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# Soil Fertility Management in Agroforestry System

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**Abstract**

**Agroforestry** or agro-silviculture is a land use management system in which trees or shrubs are grown around or among crops or pastureland. It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy, and sustainable land-use systems. Apart of meeting rural wood based demands, agro forestry system helps in improvement of soil fertility as a long term benefit. This practice helps in increasing productivity, improving nutrient cycling and also improving the socio-economic status of farmers. The comparative study on 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 has been discussed in this article. The agro forestry practices supported by these case studies reflecting its superiority over pure cultivation from nutrient management point of view. These studies have shown the amelioration of soil properties and overall increase in nutrient level below the trees.

## Introduction:

Growing of woody perennials with annual crops is an old practice to facilitate easy availability of various products. The continuous removal of nutrients from soil by crops creates deficiency of certain nutrients such as N, P K, Sulphur, Zinc and even Boron. The deficiency of organic matter decreases the soil fertility which causes ultimately low yield of crop. It is our duty to retain the balance between the nutrients in the soil, but when we harvested the crops, we just burn its residue in the field ultimately loss of nutrients. The quantity taken by crops by soil should be maintained. Many traditional practices have been devised for maintaining soil fertility of which Agroforesry is one. The main aim of Agroforestry systems to optimized positive interaction between various biological components like trees, shrubs and agricultural cropsor 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 the trees in agroforestry system.

**Process of Soil Improvement:**

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 the help of tree roots. Trees able to return nutrients through dead organic matter (leaf, branch, twig, fruits and flower) and thus helps in enrichment of top soil layer, available for the agriculture crops. 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 objective, designing agroforestry system is to modify cycling in such a way as to make more efficient use of the nutrients whether these originate from natural removal process or from fertilizer. Trees in agroforestry system promote more closed nutrient cycling than pure agriculture systems. 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.

**Nutrient Loss in A System:**

Nutrient uptake by plant stored in plant parts as biomass. Harvesting of a crop results a net loss of nutrient from the system. Recycling of nutrient through crop residuces does not offset these losses and a decline in productivity of a system would be expected without any external nutrient inputs in the form of inorganic fertilizers. Apart of the biomass removal, soil erosion and leaching also play important role in nutrient depletion from the system. In agricultural system much of the crop biomass is removed during the harvesting. Ssimilarly complete tree utilization approach found certainly to remove a sustainable amount of nutrients rom the tree based system. Table-1 indicates the amount on nutrient stored in the form of biomass which would be removed from the system during the harvesting.

In general it has been found that a cultivated soil contains lower organic carbon then forest soils. The extent of carbon loss including nutrient varies with the intensity of cultivation. Scanhez *et al.* observed *a 25%* loss of organic carbon in soil during the first year’s cultivation. A similar portion (20%) of organic carbon loss was reported by Nye and Greenland (1960) after the first year’s cultivation.

**Nutrient Recovery:**

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 residuces 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. Dry matter production and nutrient quantity that released via litter fall of various plantation systems given in table -2.

Young (1987) suggested that soil to ssoil organic matter in humid tropics, 08 ton dry matter (above ground residues) per hectare per year are needed to return to the soil while 4 ton and 2 ton per hectare per year are required for sub-humid and semi arid areas respectively. Following these observations for agroforestry system be concluded that soil organic matter can be maintained only if total three biomass is added to the soil.

The alley cropping and biomass transfer system are used to prove nutrient to the crop from the tree pruning. Young (1989) and Szott et al. (1991) reviewed that legume trees in alley cropping system, produced up to 20 ton/ha/yr dry matter f pruning's containing as much as 358 kg per hectare (Nitrogen), 28 kg per hectare (Phosphorus), 232 kg per hectare (Potassium), 144 kg per hectare (Calcium) and 60 kg per hectare (Magnesium) per year.

**Soil enrichment**

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. The theme behind the enrichment of the soil is supported by various researches finding in the tree based cropping systems.

Shankarnarayan (1984) reported an increase in organic matter nitrogen and phosphorus of soil under the tree growth as compared to bare site and *Prosopis* species of same age, Table-3. Under agroforesstry system involving *Populus deltoids* and *Eucalyptus* hybrid canopies, enhancement in soil nutrient was 33-83% organic carbon, 38-69% available Nitrogen, 3-33% available Phosphorus and 8-24% arle without canopy (Anonymous 1987). Further Aggarwal (1980) indicated greater nutrient amount in soil under Prospis based agroforestry system than that of open field (Table-4). Hazara (1990) showed inhis studies that sivi-pastoral system has higher nitrogen, phosphorus and organic carbon as compared to the open field. (Table-5).

It is accepted that 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 evapo- transpiration. Increased soil organic matter is known to promote better soil structure which improves moisture holding capacity of the soil. Various nutrients studies conducted in agroforestry systems support the view that 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.

**Biological Nitrogen Fixing**

Agroforestry trees, particularly leguminous trees, enrich soil through biological nitrogen fixation, addition of organic matter and recycling of nutrients. Some trees such as *Leucaena* species, *Acacia* species and *Alnus* species has been reported to fix as much as 400-500 kg, 270 kg and 100-300 kg nitrogen per hectare per year respectively. 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. Some important nitrogen fixing plant species are given in Table 1. Biological nitrogen fixation takes place through symbioticand 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 symbionts of a few non-leguminous species belong to a genusof 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).

**Important $N_2$ fixing plant species**

| **Plant** | **Botanical Name** | **Family** | **Nitrogen fixed (kg N/ha/yr)** |
|---|---|---|---|
| Black wattle | *Acacia mearnsii* | Mimosoideae | 200 |
| Beef wood, Saru | *Casurina equisetifolia* | Casuarinaceae | 60-110 |
| Erythrina | *Erythrina poeppigiana* | Pipil[onaceae | 60 |
| Apple ring, Areca | *Gliricidia sepium* | Fabaceae | 13 |
| Inga | *Inga jincicuil* | Mimosoideae | 34-50 |
| Subabul | *Leucaena leucocephala* | Mimosoideae | 100-500 |
| Indian alder | *Alnus nepalensis* | Betulaceae | - |
| Horse bean | *Vicia faba* | Fabaceae | 68-88 |

**Nutrient Pumping**

Tree root systems are involved in some favorable 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).

**Erosion Control**

Loss of soil productivity **and shortfall of food and cash crops are the immediate impacts** of land degradation. India has 175 million ha degraded land. It is suffered from various problems of soil erosion and land degradation. These are major causes of land degradation and soil nutrient losses

**Table 2.** Amount of nutrient stored in above ground vegetation under different systems

| Sl. No. | Cropping system | Nutrient (Kg/ha) | | |
|---|---|---|---|---|
| | | N | P | K |
| 1 | *Delbergia sissoo* | 1063 | 68 | 434 |
| 2 | *Eucalyptus tereticornis* | 246 | 21 | 276 |
| 3 | *Agri silvi- horticultural system* | 532 | 40 | 461 |

(Source 1. Sharma *et al*. 1988, 2. Bargli, 1995, and Tokey *et al*. 1989)

**Table 3.** Dry matter production and nutrient content of some fast growing tree species used in Agroforestry

| Sl. No. | Species | DM (Ton/ha/yr) | Nutrient release (Kg/ha/yr) | | |
|---|---|---|---|---|---|
| | | | N | P | K |
| 1 | *Delbergia sissoo* | 4.2 | 67 | 3 | 16 |
| 2 | *Eucalyptus globules* | 8.5 | 58 | 5 | 48 |
| 3 | *Eucalyptus hybrid* | 4.6 | 22 | 9 | 7 |
| 4 | *Populus deltoids* | 4.5 | 25 | 16 | 26 |

**DM= Dry matter**

**Table 4.** Organic matter available nitrogen and phosphorus under prosopis based agroforestry system

| Sl. No. | Tree species | Organic matter (%) | Nitrogen (%) | Phosphorus (%) |
|---|---|---|---|---|
| 1 | *Prosopis cineraria* | 0.57 | 0.042 | 0.42) |
| 2 | *Prosopis juliflora* | 0.38 | 0.033 | 0.28 |
| 3 | *Bare field* | 0.37 | 0.020 | 0.28 |

**Table 4.** Nutrient variation in agroforestry and open field system

| Sl. No. | Tree species | Organic matter (%) | Nitrogen (%) | Phosphorus (%) |
|---|---|---|---|---|
| 1 | *Prosopis cineraria* | 250 | 22.9 | 633 |
| 2 | *Prosopis juliflora* | 250 | 10.3 | 409 |
| 3 | *Open field* | 203 | 7.7 | 370 |

**Table 5.** Nutrient in soils uner different silvipastoral systems

| Sl. No. | Tree species | Organic matter (%) | Nitrogen (%) | Phosphorus (%) |
|---|---|---|---|---|
| 1 | *Acacia nilotica* | 0.71 | 216 | 15.6 |
| 2 | *Albizia lebbeck* | 0.68 | 208 | 15.0 |
| 3 | *Albizia Procera* | 0.62 | 197 | 14.2 |
| 4 | *Luceana leucocephala* | 0.98 | 273 | 16.3 |
| 5 | *Open field* | 0.28 | 178 | 13.0 |

Trees add organic matter to the soil system in various manners, whether in the form of roots or litterfall or as root exudates in the rhizosphere. These additions are the chief substrate for a vast range of organisms involved in soil biological activity and interactions, with important effects on soil nutrients and fertility. In participating in these complex processes, trees contribute to carbon accumulation in soils, a topic that is increasingly present in discussions on the mitigation of greenhouse gases associated with global warming and climate change. Although carbon (C) constitutes almost 50% of the dry weight of branches and 30% of foliage, the greater part of C sequestration (around 2/3) occurs belowground, involving living biomass such as roots and other belowground plant parts, soil organisms, and C stored in various soil horizons (Nair, 1993).

In a study that gathered information from sites around the world, Nair et al. [29] found values for soil organic C stocks ranging from 6.9 to 302 Mg ha−1. Despite the great amplitude of these values, attributed to the variation between systems, ecological regions, and soil types, the study revealed a general trend of increasing soil C sequestration in agroforestry when compared to other land-use practices, with the exception of forests

## CONCLUSIONS

Trees in agro ecosystems can be present in an infinite number of arrangements and species combinations that depend mostly on farmers' objectives as well as the environmental characteristics of the region. In general, it is safe to say that a greater diversity of species is more favourable, as it results in a more complete occupation of space above and below the soil, and the variation in the characteristics of the litter produced can maintain a greater level of soil biodiversity, with positive effects on fertility.

The intentional use of trees in farming systems occurs in many parts of the globe; however, many of their benefits, that go much beyond soil improvement, are still difficult to visualize or quantify in economic terms or only appear in the long term [47, 84], such that many farmers are hesitant to invest in trees. A better understanding of the positive effects of trees on soils, and an economic analysis of what this represents in terms of nutrients and other benefits, is an important step towards increasing the use of trees on farms.

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 and certainly merit consideration in mechanisms that propose payments for mitigation of greenhouse gas emissions to reduce clima

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