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Review Article

Improved Nutrient Cycling and Soil Productivity through Agroforestry

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A B S T R A C T

Agroforestry which is a form of multiple land use system should be adopted and encouraged. This practice helps in increasing productivity, improving nutrient cycling and also improving the socio-economic status of farmers. Apart of meeting rural wood based demands, agro forestry system helps in improvement of soil fertility as a long term benefit. Soil provides anchorage for the plants and much of the raw materials-water, nutrients and oxygen important for plant growth. Nutrient accumulation in the trees, their removal during the tree harvesting, nutrient return through litter fall and improvement in soil nutrient level of different cropping system. The amelioration of soil properties and overall increase in nutrient level below the trees. It is envisaged that agroforestry can play a vital role in maintaining soil fertility, the evidence from most indigenous agroforestry systems as recognized by the farmers show a positive trend in the maintenance of soil fertility furthermore one of the main tenets of agroforestry is that nitrogen fixing trees enhance soil fertility.

Keywords

Agroforestry, Plants, Soil fertility, Productivity, Fertility, Nutrient cycling, Nitrogen fixing trees

Introduction

Agroforestry is the land-use systems in which trees or shrubs are grown in association with agricultural crops, pastures or livestock and most importantly there is interaction between the tree and crops of the system. The most appropriate definition, perhaps, is stated by Nair (1984) as "Agroforestry is a land use that involves deliberate retention, introduction or mixture of trees or other woody perennials in crop/ animal production fields to benefit from the resultant ecological and economic interactions." Agroforestry is a distinct land use system that combines trees or shrubs with agricultural or horticultural crops or livestock, Agroforestry systems in ideal form are both stable and sustainable and Integration of trees into agricultural systems may result in more efficient use of sunlight, moisture and plant nutrients (Nelliat *et al.* 1974) than is generally possible by mono-cropping of either agricultural or forestry crops. Agroforestry is believed to promote a more efficient cycling of nutrients than agriculture.

The main aim of Agroforestry systems to optimized positive interaction between various biological components like trees, shrubs and agricultural crops or animal and between the components and the physical environment so as to obtain more diversified and more sustainable productive system from land resource. The effects of agroforestry system on soil fertility are difficult to

generalise. The improvement of soil fertility depends upon species and management system adopted. The appropriate agroforestry systems are known to improve soil physical properties, maintain soil organic matter and promote nutrient cycling. Soil conservation is one of the important service function performed by the trees in agroforestry system (Misra, 2011). Due to wide scope and multifarious benefits of agroforestry it has many potential in the context of productivity enhancement, soil fertility improvement, soil conservation, nutrient cycling, micro-climate amelioration, carbon sequestration, bio-drainage, bio-energy, bio-fuel etc. Likewise, agroforestry provides great opportunities to links water conservation with soil conservation (Dhyani *et al.,* 2015) (Fig. 1 and 2).

Tree crop interaction in agroforestry

Agroforestry system is the interaction between tree and crop are the positive, negative and neutral way. This interaction are depends upon the type of model including varying species, their nature and composition. Further, interaction is defined as the effect of one component of a system on the performance of another component and/or the overall system (Nair, 1983). In this system various interactions take place between the tree and herbaceous plants crops and pasture. Tree crop interaction in agroforestry would help to devise appropriate ways to increase overall productivity of land. Increased productivity, improved soil fertility, nutrient cycling, soil conservation are the major positive effects of interactions and competition is the main negative effect of interaction which substantially reduces the crop yield. It may be for space, light, nutrients and moisture. Ecological sustainability and success of any agroforestry system depends on the inter-play and complementarily between negative & positive interactions. It can yield positive results only if positive interactions outweigh the negative interactions.

Agroforestry, nutrient cycling and soil productivity

The property of soil under agroforestry practices is depend on tree species and their intercropping pattern, management practices, arrangement direction and the quantity and quality of litter and their decay rate. These trees provide food, timber, fuel, fodder, construction materials, raw materials for forest-based small-scale enterprises and other cottage industries and in some cases, enrich soil with essential nutrients (Ghosh *et al.,* 2011). Plantation of tree and crops are a boost to increase or sequester the carbon content of the soil which helps to beat the problem of climate change and global warming and also increase in soil carbon through plantations may also act as an important carbon sink (Kumar *et al.,* 2006). Agroforestry models are also helps in reclamation of salt affected soil. Generally agroforestry practices increases the soil organic matter through leaf litter addition. It maintains the population dynamics of beneficial microorganism and improves biological nitrogen fixation in soil. All microbiological activity in soil contributes to cycling of nutrient and other ecosystem functions and all soil functions contributes to ecosystem services (Jhariya *et al.,* 2013).

Nutrient cycling refers to transfer of nutrients from one component to another in the soil-plant animal-environment system. In agroforestry systems, nutrient additions through rainfall, biological nitrogen fixation by trees and crops, fertilizers and other organic residues from outside the system all constitute nutrient inputs. The outputs occur through removal of crop, tree and livestock products, soil erosion, leaching, volatilization

and other processes. Nutrient transfers within a system occur by litterfall, root decay and the internal recycling of nutrients through the return of tree prunings, crop residues and manure produced within the system and those nutrients recycled by trees from deep soil horizons to the soil surface. Soil fertility benefits of trees go beyond nutrient cycling by favourably modifying soil physical and biological processes and in turn of their effects on water and nutrient availability to crops. 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 at*., 1979). Trees increase the nutrient supply through biological nitrogen fixation and the recycling of nutrients at depth to the soil surface. They increase the nutrient availability to crops by decomposition of the biomass and leaf litter added to the system and by improving soil structure and enhancing biological activity. Trees reduce nutrient losses by arresting soil erosion and intercepting the nutrients that leach out of the crop root zone by means of their deep and extensive root systems.

In agroforestry system nutrient addition takes place through leaf litter, pruning of woody compounds and atmospheric fixation. Some nutrients otherwise considered unavailable to crop because they are below the rooting zone of the annual crop, might be brought into the system from deeper layers in the soil with the help of tree roots. Trees able to return nutrients through dead organic matter like leaf, branch, twig, fruits and flower and thus helps in enrichment of top soil layer. Thus most important beneficial effect of the trees on the soil can include improvement of soil structure availability of nutrients (Sanchaz 1983; Nair, 1989). The process of soil improvement under agroforestry systems is recognized through-

Increasing inputs viz., organic matter, biological nitrogen fixation and atmospheric fixation.
Reducing losses of nutrient and organic matter.
Improving soil physical properties and water holding capacity by organic additions.
Recycling of nutrients.

A major trend of agroforestry is that trees maintain soil fertility based on observations of higher crop field and nutrient status of soil near tress or where trees were previously grown. Many tree species are valued as they play an important role in traditional agroforestry. A large increase of nutrients stored in the trees and top soil compartments of tree based crop system, lead to greater efficiency in nutrient cycling and resource sharing. Improved moisture status under trees is achieved through canopy shade by reducing evapotranspiration. Increased soil organic matter is known to promote better soil structure which improves moisture holding capacity of the soil. Trees helps in enrichment of nutrient pool by adding organic matter reducing losses and checking, soil erosion. Thus the tree based cropping systems can be helpful in sustainable utilization of land resource.

Greater amount of nutrients that added to the soil, takes place through litterfall, trees translocate nutrients from deeper soil and deposit them on the soil surface via leaf sheading and other organic residues. The decomposition of organic matter residues and its mineralization results release of nutrients to the soil. However the amount of nutrients released in agroforestry systems will be much smaller than tree monoculture plantations.

Agroforestry trees particularly leguminous trees enrich soil through biological nitrogen fixation, addition of organic matter and

recycling of nutrients. The fixed nitrogen may benefit symbiotically to the crops growing in its association and helps in soil fertility improvement. The amount of nitrogen added from the legumes or pruning of trees species taken up by the first crop is reported quite low and large portion is left in the soil organic matter indicating a long term nitrogen benefit than immediate. Different tree components viz., leaf, twigs, fruit and wood have different decomposition rates which helps to distribute the release of nutrient over time. Biological nitrogen fixation takes place through symbiotic and non-symbiotic means. Symbiotic fixation occurs through the association of plant roots with nitrogen-fixing microorganisms. Many legumes form an association with the bacteria Rhizobium while the symbiosis of a few non-leguminous species belongs to a genus of actinomycetes, Frankia. Non-symbiotic fixation is effected by free-living soil organisms and can be a significant factor in natural ecosystems which have relatively modest nitrogen requirements from outside systems (Nair, 1993).

Some nitrogen fixing tree species (Misra, 2011) are given in Table 1.

Tree root systems are involved in some favourable effects on soils such as carbon enrichment in soil through root turnover, the interception of leached nutrients or the physical improvement of compact soil layers. Trees have deep and spreading roots and hence are capable of taking up nutrients and water from deeper soil layers usually where herbaceous crop roots cannot reach. This process of taking up nutrients from deeper soil profile and eventually depositing on the surface layers through litter-fall and other mechanisms is referred to as 'nutrient pumping' by trees. This process is mainly depends on characteristics of tree species and other soil, climatic and topographic factors. Trees of low moisture content soils have deep root systems and helps in nutrient and water pumping as compared to high moisture soils (Makumba *et al.*, 2009; Schroth and Sinclair, 2003; Schroth, 1999).

Table.1 Some nitrogen fixing tree species (Misra, 2011)

S. No.	Local name	Botanical name	Family
1	Black wattle	*Acacia mearnsii*	Mimosoideae
2	Beef wood, Saru	*Casurina equisetifolia*	Casuarinaceae
3	Erythrina	*Erythrina poeppigiana*	Pipil[onaceae
4	Apple ring, Areca	*Gliricidia sepium*	Fabaceae
5	Inga	*Inga jincicuil*	Mimosoideae
6	Subabul	*Leucaena leucocephala*	Mimosoideae
7	Indian alder	*Alnus nepalensis*	Betulaceae
8	Horse bean	*Vicia faba*	Fabaceae

Fig.1 Agroforestry, nutrient cycling and soil productivity

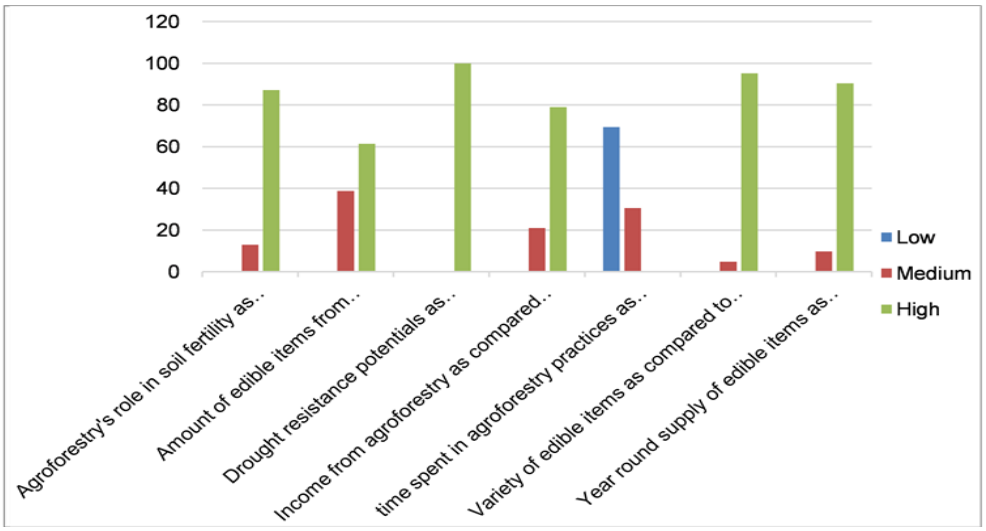
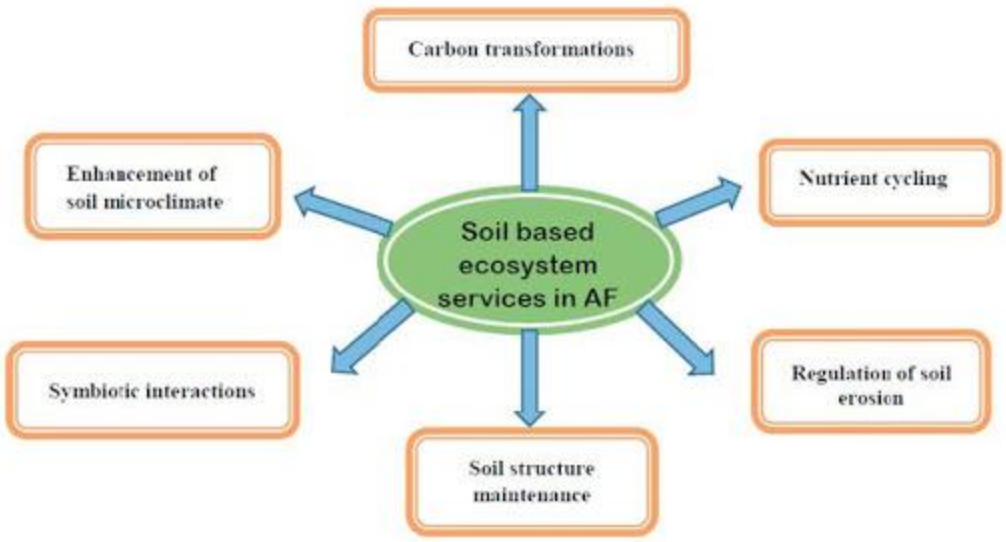


Fig.2



In conclusion, agroforestry system gives diversification, creates green cover for carbon sequestration and increases the nutrient uptake and their utilization management practices that lead to improved organic matter status of the soil will lead inevitably to improved nutrient cycling and better soil productivity. Under the agroforestry model, a suitable combination of nitrogen fixing and multipurpose trees with field crops are played a major role in enhancement of better yield productivity, soil nutrient status and microbial population dynamics which plays a major role in nutrient cycling to maintain ecosystem. Soil improvement under trees and agroforestry systems is in great part related to increases in organic matter whether in the form of

surface litter or soil carbon. Therefore besides their role in above-ground carbon sequestration, agroforestry systems also have a great potential to increase carbon stocks in the soil.

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