AGROFORESTRY: MYRIAD BENEFITS FOR BOOSTING SOIL HEALTH

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Soil health is considered as the cornerstone of life by maintaining food production, carbon addition by recycling waste, purifying and storing water, maintaining biological diversity and including many other services to mankind. Soil health often defined as the capacity of soil to function as living system supporting plant and animals, maintain air and water quality and promoting various ecosystem services (Kibble white et al., 2008). However, with increasing population pressure, land scarcity, climate change patterns, and with depleting resources caused soil health deterioration. This has further led to carbon loss, erosion losses, nutrient depletion overall negatively affecting soil as a whole. Therefore, good soil health is crucial for improving and sustaining crop yields under changing climate scenario.

Soil conservation measures are essential to prevent soil degradation, maintain soil health and other related ecosystem services. Agroforestry is one such land use practice in agriculture which can enrich both soil and environment (Figure 1).

Figure 1. View of Agroforestry systems (a) Citrus fruits with brinjal (b) Aonla with grass

Agroforestry system (AFS) is a land use system in which perennial trees/ plants are integrated with arable crops (grasses, other crops) with or without livestock either in rotation or not associated with ecological and environmental benefits among tree and non-tree components (Lundgren and Raintree 1982). This land management practice has the potential to provide food, fuel, fibre, and various ecosystem services along with conserving biodiversity (Figure 2). This land use system could also act as shield against climate change, crop failure and economic crisis in agriculture. Recently, agroforestry or agroecology has received attention due to its holistic approach of contributing to Sustainable Development Goals (SDGs) of United Nations which aims at achieving food security, improving nutrition and promoting sustainable agriculture (FAO, 2017).

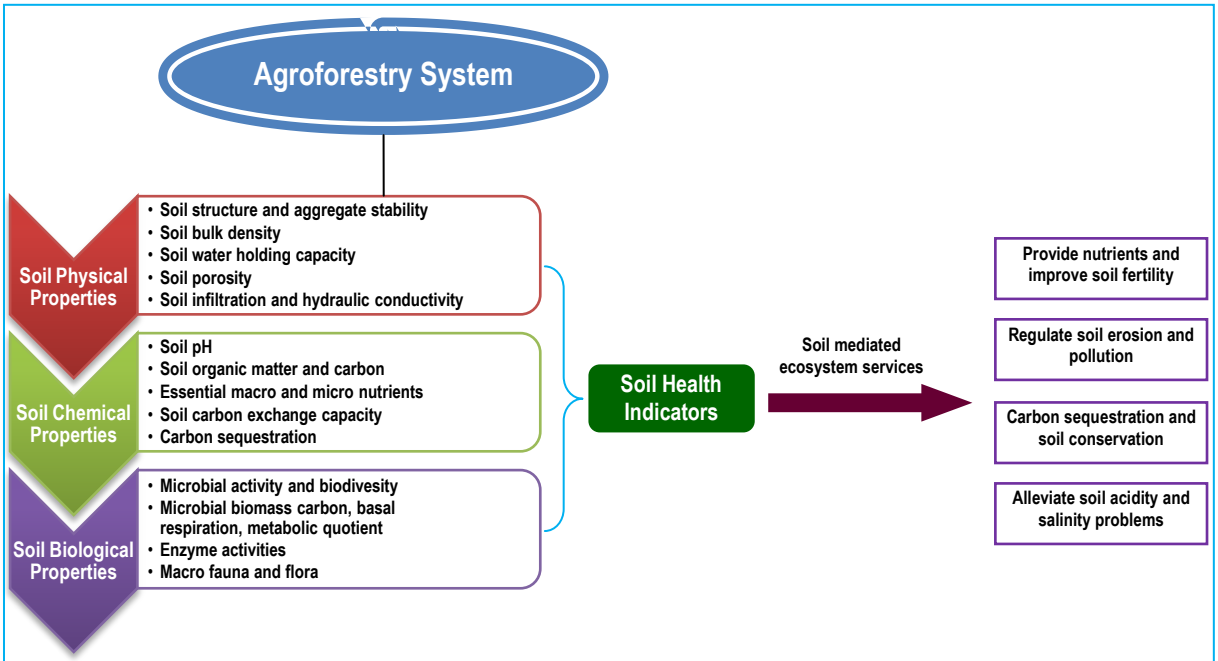

Figure 2. Soil health indicators and ecosystem services as influenced by agroforestry systems

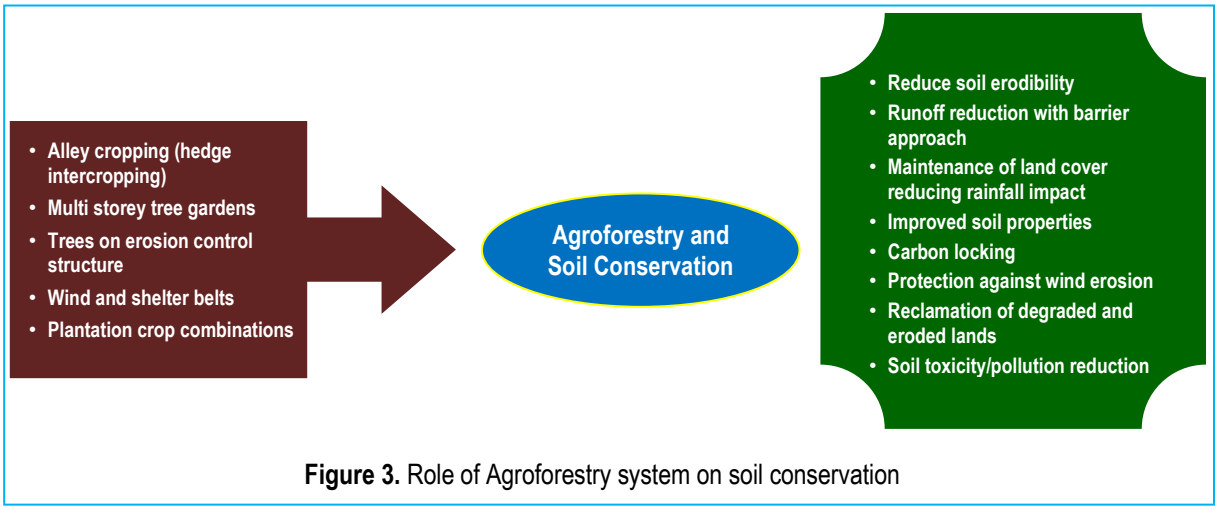

Figure 3. Role of Agroforestry system on soil conservation

The unique combination of woody perennials, arable crops and livestock, creates a permanent soil cover and prevent against erosion, minimises flood damages, enhances infiltration and water storage, improving soil and crop productivity. Beneficial effect of agroforestry system is very crucial in reversing land degradation problems through their positive effect on soil health and related ecosystem services. Agroforestry systems such

as alley cropping, plantation crop combinations, multi storey gardens, wind belts, horti-pastural etc are widely used in tropical regions for erosion control (Figure 3). Litter fall contribution by including trees, have significant impact on soil physical, chemical and biological properties, depending upon litter quality, their amount and rate of decomposition. Thus, integration of trees with arable crops improves soil fertility, maintain and increase soil organic matter through carbon fixation during photosynthesis process aid in sustaining agroecosystem. Compared to monoculture cropping system, AFS enhance soil fertility and biodiversity, while also maintain soil and agriculture productivity for long term goals.

SOIL PHYSICAL PROPERTIES

Agroforestry system contribute to soil physical properties by improving soil aggregates, bulk density, water holding capacity etc. Litterfall in these systems provides soil surface cover minimizing evaporation, runoff, soil loss, soil compaction thereby improving water infiltration and moisture conservation. Soil aggregate stability is the powerful indicator of land degradation. Agroforestry system improves soil aggregation through litterfall and root biomass turnover. Soil organic matter addition thus provide better soil structural stability improving soil aggregate distribution and water stable aggregates thereby reducing soil erosion. Trees based agroforestry system help to conserve more moisture in soil profile. Perennial tree crops enhance organic matter addition, reduce soil moisture losses and prevent erosion in agroecosystem.

Another important physical property is bulk density, an indicator of soil health, influenced by management practices. Bulk density affects soil moisture content, infiltration, porosity and influence directly biochemical process in soil. High density plantation of trees increases litterfall addition and organic matter content thus decreasing bulk density. Thus, inclusion of various multi-purpose tree species (MPTs) in agro-ecosystem would improve various various hydro-physical properties of soil, thus acts as barrier against soil erosion rates, improve macro aggregation and infiltration capacity, lowering runoff. Moreover, agroforestry system practiced with reduced/ no-tillage lowers soil erosion, providing additional soil surface cover with litterfall, minimum disturbance and crop diversification.

SOIL CHEMICAL PROPERTIES

Soil pH is an indicator of soil acidity or alkalinity effecting nutrient availability, which directly influence their uptake and trees growth. Soil pH is highly influenced by tree species where, lower pH values indicates higher accumulation of aboveground biomass, related cation uptake, organic acid produced during decomposition of organic matter under agroforestry system. Inclusion of perennial plants improves cation exchange capacity of soil by enhancing cations such as K, Ca, Mg content in soil solution interface.

Soil organic carbon through litterfall addition and their decomposition, are the major pathways of carbon turnover in soils under AFS. SOC is an important yardstick governing soil health that enhances carbon storage thereby, reducing greenhouse gas emission. Soil organic matter is the substrate or energy source for microbial activity which influences soil microbial biodiversity and soil-based ecosystem services. Almost all the AFS illustrates similar contribution to SOC increment and is reflected in improvement of soil aggregation. Soil aggregate provide greater protection to SOC, and thus could enhance SOC storage to the tune of 30% in macroaggregates as reported in many AFS. The improvement in SOC has significant implications on both provisioning (crop yield, nutrient cycling etc) and regulation (soil erosion, pollution, acidity etc) ecosystem services.

Tree components in agroforestry system play an important role in nutrient cycling in arable lands. Litterfall addition and its mineralization are considered nutrient stock for supplying essential nutrient to agroforestry system, consequently improving crop yields. Agroforestry system contributes to soil N pools by addition of above ground biomass (litterfall, pruning etc) and below ground (root biomass), contributing to inorganic N forms becoming available to crops and also potentially lost either through gaseous or leaching forms due to microbial activity. Nutrient addition and turnover depend upon, tree species, litterfall, spacing,

intercrops and management practices. Biological N fixation (BNF) by legume perennials contributes to substantial amount of N inputs for agriculture crops. This symbiotic association between rhizobia and roots results in improvement of soil fertility and productivity. Nitrogen addition through BNF and litterfall could be best N alternative as compared to costlier N fertilizers for famers. Nutrient availability in soil is a function of mineralization process through microbial activity and could vary depending upon different AF systems.

Phosphorus availability in soil is also significantly influenced under different AFS. Mineralization of organic P pools to inorganic forms due to organic acids released during decomposition of organic matter and blocking of P sorbing sites by organic C radical is an important mechanism governing P availability under AFS. Besides, mycorrhizal association in tree species also improves P availability in P deficient soils. Home garden based AFS is the most common type in many tropical countries, in improving soil fertility due to greater soil nutrient availability as compared to forests.

SOIL BIOLOGICAL PROPERTIES

Soil biological activity is governed by soil microbes, play important role in improving soil quality and physico-chemical properties. Soil biota are crucial indicators of soil health which governs nutrient cycling/ mineralization, sequester carbon, which ultimately determine soil fertility and sustain agriculture productivity. Soil biological diversity and activity depends upon amount of litterfall, type of tree species, decomposition rate and climatic factors under different AFS. Among soil factors, SOC and soil pH are important factors governing microbial survival and growth. Both soil moisture and humidity content varies under AFS, regulating soil temperature and reduce soil evaporation rate. Such modification in microclimate under AFS varies with tree/ perennial phenology and morphology can change soil micro fauna and flora activity. Agroforestry plantation with filter strip in north central MO, USA increased total bacteria (15%), gram negative bacteria (21%), anaerobic bacteria (23%) and mycorrhizal fungi (35%), indicating the beneficial effects of AFS (Unger et al., 2013).

Agroforestry systems are known to improve functional diversity of enzyme activities. Perennial vegetation provides favourable microclimate suitable for higher SOC and N accumulation due to tree litterfall, root exudates and crop residues. Higher activity of dehydrogenase, fluorescein diacetate (FDA), and alkaline phosphatase activity was found greater under tree-based agroforestry system as compared to mono cropping system. Further, soil macro fauna (earthworms, ants etc) considered as "ecosystem engineer" play important role in maintaining soil structure stability, thus are major contributors in reducing soil erosion under agroforestry. Moreover, integration of trees with crops has shown decrease in metabolic quotient indicating higher substrate efficiency by soil microbes. Similarly, higher basal respiration rate is usually observed under AFS due to presence of large labile C pools which proliferates higher microbial activity.

ALLEVIATES SOIL ACIDITY AND ALKALINITY

Soil acidity is a major soil constrain in tropical regions due to high rainfall causing leaching of base cations, use ammonium-based fertilizers, parent materials etc limiting crop production. On the other hand soil salinity is common problem either due to use of poor-quality irrigation water, poor soil drainage, accumulation of higher levels of sodium salts etc results in deteriorating soil health and poor crop establishment. Agroforestry system through N fixing trees can alleviate soil acidity problem compared to monocropping. This is because of lower uptake of cations by legume trees and amino acids released during N fixation has less affinity to protons, thus lowering rhizosphere acidity. Additionally, trees minimize acidity by capturing the leached nutrients and recycle back to soil.

In saline soils, woody perennials/ trees intercept seepage losses, provide bio drainage and minimize spread of soil salinity under both rainfed and irrigated conditions. Moderately to high salt tolerant grass and tree species are identified which can thrive well under such environmental stress and provide higher production. Tree/ woody perennial crops could minimize both acidity and alkalinity, as leaf litter added

by trees are rich in Ca, higher cation exchange which can reduce salt toxicity thereby balancing soil pH. Biosaline AFS provide numerous ecosystem services such as enhanced soil fertility, C sequestration, crop productivity, reduce soil erosion, thus could maintain environmental stability and sustainability.

CONCLUSION

Soil health degradation is major problem in the present agriculture system due to monoculture, intensive tillage and chemical inputs, which borne negative impact on natural resources and livelihood security. Agroforestry system is a technique where integration of woody perennials/ grass with agriculture crops has huge potential of reviving soil health. This system increases and maintain soil organic matter through litterfall, prunnings and root biomass which constantly enhance carbon content, limiting emission to atmosphere. Ecological interactions between trees/ perennial plants and arable crops, performs multiple soil-based ecosystem services which could provide better climate adaptation and mitigation strategies. Agroforestry practices can reduce soil erosion, add SOC, N and other macro and micro nutrients, enhance microbial diversity thus, improving soil health as compared to monocultures. Agroforestry has great potential to sustain and restore soil health, which ensures soil-plant-food- climate security and supports sustainable agriculture in tropical regions.

REFERENCES

FAO, 2017. The Future of Food and Agriculture – Trends and Challenges. Rome, Italy.

Lundgreen, B.O. and Raintree, J.B. 1982. Sustained agroforestry, In.*Agricultural researchfor development: potentials and challenges in Asia* (eds) Nestel B, ISNAR. HagueNetherlands 37-49 pages.

Unger, I.M., Goyne, K.W., Kremer, R.J. and Kennedy, A.C. 2013. Microbial community diversity inagroforestry and grass vegetative filter strips, *Agroforestry Systems* 87:395-402.

Kibblewhite, M.G., Ritz, K. and Swift, M.J. 2008. Soil health in agricultural systems. *Philos. Trans. Biol. Sci.* 363: 685–701.

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