# AGROFORESTRY

## *(A Sustainable Approach towards Soil and Water Conservation)*

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**ABSTRACT**

*This paper investigates the potential of agroforestry in combating soil and water depletion, focusing on its ability to enhance food production, sustain ecosystems, and secure farmer livelihoods. It highlights the significant agroforestry land coverage in India and globally, showcasing various agroforestry systems. The paper delves into the multifaceted benefits of agroforestry for soil and water conservation, such as reduced run-off, improved carbon and nitrogen cycling, and enhanced soil physical properties. It emphasizes the critical role of ground cover and the synergistic effects of tree canopies, leaf litter, and undergrowth in controlling erosion. Additionally, the paper explores the technology& appeal to farmers, advocating for agroforestry practices that are cost-effective and straightforward and align with farmers; production goals while promoting environmental stewardship.*

***Keywords: Agroforestry, Soil and water conservation, Erosion control, Nutrient cycling***

## INTRODUCTION

Two of Mother Nature's most precious gifts to humankind are soil and water. Our existence depends on the sustainable use of both these resources. The gradual deterioration of land and water due to anthropogenic interventions such as excess use of inorganic fertilizers, overuse of groundwater, pollution, dumping of wastes, unsustainable farming practices, *etc*. pose a great risk for the survival of all living beings including human beings. This calls for a global collaborative effort to reverse such negative trends of soil and water depletion by encouraging novel sustainable approaches like Agroforestry practices which is a blessing in disguise.

In India, the area under agroforestry spans around 25.32 million ha, equating to 8.2 percent of the nation’s geographical area (Dagar *et al.*, 2014). Globally, the potential land area suitable for agroforestry is about 1023 million ha. Approximately, 823 Mha worldwide area is dedicated for plantations in which agroforestry occupies 307 Mha (Nair *et al.*, 22). Agroforestry helps to alleviate the strain on natural forests for timber and non-timber forest products.

Agroforestry is a system of integrating two or more components *viz*., trees, arable crops and/or livestock on the same land for increasing food productivity, ensuring a healthy ecosystem, and providing financial stability to the cultivator at the same time. The cohesive effects of trees with crops combined reducing the erosion of soil and improving the soil quality is far superior than sole crop or tree component.

There are diverse Agroforestry systems (AFS) like Improved fallows, home gardens, Alley cropping, Shelterbelts, Windbreaks, Protein banks, *etc*. which can be adopted as per the site factors and specific soil and moisture-related problems in a region.

### *Agroforestry Practices' Positive Impact on Soil and Water*

Dwivedi (1992) suggested that agroforestry can benefit soil in multiple ways such as, (i) reducing run-off to decrease soil and nutrients; (ii) enhancement of carbon and its transformation through plant materials; (iii) enriching the content of nitrogen in soil fixed by leguminous trees and shrubs; (iv) enhancing soil physical conditions like moisture retention capacity, water permeability, water recycling, *etc*.; (v) facilitating nutrient availability through biochemical processes; (vi) fostering a richer microbial environment and root system; (vii) balancing soil pH level; (viii) improving local climate conditions with vegetative barriers like shelterbelts; (ix) reducing groundwater levels in regions with high water tables.

### *Supplementary And Primary Use of Trees and Crops in Afs*

In AFS, trees and crops both play a supplementary and central role by incorporating them with the soil conservation structures to reduce erosion to a great extent. The primary use is growing trees and shrubs as a direct measure for erosion control where the deep and spread roots of trees hold the soil aggregates firmly. The trees also play a productive role by providing food, fodder, fuelwood, *etc*.

### *Concept Of Soil and Water Conservation*

Mostly the term soil water conservation means a reduction of soil erosion, however, it is not all. The broader aspect is not only prevention of land erosion but enrichment of soil fertility, improving soil physical, chemical, and biological attributes, nutrient status, addition of leaf litter and simultaneously treatment the soil nutrient toxicity and deficiencies. When soil water conservation measures are carried out, then there are open channels for conserving the other natural resources in turn such as the forest, pasture, streams, mountains, wildlife, etc. In Agroforestry, the deep rooting of trees helps to enhance the soil porosity, infiltration rate, groundwater quality and overall soil structure which also conserves water and increases the crop yield.

The run-off percentage and soil loss are less in agroforestry systems as compared to monocropping system. For example, the erosion in Maize crops is 27.5 percent, whereas in Eucalyptus raised along with grass, runoff is 6.3 percent. Alternatively, the soil loss in Maize alone is 28.27 tons $ha^{-1}$ but in Eucalyptus with grass treatment, soil loss is decreased to 3.52 tons $ha^{-1}$ (Young, 1989).

### *Run-Off Barriers in Afs for Flat/ Sloping Lands*

Naturally, the erosion rates on steep slopes are higher than on plains. So, it becomes essential for farmers to control the run-off to protect their crops. Multi-story tree gardens, hedge row intercropping, and barrier hedges of trees and shrubs offer great potential for checking run-off and replenishing the soil fertility through deterioration of pruning and root remaining. The hedgerows should not be spaced more than 6 m for maximum effects and are partly permeable allowing a section of sediments carried by run-off to pass through the hedges in case of storms rather than as complete breakage as in case of earth barriers. In addition, the pruning from trees distributed across the alleys leaves the alley for leaf litter decay and tillage operations, and live vegetation provides mulch for the soil cover. Trees of smaller heights do not give more materials for mulch except for leaf litter.

An agroforestry watershed having 4.5 m wide buffers with Pinhead oak, Swamp white oak, and blue oak with Redtop, spear grass, and birds foot trefoil grass reduced 25 percent of nitrate-nitrite (NN) loss compared to a sole grass buffer watershed that reduced only 14 percent NN (Gonzalez *et al.* 2024).

***Ground cover for erosion control in AFS***

Ground cover is always better than bare soil and more efficient than run-off barriers. It has been found that even a crop like maize which has a higher rate of erosion manages to reduce erosion by its crop residues than a bare ground. As the density and rate of growth of plants is higher, the ground cover is more which means more protection. For example, palm trees when young are grown with *Pueraria* spp. as the latter forms dense ground cover decreasing the run-off. But the mature palm shades out *Pueraria*, so pruned palm fronds can be used as a mulch. The crop residues, pruning, and leaf litter from trees can be substantially used as a mulch at the rate of 5 t/ha to give the best results. A ground cover of 50 percent provides a cover factor (C) of 0.1; while an 80 percent cover gives a factor of 0.05.

Considering the example of coffee-based agroforestry system which reduced erosion by 80 per cent due to the litter ground cover (Blanco-Sepúlveda *et al.*, 2024). Moreover, the splash erosion potential was 3.12 times greater in rubber monocultivation, 1.22-2.18 times in AFS and 0.87 times in Rubber- tea system compared to open environment. Thus, the rubber-tea agroforestry system was the most crucial in controlling splash erosion (Lie *et al.*, 2016).

In various countries, AFS are adopted for run-off control, soil status improvement, *etc*. For instance, in the volcanic slopes of Indonesia, contour hedgerows of Leucaena have been successfully raised since 1973 while single or double rows of Leucaena or Gliricidia are adopted in the sloping lands of the Philippines to stabilize soil disintegration and increase fertility. Similarly, in Kenya, earth conservation structures like ditch and bank structures are supplemented with hedges of *Grevilia robusta* for additional soil protection. In India and Nepal, the sloping land terraces are planted with *Grewia oppositifolia* and *Alnus nepalensis* as dense hedges for run-off control. *Casuarina* spp. have been raised as windbreaks along the canals and irrigated fields of Egypt for the protection of crops against wind erosion.

***The combined effect of canopy, leaf litter, and undergrowth in AFS***

The tree canopy or undergrowth alone can't reduce soil erosion to the maximum. The leaf litter of trees and undergrowth alone can offer 95 percent erosion protection than bare soil. Moreover, in a natural forest when trees and undergrowth were removed, the erosion rose to 26 t/ha/yr than 1 t/ha/yr with only leaf litter. Thus, the desirous effects of AFS for soil conservation can be achieved more from leaf litter *i.e.* maintenance of ground cover and soil temperature, than from canopy. This implies that a combination of fast (Subabul) and slow decaying leaf litter tree species (*Gliricidia sepium, Cassia siamea*) should be employed for extended surface cover and simultaneously for fast release of nutrients.

***Addition of organic matter in AFS***

Although the organic matter content is maximum under forests but it is still greater in AFS than in pure agriculture. Soil structure; lower detachability, more porosity, and infiltration rate are evident under forest than in AFS and least in the monocropping. The organic matter content of 1.5 percent maintained in AFS than the 1 percent in agriculture leads to a reduction of soil erodibility factor 'K' up to a substantial 7 percent. The slow decomposition of organic matter owing to shading sustains the soil's nutrient status. It helps maintain the soil's physical properties like porosity, moisture-holding capacity, permeability, and structure.

***Nitrogen fixation of leguminous and non-leguminous trees in AFS***

The introduction of leguminous trees in the AFS helps to fix the atmospheric N by mycorrhizal associations in the root nodules and add the nitrates or nitrites to the soil thereby increasing the fertility of soil. Examples of such leguminous trees are Acacia, Albizzia, Gliricidia, Leucaena, Prosopis, *etc*. and non-leguminous trees like Alnus, Casuarina, Elaeagnus, *etc*. In Agri silvicultural systems of Acacia, Eucalyptus and Poplar along with rice-berseem in northern India, N mineralization was higher (12- 37%) compared to monocropping (Kaur et al. 2000). Similarly, in Costa Rica, maize N content was 2.8 fold higher in the alley crop than the sole crop (Haggar *et al*., 1993).

Among the trees, *Leucaena leucocephala* is an excellent nitrogen-fixing leguminous tree fixing about 100-500 kg N $ha^{-1}$ $yr^{-1}$ and has a high level of nitrogen in leaves (2.5-4.0 %) and thus increased rate of return can be expected in litter or cuttings. Comparing different agroforestry systems, large amounts of nitrogen can be fixed by an alley cropping system, *e.g.* 75 to 120 kg N $ha^{-1}$ in six months by Leucaena (Mulongoy, 1986).

***Nutrient pumping and cycling***

The deep roots of trees are able to extract the nutrients like potassium, phosphorus, bases and micronutrients released from weathering of rocks from B/C soil horizons and release it on the upper surface for the crops to absorb (Fig.-1). The nutrients are trapped and recycled via leaf litter decomposition by mycorrhizal association and root exudations which would otherwise be lost due to leaching. The roots further help to break down compact indurated soil pans into simpler aggregates. The addition of bases from leaf litter helps to reduce the soil acidity thereby moderating the effects of leaching.

The presence of soil nutrients like organic carbon, nitrogen, potassium, calcium, and magnesium was higher in the coffee agroforestry system than in coffee monoculture in Indonesia. The reasons are greater plant species diversity, higher organic matter content, and reduced leaching derived from larger amount of litter generated from coffee agroforestry (Ramadhani *et al.,* 2024). Moreover, the soil organic carbon was estimated to be 168.9 Mg C $ha^{-1}$ and 177 Mg C $ha^{-1}$ for 11-15 years and 15-year-old stands respectively of pineapple agroforestry system which are comparable with adjacent natural forest land which was 182.7 Mg C/ha (Hazarika *et al.,* 2024). Carbon and nutrient returns via litterfall exhibited 1.3-1.6 times higher in rubber agroforestry (rubber-tea, rubber-cacao, rubber-*Flemingia* macrophylla) than in rubber monoculture (Yuan *et al.,* 2024).

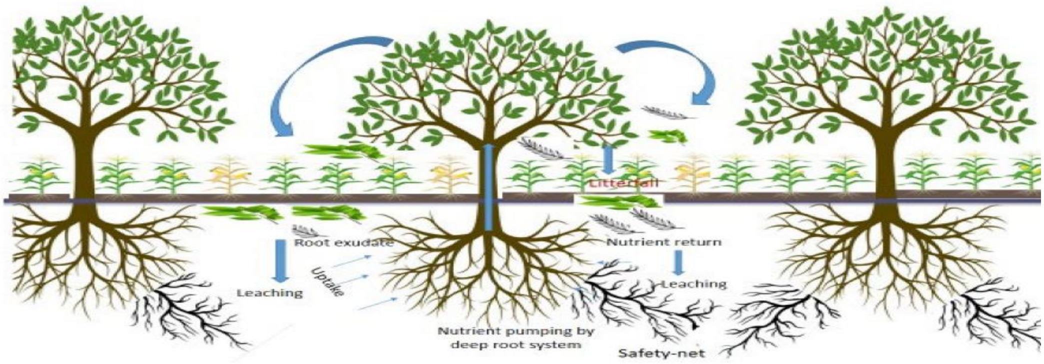


*Figure 1: Nutrient pumping by deep root system in AFS via 'safety net' formation (Fahad et al., 2022)*

***Technology readily acceptable by farmers***

Farmers are more interested in production rather than protection aspects because ultimately, they need better monetary return. So, the AFS is flexibly designed to meet the needs of the farmers. For example, *Leucaena leucocephala* hedges with Napier grass serves both for the productive demand for livestock and protection against soil loss. The AFS which are simple to implement, inexpensive, and problem specific attract the farmers.

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