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Agroforestry Systems For Efficient Nutrient Cycling

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Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982).

Different agencies have been estimated agroforestry areas at different scales since 2000s. One such estimate at the worldwide scale reported that 43% of all agricultural land has at least 10% tree cover, involving the practice of including trees in farmlands. In recent times, the Global Forest Resources Assessment 2020 released by Food and Agriculture Organization (FAO) has reported 45.4 million hectares of land under agroforestry.

The practices of agroforestry involves the association of trees with agricultural crops has been recognized as a viable land use system for maintaining the soil fertility and productivity in the agro-ecosystems. Soil nutrients are very dynamic in nature and tend to change into various forms, which control the availability of nutrients to the plants. In Agroforestry systems, tree component is capable of taking up the nutrients and water from the deep soil layers that are usually not exploited by the herbaceous crops. Fungal association in the tree roots helps in solubilisation and absorption of nutrients that are deep underground. Once absorbed, trees convert those nutrients into biomass such as leaf litter, branches, and shallower roots, which eventually fall and/or decompose in upper soil layers, thereby increasing nutrient content in areas where crops are. Trees significantly increase the soil organic matter content by 50-100% in agroforestry system through leaf fall, pruning material and root decomposition. This additional organic matter serves as increased food for microbes, which, in turn boosts soil microbial activity upto 30% (Young, 1989). Increased microbial activity increases mineralization and decomposition of organic matter and makes nutrients available to plants. The increased soil organic matter that trees add to soil results in higher cation exchange capacity in soils, which allows soil to better hold on to applied nutrients and resist nutrient leaching (Young, 1989).

Nutrient cycling refers to transfer of nutrients from one component to another in the soil plant animal-environment system. Nutrient additions in agroforestry systems happen through rainfall, fertilizers, nitrogen fixing trees and crops and organic residues outside the system all comprise nutrient inputs. The outputs occur through crop harvest, tree and livestock products, soil erosion, leaching, volatilization and other processes. Nutrient transport within a system occurs by leaf litter, root decay and return of nutrients through tree prunings, crop residues and manure produced within the system and nutrient pumping by trees from deep soil horizons to the soil surface. Trees in agroforestry mediate nutrient cycling by increasing the supply of nutrients in the crop root zone, increasing the availability of nutrients to crops and reducing the losses of nutrients from the system through leaching and erosion (Nair et aI., 1979).

However, the amount of nutrient released from the system depends on the several factors like climate, microbial activity, species characteristics, land use pattern and their management activities, etc. Agroforestry

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systems not only maintains the soil fertility by nutrient cycling and also prevents nutrient loss occur through erosion, leaching and runoff. Therefore, the understanding of soil nutrients dynamics in agroforestry is extremely crucial as it influences the amount of biomass production and availability of soil nutrients in soil.
Nitrogen

In agroforestry systems, nitrogen will be added to soil by two processes: Biological nitrogen fixation and deep nutrient capture. On an average leguminous and non-legminous trees can fix nitrogen in therange of 20-300 kg N ha-1 yr-1.trees can fix nitrogen. Trees can also supply considerable nitrogen to crops through dead leaves, twig, bark, needles, etc. Some trees such as cherry and mandarin do not fix nitrogen, but accumulate as much or more nitrogen in their leaves as do NFTS. This might be due to their greater root volume and ability to capture nutrients from deeper soil layers. Conversely, these non- NFTS are only cycling nutrients and not adding them to the system. The second process, through which trees can provide nitrogen inputs, is the uptake of nutrients by tree roots at deeper depths where crop roots are not present. This is an additional nutrient input in agroforestry systems because those nutrients are leached and lost for crop use. However they will be converted into an input on being transferred to the soil through tree litter decomposition.

The litter and other organic residue accumulation on the soil surface in agro forestry system, break down into smaller fragments through chemical and physical processes by reducing organic matter into CO2, water and mineral nutrients. The process of decomposition and mineralization through soil microbes increases the availability of nutrients in soil and this is facilitated by soil fauna like non symbiotic N2 fixing bacteria, phosphate, solubilizing bacteria and thiosulphate oxidizing bacteria. The rate of organic matter decomposition is influenced by several factors such as plant species, climatic factors, soil nutrient availability (C:N ratio), microbial community, etc. Efficient fixation of nitrogen requires presence of minimum level of phosphorus in the soil. Nitrogen fixation is negligible in soils that are low in phosphorus, and this is often the limiting growth factor.

PHOSPHORUS

Agroforestry systems cannot supply most of the phosphorus that crop requires. There is no possibility of adding phosphorus to the system as there is no such process like nitrogen. Absorption of phosphorus from deeper soil layers by tree roots is negligible because of low availability of phosphorus in the subsoil. Phosphorus in agroforestry system does get accumulated in the tree biomass and returns to the soil when litter decomposes, but this is purely nutrient cycling and not an input. But during this process unavailable forms of organic phosphorus can be converted to more available inorganic forms. Many trees provide shoots and leaves that can be fed to animals, resulting in nutrient-rich manure which can be applied to crops in the system. Ttherefore, livestock is an important part of agroforestry systems as it provides animal manure, which is a good source of phosphorus.

The phosphorus cycle provides a valuable index to the levels and types of biological activity in an ecosystem, since photosynthesis and microbial activity in decomposing litter need sufficient levels of phosphorus in specialized biochemical forms. Unlike nitrogen, phosphorus cycle is closed, i.e. no significant gains or losses occur from the system over time. For this reason, inorganic phosphorus must be applied in soils where it is exhausted. For efficient utilization of Phosphorus application of both inorganic and organic forms are combined.

CARBON

Plant absorbs CO2 from atmosphere during the process of photosynthesis. Thus the carbon reaches to soil when litter falls and converts into different forms. Recent studies under various agroforestry systems in diverse

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environmental conditions showed that agroforestry systems, compared to other land use management systems, accumulated more C in deeper soil layers. Higher soil organic carbon content was associated with higher species richness and tree density. Soil carbon, in the form of organic matter, is considered as an indicator of biological activity in the system.

Conclusion

Agroforestry has the ability to recover, recycle and effective utilization of nutrient. Appropriate agroforestry system maintains or restores Nitrogen nutrient through NFTS, deep nitrate capture and several cycle. Agroforestry systems cannot supply sufficient phosphorus that crop requires. The amount of Phosphorus can be increased by adding synthetic fertilizer. Carbon is the next important nutrient however there is no problem of carbon deficiency in Agroforestry as system itself produces huge biomass. Hence, Agroforestry is one of the efficient ways of land use to enhance production and productivity in which the nutrient loss under the crop component is matched by a gain under the tree component.

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