson *et al.*, 2014). Tree roots in agroforestry has a potential to reduce Nitrogen and phosphorus residues up to 20-100% in soil. Trees in agroforestry system don't compete with agricultural crops for nutrients

because tree roots are able to catch nutrients from deeper soil layers thus reducing the impact of fertilizers on environment. Phytoremediation is a advance plant based process in which plants are used to remove toxic pollutants from soil and make the environment safe (Berti *et al.*, 2000). *Azadiracta indica* has highest potential in removing Pb from industrial waste water followed by *Acacia ampliceps* (Hussain *et al.*, 2020).

Impact of agroforestry on Soil erosion

Nowadays, soil erosion has become a big issue causing fertility loss, altering structure and texture of soil and affecting growth, development processes of a plant, ultimately badly impacting on productivity and ecological sustainability. Rainfall is the most important climatic factor which is causing soil erosion & transfer of sediments (Cao *et al.*, 2020). Through slope stabilization, development in agriculture can be done in arid and semi-arid regions (Montagnini *et al.*, 2027). Addition of biomass through above ground litterfall and root turnover increases microorganism activities inside the soil, it maintains structural stability between soil particles and promotes macroporosity indirectly reducing rate of soil erosion (Muchane *et al.*, 2020). Hydrological forest activities are ensured by the required forest cover provided by agroforestry system (Van'Noordwijk *et al.*, 2020). Canopy interception and canopy retention are the two main barriers against rainfall. Canopy interception directly leads to evaporate through litterfall and canopy retention lengthen the infiltration time (Van'Stan *et al.*, 2016). If compare to mono-cropping, agroforestry system was more infiltration rates 75% followed by reduced runoff rates up to 57% (Muchane *et al.*, 2020).

CONCLUSION

Soil improvement under agroforestry system is interlinked with soil organic matter accumulation in the form of litter fall. This review paper described various agroforestry land use practices performed in India. What are the benefits of agroforestry system over mono-culture? The incorporation of trees in agriculturable land can promote soil biological and physical health. It can restore the polluted soil through removal of the pollutants or modifying them in a less harmful form. By adding few vegetative cover agroforestry increase nutrient availability and soil fertility by reducing top soil loss

loss through runoff. The more organic matter accumulation through litter fall and root turnover the more will be the microbial activities inside the soil. Rainfall captured by tree canopies can reduce the risk of soil erodibility. Agroforestry is a sustainable approach should performed by the farmers for modified ecosystem services such as improved socio-economics, resource-use-planning. Agroforestry is a multi-functional cropping system not only required for crop yield fulfillment but also bring down the effects of soil and environment pollution. So, Agroforestry has taken in account to minimize climate variability to promote sustainability and more diversified income generation.

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