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Trees for soil amelioration- A Review

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ABSTRACT

Today agriculture struggles to find a way between feeding the world and managing the threats such as soil erosion, compaction, acidification, diversity and so on. In order to emphasize importance of soils and create awareness on the foundation of food, clean water, nutrient cycling and feed, UN general assembly has declared 2015 as 'International year of soils'. Under such context, sustaining soil's health and productivity has become the utmost need of the hour and a major shift in cultivation practices should be focused more for maintaining and improving soil resources which is crucial to our wellbeing. Integration of trees in agroforestry (combination of trees, crops and pastures) with suitable selection of tree species such as Nitrogen fixing trees or multipurpose tree species will help in adding organic matter and improving fertility status of soil. Thus, more attention should be focussed on tree based farming for evergreen agriculture productivity and livelihood security.

KEYWORDS : soil improvement, organic matter, agroforestry

Introduction

In last sixty years, agriculture production has increased dramatically and even greater productivity may be expected in future as result of further advancement in technologies and innovations. Although, it has improved the socio-economic condition but at the cost of environmental degradation. Monoculture of crops and varieties led serious problems such as depletion of biodiversity, deterioration of soil health, and the environment calls upon a critical concern. In addition, increasing levels of costly inputs like fertilizer, pesticides, etc. resulted not only in the escalation of cost of production but also jeopardized the buffering capacity of the agro-ecosystem. Applying chemical fertilizers may be one of the quickest ways of restoring productivity. But inorganic fertilizers can only add nutrients but cannot contribute to soil formation, unlike trees. Trees can potentially improve soilsthrough numerous processes including maintenance orincrease of SOM, biological N_2 fixation, uptake ofnutrients from below the reach of crop roots, increasedwater infiltration and storage, reduced loss of nutrients byerosion and leaching, improved soil physical properties,reduced soil acidity and improved soil biological activity**(Young, 1997).**

It is evident from several studies taken up in different parts of the world, that agroforestry practices wherein trees are deliberately integrated with agricultural crops can re- establish some of the forests ecological goods and services like timber production, restoration of degraded land, potentially improves agricultural productivity, soil fertility improvement, carbon sequestration and enhances biodiversity (**Montagnini and Nair, 2004**). The agroforestry soil basket (Figure 1) explains various mechanism by which trees improves the soil health. Therefore, an effort has been made in this paper to include review of studies on how trees improve the physico-chemical and biological soil characters.

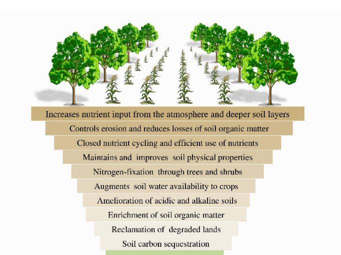

Figure1: Maintaining soil health through agroforestry

2.1 Soil physical properties

Soil physical properties have long been considered to exert great influence on the distribution, growth and development of plants. Addition of organic residue to the soil can lower bulk density by improving soil structure and increasing pore space.**Biswas *et al.* (2003)** studied the effect of seven tree species, viz., *Gliricidiasepium, Casuarina equisetifolia, Dalbergia sissoo, Gmelinaarborea, Albizialebbeck, Acacia auriculiformis*and *Eucalyptus hybrid,* on some soil properties under an agroforestry system of West Bengal, India and found that the soil bulk density was lowest under *Acacia auriculiformis* but observed a significant increase in percent aggregation of soil, and maximum water holding.

Gupta and Sharma (2008) studied the effect of poplar plantation on soil properties in Uttarakhand and concluded that soil physical properties such as porosity, density and water holding capacity improved significantly under 4 year old poplar plantation compare to sole cropping establishing significant role of the woody perennial in improving physico-chemical properties of soil under agroforestry. **Tandel*et al.* (2009)** alsoreported thattree cover significantly contributed towards improving different physical properties such as particle density, bulk density, WHC and porosity. The reason for such improvement was attributed to addition of organic matter to soil by trees in the form of leaf litter. **Imogie*et al.* (2008)** while investigating the long-term effect of *Leucaena leucocephala* on the soil physical properties observed that structure and bulk density of the soil were significantly improved over the control. Similarly, **Oyedele*et al.* (2009)** carried out a study to evaluate the effects of 20 years of different species of hedgerow crops on the physical and chemical properties of soil and found reduction in bulk density under the hedgerow species from a maximum of 1.52 g cm^{-3} under control to 1.33 g cm^{-3} under *Pterocarpussantalinoides*and *Enterolobiumcyclocarpum*hedgerows

2.2 Soil chemical properties

The trees improve soil chemical properties mainly through addition of organic matter from above ground and below ground inputs and biological nitrogen fixation. **Patil*et al.* (2004)** performed profile studies, organic matter build up and nutritional status of soil under *Dendrocalamusstrictus* based agroforestry system and observed that the soil organic carbon and soil organic matter of these soils was increased from 0.37-0.58% and 0.63-0.99% respectively at the harvesting age of bamboo. Topsoil organic carbon content was also reported to increase significantly in Oxisols successively during ten years of growth of various timber species (**Dutta and Singh, 2007**).

Gupta *et al.* (2009) reported that the average soil organic carbon increased from 0.36 in sole crop to 0.66% in agroforestry soils. The increase was higher in loamy sand than sandy clay. The soil organic carbon increased with increase in tree age. The soils under agroforestry had 2.9–4.8 Mg ha^{-1} higher soil organic carbon than in sole crop. The agroforestry trees viz. poplar add 3–4 t ha^{-1} of litter **(Rasool, 1996)** from second to fifth year of plantation and physical barriers like root and stem **(Garrett and McGraw, 2000)** in alley cropping lead to an increase in soil organic carbon through reduced soil erosion, these are likely to influence the physico-chemical characteristics of soil particularly their resistance (soil erodibility) to the impact of falling rain drops.

Imayavarambane*t al.* (2001) also reported that pH and EC were reduced by planting of *Leucaena leucocephala* to the extent of 7.62 from 8.28 and 1.94 from 5.37 dSm^{-1} respectively over a period of six years. The fertility status of soil under *Acacia catechu* and *Aeglemarmelos* plantations were improved compared to control. There was an increase in pH, EC and organic matter to a magnitude of 10.92%, 900% and 366 % respectively under plantations. Available N, P and K increased upto a tune of 46.76%, 140% and 174% respectively **(Vermae*t al.,* 2001).** By the plantation of MPTS, soil pH and EC have also been reported to decrease upto 8.2 and 0.2mmhos/cm (table 1), from initial value of 10.5 and 0.736 mmhos/cm, respectively, in 11 years period on sodic soils, however, the soil organic carbon, available phosphorus and available potash was found to increase (**Khan and Shukla, 2003).**

Table 1: Sodic soils amelioration through multipurpose tree species

Tree species	Chemical properties (on 2001)				
	Soil pH	EC (mmhos)	OC (%)	Available P (kg/ha)	Available K (kg/ha)
Azadirachta indica	8.45	0.25	0.75	12.0	240
Dalbergia sissoo	8.6	0.20	0.61	14.4	210
Albizzia procera	8.3	0.25	0.45	9.0	125
Terminalia arjuna	8.7	0.25	0.58	10.8	175
Eucalyptus hybrid	7.2	0.20	0.53	9.0	140
Leucaena leucocephala	7.8	0.20	0.56	10.8	210
Acacia catechu	8.35	0.20	0.67	20.0	225
Acacia nilotica	8.52	0.20	0.85	13.4	165
Morus alba	8.38	0.20	0.61	14.4	210
Cassia siamea	8.35	0.20	0.85	23.4	165
1989 (planting time)	**10.5**	**0.74**	**0.12**	**6.0**	**85.0**

Chaudhry *et al.* (2007) carried out a study to compare the effect of poplar based agroforestry system and conventional agricultural system on soil and found that soil under agroforestry system had higher soil organic carbon, total N, available phosphorus and potassium compared to sole cropping system. **Ahmed *et al*. (2010)**studies revealed that soil organic C, total N, available P, exchangeable K and Ca, CEC and S were increased by 25, 31.25, 16.69, 53.26, 38.87, 15.35, and 19.75%, respectively, as compared to the initial status of the experimental soil and concluded that *Gliricidiasepium, Indigoferatysmanii*and *Leucaena leucocephala* were better in building up of soil fertility than that of *Cassia siamea*. The better performance of *G. sepium, I. tysmanii*and *L. leucocephala* in building up of soil fertility was attributed due to higher nutrient content and faster decomposition rate of the pruned materials.

Singh and Sharma (2007) studied the tree growth and nutrient status of soil at an interval of six months in one and four year old poplar clone G-48 spaced at 5x4 m and concluded that soil OC was significantly greater (6.83 g/kg) in older than the younger (5.35 g/kg) plantations and available macronutrients in soil increased at successive sampling times. The average Zn concentration at final (four year age) sampling was 17% lower compared to initial sampling (one year age), whereas the other micronutrients(Fe, Mn and Cu) tended to increase with age of poplar plantations due to increased inputs of organic matter**.**

2.3 Soil biological properties

Soil microorganisms are responsible for nutrient mineralization via organic matter decomposition. Soil organic matter decomposition is mediated by microorganisms through enzymes that catalyze innumerable reactions necessary for the life processes of microorganisms in soils, decomposition of organic residues, nutrient cycling, and formation of organic matter and soil structure (**Dick, 1994**).

Studies show that enzyme activities are greater in agroforestry alley cropping practices due to differences in litter quantity and quality and, root exudates (**Mungai*etal*., 2005).** Dehydrogenase, which indicates the overall metabolic activity (**Quilchano and Maranon, 2002**) was highest for *G. sepium, and G. pinnata* (244.0 and 249.0 nmol TPF g^{-1}soil h^{-1} respectively) and the activity under the control (126 nmol TPF g^{-1}soil h^{-1}) indicated a 43.0–49.0% decrease in comparison to the tree rhizospheres. This confirmed thatthe microbial biomass is biologically more active in the treerhizosphere principally because of higher amounts of SOC/substratesentering the soil system.

The deviation in dehydrogenase activity in soils under various tree species in irrigated conditions was noticed which has been significantly higher (9.0–18.8 µg $TPFg^{-1}$ $24hr^{-1}$) than that in rainfed conditions (9.9–15.0 µg $TPFg^{-1}$ $24hr^{-1}$ (**Prasad and Mertia, 2005**) and the higher microbial activities in tree rhizosphere as compared to non-rhizosphere soil were said to be the result of increased supply of carbon and nutrients from dead root cells and rhizo-depositions. Factors such as organic matter and nitrogen are said to be good indices of microbial activity in areas where vegetative cover is maintained continuously either in the form of pure trees or in the form of multi-component systems likes agroforestry (**Prasadini and Sreemannarayana, 2007**).

Yadave*t al.* (2011) evaluated the effect of traditionally grown trees on soil biological characteristics **(Table 2)** and found that there was 1.60–1.87-fold increase in dehydrogenase activity due to different MPTs based land use systems as compared to sole cropping, with maximum activity under *P. cineraria* based agroforestry system. The increase in alkaline phosphatase activity in soil due to different MPTs based cropping systems

Table 2 :Soil biological properties under different agroforestry system (Source: **Yadave*t al.,* 2011)**

Land use	Dehydrogenase	Phosphatase	Cmic	Nmic	P mic
Sole cropping	12.3	10.0	186	23.2	8.4
P. cineraria + crop	22.9	26.4	320	42.4	15.6
D. sissoo + crop	19.9	21.3	283	35.8	13.6
A. nilotica + crop	19.6	19.4	262	32.1	11.6
A. leucophloea + crop	20.8	18.9	272	32.8	11.9

ranged between 88.3–163% as compared to sole cropping. The significantly higher alkaline phosphatase activity was found under *P. cineraria* + cropping system followed by *D. sissoo*+ cropping.Across the MPTs based agroforestry systems, Cmic ranged from 262–320 µg g^{-1} soil, Nmic from32.1–42.4 µg g^{-1} soilsoil and Pmic from 11.6–15.6µg g^{-1} soil. Soil microbial nutrients under agroforestrysystems were significantly higher incomparison to sole cropping.

Tripathi and Sharma (2005) observed that the soil temperature, moisture, organic carbon, nitrate- and ammonical-nitrogen, available phosphorus, soil respiration and dehydrogenase activity to be greater under trees than tree plus cropping system and showed accumulation of nitrate-nitrogen in tree field and more utilization by crops in cultivated lands. Some of the important characteristics of trees suitable for agroforestry has been mentioned in Box-1

Characteristics of a good soil improving tree

- A high rate of production of leafy biomass.
- A dense network of fine roots, with a capacity for abundant mycorrhizal association
- The existence of deep roots
- A high rate of nitrogen fixation
- A high and balanced nutrient content in the foliage: litter of high quality (high in nitrogen, low in lignin and polyphenols).
- An appreciable nutrient content in the root system.
- Absence of toxic substances in the litter or root residues
- Either rapid litter decay, where nutrient release is desired, or a moderate rate of litter decay, where maintenance of a soil cover is required.
- For soil reclamation, a capacity to grow on poor soils.
- Absence of severe competitive effects with crops, particularly for water.
- Low invasiveness
- Productive functions, or service functions other than soil improvement.

Conclusion

The selection and integration of compatible and desirable species of woody perennials on farmland will provide both tangible and intangible benefits. The experimental findings from various studies have showed that trees are needed to maintain and improve the soil health. Trees can influence both the supply and availability of nutrients in the soil. The trees by addition of organic matter and its presence will influence the soil physico-chemical and biological properties. The trees are considered one of the best sustainable option for practicing climate smart agriculture. Integration of trees in farmland can solve problems of food, wood and climate change.

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