# EVALUATION OF SOIL PROPERTIES UNDER FODDER BASED AGROFORESTRY SYSTEM - A REVIEW

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**SUMMARY**

Among the various benefits of agroforestry system, the most important one is improvement in soil fertility. In addition to this, mitigation of the soil carbon loss by erosion control, nutrient replenishment of the nutrients which are removed by biomass harvest and improving microbial population. There was less effect on soil bulk density but infiltration rate, texture, hydraulic conductivity and other soil physical properties along with soil pH and EC improved in the fodder based agroforestry system as compared to sole crop. The interpretation of the available results showed higher amount for organic carbon, available nutrients than sole cropping at different depths. Different tree based system significantly affected the DTPA extractable micronutrients (Zn, Mn, Cu and Fe) contents in soil. Mineralization increased significantly by incorporating trees with fodder crops. The microbial biomass C and urease activity, dehydrogenase and phosphatase activity increased and the enzymatic activities were found highest under tree with crops as compared to devoid of tree treatment. Hence, it may be concluded that Soil physical, chemical, and biological properties are effectively improved by adopting the fodder based agroforestry practices.

**Key Words:** Fodder based agroforestry system, soil properties, soil fertility

Due to intensive cultivation and monocropping, the fertility of soil is deteriorating day by day. Simultaneously it is creating a pressure on the natural resources like soil because the population is increasing day by day. Therefore, it is wise to use degraded and problematic soil for cultivation. Agroforestry systems have been recognized as an alternative for the rehabilitation of degraded areas and it provides ecosystem services and reduces human impacts on natural forests (Nair *et al*., 2009). Improved soil fertility through the production of fodder, leguminous and other crops with trees is another benefit of agroforestry. Plantation of trees apart from improving the ecosystem, will sustain the agricultural productivity, raise the farmer's income and yield multiple products. The farmers are dependent on trees and livestock especially during the drought years. The livestock constitutes a very important component in rural economy as agriculture in our country. India is home to 536 million livestock population which is about 18% of the total livestock population of the world (Anonymous 2020). Green fodder is a crucial input in dairy management and needed to increase the productivity (Gupta *et al*., 2007). To feed 536 millions of livestock a total of 4.4 per cent cropped area under fodder cultivation is available in India. As a result, cattle are starving and yielding below their potential. Poor soil-fertility and low moisture content are major factors limiting crop production in arid and semi-arid regions. In this scenario, fodder based agro forestry appears to be the most appropriate technology for cultivated soils, as one of the alternate land use options in these areas. Importance of forage production in maintaining food security as well as nutritional security is the need of the hour. The overall scene of forage production is very alarming and corrective measures need to be taken to improve this situation. Tree fodders serve as a livelihood support to farmers in drylands with their regular supply of nutritive green fodder throughout the year, their rugged-ness to survive in harsh climates, and faster growth rates (Dhillon *et al*., 2023).

## Effects of agroforestry system on soil fertility

The effects of fodder based agroforestry system on soil fertility are difficult to generalize. Although, the improvement of soil fertility depends upon species and management system adopted.

Further the introduction of multipurpose tree species in agricultural fields is important from economic viewpoint of supplying fodder, fuel and timber. It plays diverse roles including the provision of food, fuel wood, soil fertility improvement, finance, erosion control and many others. Sorghum, berseem and cowpea are among the most widely grown and important forage crops in India due to their significant level of drought tolerance and rapid growth rates (Ram *et al*., 2018). In India, farmers sow berseem during the *rabi* season (winter) to feed their livestock (Kumar *et al*., 2013). Crops like sorghum beside fodder production ensure food security for much of the population being the most cultivated cerealin some countries. Under agroforestry 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% potassium without canopy. Similarly greater nutrient amount in soil under *Prospis cineraria* based agroforestry system was observed than that of open field.

It has been well documented that agroforestry practices could effectively improve soil physical, chemical, biological properties and maintain long-term soil productivity (Jose, 2009). A linear positive regression relationship was observed among organic carbon and microbial biomass carbon of soil in semi-arid region of Haryana showing the coefficient of determination of 98.3% for organic carbon and microbial biomass carbon (Sonia *et al*., 2021). The various strategies employed to achieve the best land use options are reduction land degradation, efficient soil health management strategies, resource conservation strategies, selection of efficient crops and cropping systems and alternate land use systems (Srinivasarao *et al*., 2014). To mitigate the effect of these extreme weather events, integrating food and fodder crops preferably with perennial grass and legumes combination is better alternate option for improving system productivity, soil fertility and promoting nutrient cycling under rainfed situation. Keeping in view the above facts, the attempt has been made to review effect of fodder based agroforestry on soil properties.

## Physico-chemical properties

Kibet *et al* (2002) worked out soil organic carbon (SOC) stocks under sorghum based agroforestry systems in Western Kenya. The study showed that soil organic carbon and bulk density varied across land utilization types and depths. Greater SOC stocks were detected under agroforestry land and grazing land. In conclusion, the type of agroforestry systems adversely affects SOC accumulation. The variability of SOC stock highlights a possibility of increasing carbon inputs by practicing sustainable agriculture, such as agroforestry with *Leucaena* sp. that helps build carbon in soils. The soil bulk density significantly influences the variations in SOC stock. The variability of soil bulk density showed a significant influence on SOC stock storage across the systems. The negative correlation between the SOC and soil bulk density depicts a strong impact of soil bulk density on the SOC stock.

Chaudhary *et al* (2007) reported that significantly highest 0.65% total mean value of organic matter was observed in the poplar based agroforestry treatment, while lowest quantity of organic matter (0.46%) was observed in sole wheat, fodder maize treatment. Nitrogen fertility increased (6.6%) in intercropping treatments during the year 2000-2001 compared to 1999-2000 while it decreased 0.45% slightly in sole wheat, fodder maize treatments. Mean post wheat harvest phosphorus content of soil in sole wheat, fodder maize treatment was 10.97 ppm while it ranged from 13.20 ppm to 13.47 ppm in intercropping treatments. Potassium fertility increased from 1.8 ppm to 2.7 ppm in intercropping treatments during the year 2000-2001 compared to 1999-2000 while it decreased in sole wheat, fodder maize treatment to 0.9 ppm.

Raddad and Luukkanen (2007) reported that the bulk density of the soil in fodder based agroforestry systems did not differ significantly from that found under sorghum or sesame crops after 4 years of observation. However, there was a gradual increase in soil bulk density with time. This increase in the uppermost soil layer (0–25 cm) amounted to 8.6%, 14.3% and 19.3% in the *A. senegal* intercropping systems, *A. senegal* tree alone and mono-crop system, respectively.

Saha and Mishra (2007) concluded that there was a general increase in bulk density values with increasing soil depth in different agroforestry systems. Adoption of modified land use system like oat based agroforestry system significantly increased the mean weight diameter (29.4%) and decreased the dispersion ratio (52.9%) over the shifting cultivation. With respect to the available water content under modified systems, it increased by 24.0- 36.5% over the shifting cultivation.

Singh and Sharma (2007) studied nutrient status of soil in a poplar based agroforestry system in Punjab. The observations were taken from plantations having sorghum as fodder/pearlmillet (*Pennisetum american*um) in summer, wheat (*Triticum aestivum*) (in winter) rotation throughout the poplar age and those having sugarcane (*Sachharum officinarum*) initially during two years and fodder-wheat rotation thereafter. Soil organic carbon was significantly greater in older (6.83 g/kg) than the younger (5.35 g/kg) plantations. Available macronutrients in soil increased at successive sampling times. The average Zn concentration at final sampling was 17% lower compared to initial sampling, whereas the other micronutrients tended to increase during April 2002 to October 2003 and the increase was higher in four year old plantations than one year due to higher inputs of organic matter.

Palsaniya *et al*. (2009) found that wherever, Shisham and Subabul were introduced with fodder crop (maize), the organic carbon content increased significantly over treatments of pure crop and trees alone. The organic carbon status in Subabul+maize treatment was 0.72%. In Shisham + maize, it was 0.61%, while in crop alone it was 0.48% only.

Bulk density and soil moisture influenced by presence of *Ziziphusspina – christi* trees (Wolle *et al*., 2009). Soil moisture content was significantly increased with increasing soil depths and decreased with increasing distance. Bulk density increased with increasing distance from the tree trunk and soil depths while soil texture (sand, silt and clay) fraction was not influenced by presence of scatter pattern of tree. Soil OC, TN, available P, K, Ca and Mg were improved by the tree while soil pH, EC and CEC were not influenced by its presence.

Hailemariam *et al*. (2010) studied *Balanites aegyptiaca* and sorghum based agroforestry systems in different sites of Northern Ethiopia. They found no significant differences in total N, EC, CEC, exchangeable K and organic carbon among the three zones. However, available P and pH was significantly different at various sites. Apart from the one site, clay, silt and bulk density were not significant. *B. aegyptiaca* depletes soil moisture under canopy during the first two months; however, sorghum performance was not significantly affected.

Dhillon *et al*. (2017) studied the effect of spacing on soil nutrient status under berseem and poplar based agroforestry system in semi-arid ecosystem, Haryana. Among different spacings of poplar, highest organic carbon (0.76%) build up was recorded in 5×4 m. Soil pH and the electrical conductivity were also lowered from its initial value under different spacings. The available soil N, P and K increased significantly under different spacings of poplar based agroforestry system. The available phosphorus in the soil increased substantially and it was more than two times under poplar based agroforestry system from the initial value.

Dhaliwal *et al*. (2018) studied soil organic carbon stock in relation to aggregate size and stability under tree-based cropping systems in Typic Ustochrepts The agroforestry system comprised of poplar (*Populus deltoides*) trees intercropped with sorghum fodder (*Sorghum bicolor*) during summer and wheat during winter season. The SOC concentration decreased with soil depth, the decrease was higher (89.6%) in soils under maize-wheat than in soils under agri-horticulture (81.3%) and agroforestry (77.8%). The mean SOC concentration decreased with the size of the dry stable aggregates (DSA) and water stable aggregates (WSA). In DSA, the mean SOC concentration was 58.06 and 24.2% higher in large and small macro aggregates than in micro aggregates respectively; in WSA it was 295.6 and 226.08% higher in large and small macro aggregates than in micro aggregates respectively in surface soil layer. The mean SOC concentration in surface soil was higher in DSA (0.79%) and WSA (0.63%) as compared to bulk soil (0.52%). The SOC concentration and stock being highest in soils under agroforestry resulted in higher SOC concentration in dry as well as WSA.

Ahmed *et al*. (2020) reported that *Acacia* species plantations grown with sorghum significantly increase soil fertility in terms of available nitrogen, phosphorus, potassium and organic carbon contents as compared to control. Highest level of N and P content (59.01 ± 1.45 and 58.77 ± 1.10 mg/kg) was reported in strip between rows of *A. tortilis.*

Kaur*et al* (2020) studied depth wise dynamics of total, DTPA-extractable, water-soluble plus exchangeable (WSEX), specifically adsorbed (SpAd), carbonate bound (CARB), Mn-Oxide bound (MnOX), amorphous Fe-Oxides bound (AFeOX), crystalline Fe-Oxides bound (CFeOX), organically bound (OM), and residual (RES) fractions of cationic micronutrients (Fe, Mn, Zn, and Cu) were observed on the sites having poplar (*Populus deltoidesBartr.*)-based agroforestry system (AFS) for 10, 20, and 30 years, fodder-fodder (F-F) rotation and fallow land (FL). Total and DTPA-extractable micronutrients followed the order AFS>F-F>FL, and in chronosequence of AFS, the total content of Fe, Mn, Zn, and Cu increased by 9.8, 24.8, 50.8, and 9.2%, respectively, in 0–15 cm soil depth on the sites having AFS for 30 years over 10 years of AFS. All the micronutrients were highest in residual fraction than their other fractions in each land use system. Adoption of poplar-based AFS led to buildup of total micronutrients and their various pools in the soil. Chronosequence of AFS resulted in increase and redistribution of micronutrients from unavailable (CARB and CFeOX) to readily available (WSEX) and potentially available (OM, MnOX and AFeOX) forms in the soil.

Pandey *et al* (2018) assessed the physical properties of soil under different land use systems including rice–wheat–green gram, rice–pea (vegetable)-maize, rice-potato –okra, rice–berseem + oat + mustard (fodder)-maize + cowpea(fodder), maize–wheat–cowpea, sorghum(fodder)-yellow sarson black gram, guava + lemon, poplar + turmeric, eucalyptus + turmeric and fallow(uncultivated land). The clay content varied from 25.16 to 30.16, silt content ranged from 19.99 to 25.72 and sand content varied from 49.02 to 49.84. Bulk density ranged from 1.29 to 1.43 g $cm^{-3}$, particle density varied from 2.55 to 2.74 g $cm^{-3}$ whereas porosity ranged from 47.62 to 49.71 percent. Water holding capacity varied from 41.56 to 61.82 percent. Results indicated that soil under agroforestry based systems was found superior with respect to soil physical environment.

Chhavi *et al* (2022) studied soil nutrients when sorghum (*Sorghum bicolor*), berseem (*Trifolium alexandrinum L.*) and cowpea (*Vigna unguiculata*) were intercropped with *Populus deltoids* arranged in six spacing geometries (3 m × 3 m, 4 m × 3 m, 5 m × 3 m, 6 m × 3 m, 7 m × 3 m and 8 m × 3 m). The soil organic carbon and available N, P and K decreased exponentially with the increase in row to row distance of poplar trees. Greatest soil organic carbon and available N, P and K were measured under the closely spaced (3 m × 3 m) trees managed with cow-pea-berseem rotation.

**Soil biological properties**

Kaur *et al*. (2000) found that agroforestry system had significant effect on soil microbial biomass. They reported that soils under rice-berseem crops had lower microbial biomass carbon (96.14 mg/g soil) and it increased in soils under tree plantations (109.12 to143.40 mg/g soil) and agrisilvicultural systems (133.80 to 153.40 mg/g soil). Tree based system increased the carbon and nitrogen by 42 and 13%, respectively, as compared to monocropping.

Yadav *et al*. (2011) analyzed microbial biomass C, N and P in different tree based traditional agroforestry systems in a semi-arid region of Rajasthan. Soil microbial biomass C, N and P under agroforestry varied between 262-320, 32.1-42.4 and 11.6-15.6 mg/kg soil, respectively, with corresponding microbial biomass C, N and P of 186, 23.2 and 8.4 mg/kg soil under (berseem, sorghum and clusterbean).

Benbi*et al*. (2012) analyzed microbial biomass carbon (MBC) under poplar-based agroforestry, rice-wheat, and fodder-wheat (maize) cropping systems in semi-arid India. Soil MBC was higher in agroforestry systems (203 mg/kg soil) as opposed to the maize-wheat (185 mg/kg soil) and rice-wheat system (104 mg/kg soil).

Mao *et al*. (2012) tested the effects of land use change from monocropping to agroforestry systems on soil biological properties. The cropping sequences in the poplar based agroforestry and monocropping systems were sorghum (*Sorghum bicolor*), millet (*Setari aitalica*), and 2 years of maize (*Zea mays*), respectively. Poplar-based agroforestry systems increased soil MBC both in the 0-15-cm and 15-30-cm layers, irrespective of soil texture. In sandy loam soils, agroforestry systems had a higher percentage of MBC to TOC (MBC/TOC) than monocropping systems at each soil layer, but only had greater soil MBN at the 15-30-cm layer. For each land use type, soil MBC in sandy clay loam was significantly greater than that in sandy loam. In addition, at the 15-30 cm layer, monocropping systems in sandy clay loam had higher MBN than that in sandy loam, whereas agroforestry systems in sandy clay loam had lower MBC/TOC and percentage of MBN to TN (MBN/TN) than that in sandy loam.

Rodrigues *et al*. (2015) analyzed the soil microbial biomass C and activity under AFS with different densities of babassu palm associated with *Brachiari abrizantha* grass. Soil microbial biomass C, soil microbial biomass N, showed highest values in plots with high density of babassu palm. An increase in the size of the soil microbial biomass is considered essential for the improvement of soil fertility.

Maini *et al.* (2020) evaluated soil biological properties of various land use systems (intercrop of fodder crop during *kharif* and oil seed crops during *rabi* season) in Shiwalik foothills of Punjab, India. Dehydrogenase activity varied from 5.4–10.9 µg TPF $g^{-1}$ $h^{-1}$, acid and alkaline phosphatase from 17.0–36.5 µg pNP $g^{-1}$ $h^{-1}$ and 36.3–61.3 µg pNP $g^{-1}$ $h^{-1}$ urease from 4.05 to 4.80 µg $NH_4^-N$ $g^{-1}$ soil $min^{-1}$, basal soil respiration from 0.13–0.27 µg CO2 $g^{-1}$ soil $h^{-1}$, MBC from 34.9 to 184.5 μg $g^{-1}$ soil, total and easily extractable glomalin from 4.19 to 8.80 g $kg^{-1}$ and 1.70 to 8.32 g $kg^{-1}$, respectively.

Sarto *et al* (2020) investigated the effect of *Eucalyptus* integrated with palisade grass on the soil microbial community and activity in the tropics. Soil microbial community composition and enzymatic activity (β–glucosidase, acid phosphatase, and N–acetyl glucosidase) were reduced near *Eucalyptus* but increased in the pasture component likely due to improved soil water conditions. Soil microbial biomass, actinomycete, gram-positive bacteria, AMF, and fungi abundance were significantly higher in the native Cerrado than in the monoculture pasture.

Arora *et al.,* (2021) studied the temporal changes in soil biological properties with seasons under rainfed land use systems in Shiwalik foothills of northwest India. The agroforestry system included poplar (*Populus deltoides*), *Eucalyptus* species and dek (*Melia azedarach*)-based systems being less than 8 years old. The fodder crops during *kharif* and oil seed crops during *rabi* season were grown as intercrops. The rainy season had highest MBC and least in winter and summer season being at par with each other. Among systems, agroforestry and agri-horticulture had highest values for MBC. The basal soil respiration rates were recorded in rainy season with agroforestry systems which was at par with rainy season with agri-horticultural systems.

## CONCLUSION

Fodder-based agroforestry system increased the soil organic matter due to the continuous addition of organic material from tree leaves, branches, and fodder crop residues. Higher soil organic matter improved soil structure, water retention, and nutrient availability. Tree roots can access nutrients from deeper soil layers and bring them to the surface through leaf litter and root turnover. Due to these benefits there was overall improvement in physical, chemical and biological properties of soil in fodder-based agroforestry systems as compared to sole cropping enhanced the soil-fertility which is the major factors limiting crop production.

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