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Review Article

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Soil Treatment through Agroforestry: A Review

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ABSTRACT

The function and relevance of soils in agro-ecosystems has been recognized in the context of sustainable management, soil quality, soil resilience or soil conservation and protection of local or regional agro-ecosystem. NRM involves the concept of using, improving, and restoring the productive capacity and life support processes of soil. Agroforestry have the potential to improve soil properties viz.: soil structure, micro aggregates, soil water retention and transmission properties, cation exchange capacity, exchangeable cations, soil organic matter content and transformation, nutrient supplying capacity, soil pH, rooting depth, soil biodiversity, soil fauna and microbial activity. Agroforestry includes any system where trees are deliberately planted or encourage on land where crops are grown or animals grazed. Present investigation indicate that agroroforesty system including silvorable agroforestry, hedgerow intercropping, mixed and zoned agroforestry and many other agroforestry practices are positvely contributed for controling of soil erosion, maintainance of soil organic matter, improving physical and other biological properties of soil. So there is a considerable potential for soil conservation through agroforestry, both in control of erosion and by other means of maintaining soil fertility. This potential applies to many agroforestry practices and over a wide range of climatic zones and soil types which is the main aim of this investigation.

Key words: *Agro-ecosystem, Agroforestry, Silvorable agroforestry, Soil erosion and Soil fertility*

INTRODUCTION

Soil conservation refers to both control of erosion and maintenance of fertility. Earlier soil conservation was equated with erosion control only. It leads to erosion is thought of in terms of loss of soil material, and its control is treated in isolation from other aspects of agricultural improvement. But today, it is well known that the principal adverse effect of erosion is lowering of fertility, through leaching of organic matter and nutrients. Another is the identification of different types of soil degradation such as physical, chemical and biological degradation sometimes grouped as decline in soil physic-chemical properties and fertility[27]. Degradation of soil adversely affects the agro-ecosystem (flora, fauna, nutrients etc.) and makes the soil sick. These aspects show that the primary objective of soil conservation is maintenance of fertility.

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To achieve this, control of erosion and maintenance of the physical, chemical and biological properties, including nutrient status, which together lead to soil fertility.

Agroforestry has great contribution in all these aspects and has a major role to play in some. Agroforestry refers to growing of agricultural and forest trees together. The capability of trees to grow under complex climatic and soil environment, coupled with their potential for soil conservation, gives agroforestry a potential in the challenging lands viz. semiarid, sloping and soil with other constraints. Tree roots and recycling of nutrients have been proved to effectively contribute to maintanance and recovery of soil structure and fertility[4].When leaves are returned to the soil, the adoption of leguminous nitrogen fixing trees may also contribute to soil fertility[13]. In Agroforestry system different models such as agri-silvi, horti-silvi-pastoral, etc. may be adopted to enhance the soil fertility and also in food security point of view. Agroforestry systems also have potential for reclamation of degraded or ruined land. Tree litter and plant parts may prove helpful to maintain soil organic matter, physico-chemical properties and nutrient status. The natural and agricultural ecosystems suggest a high potential for agroforestry to also improve nutrient status and fertilizer use efficiency[28]. Besides soil conservation, as different species of crops and trees participate in agroforestry thus may prove helpful in germplasm conservation. Therefore to know the role of agroforestry in various aspects of soil conservation and germplasm conservation has been discussed hereunder.

CONTROL OF SOIL EROSION

The major adverse effects of erosion are loss of soil organic matter and nutrients thereby reduction in crop yields. This process not only affects the land/soil but also cause loss of biodiversity and other resources. In the north-eastern hill (NEH) region of India, shifting cultivation (*Jhum*) is the only and prime factor for the loss of forest land[2]. The loss of soil due to shifting cultivation has been reported about 5 tos 83 t ha^{-1} depending upon crops grown and slope of the land[18]. The erosion of topsoil reduces the inherent productivity of land through leaching of nutrients and degradation of the physical as well as chemical properties. The loss/removal of nutrient rich surface layer is very difficult to compensate by additional inputs or fertilizers (Table- 1). It also increases the cost of cultivation of depending upon the crops. For cultivation of crops such as potato and ginger for quick returns the land resources are being intensively utilized along the slope under the *jhum* (closed burning of biomass on raised beds '*bun*') in *Khasi* hills of Meghalaya without thinking long-term implications. Due to this shallow hill soils gets lost rapidly and continues till the entire ridge becomes barren. In such area the soil fertility cannot be fully restored even by heavy applications of fertilizers/inputs. The deforestation of hill slopes has resulted increased silt problem in rivers due to erosion by splashes of rain from the hill and mountains. Sedimentation load in Brahmaputra and its tributaries[15] as compared to Ganges and local damage being proportionate to angle of slope.

Table 1. Response of rice to nitrogen at different rate of soil removed[8]

Soil removed (cm)	Rate of nitrogen (kg/ha)				
	0	60	120	180	Mean
		Rice grain yield (q/ha)			
0	40.2	43.6	41.7	41.5	41.8
5	27.2	34.6	36.7	31.5	32.5
10	21.4	37.7	35.5	30.7	31.3
15	15.2	33.1	31.7	32.8	28.2
Mean	26.0	37.2	36.4	34.1	33.4
C.D. at 5% for soil removed		5.52			
C.D. at 5% for nitrogen		5.13			

Comparison of erosion rates under tropical forest, tree crops and some agroforestry systems has been depicted in Table-2, which reveals that both mixed and zoned agroforestry systems, have the great potential to control soil erosion to below limits that are acceptable, both for soil retention and prevention of fertility loss.

A agroforestry system known as Silvoarable agroforestry (SAF) involves the deliberate combination of trees and agricultural crops on the same land management unit in some form of spatial arrangement or temporal sequence such that there are significant ecological and economic interactions between trees and agricultural components[21]. Silvoarable systems can reduce soil erosion compared with the existing arable systems, especially, if combined with contouring practices[14] (Figure-1).

Table 2. Rates of erosion in tropical forest and tree crop systems[24]

Land-use system	Erosion (t/ha/yr)		
Multistorey tree gardens	0.01	0.06	0.14
Natural rain forest	0.03	0.3	6.16
Shifting cultivation, fallow period	0.05	0.15	7.4
Forest plantations, undisturbed	0.02	0.58	6.2
Tree crops with cover crop or mulch	0.1	0.75	5.6
Shifting cultivation, cropping period	0.4	2.78	70.65
Taungya, cultivation period	1.63	5.23	17.37
Tree crops, clean weeded	1.2	47.6	182.9
Forest plantations, burned or litter removed	5.92	53.4	104.8

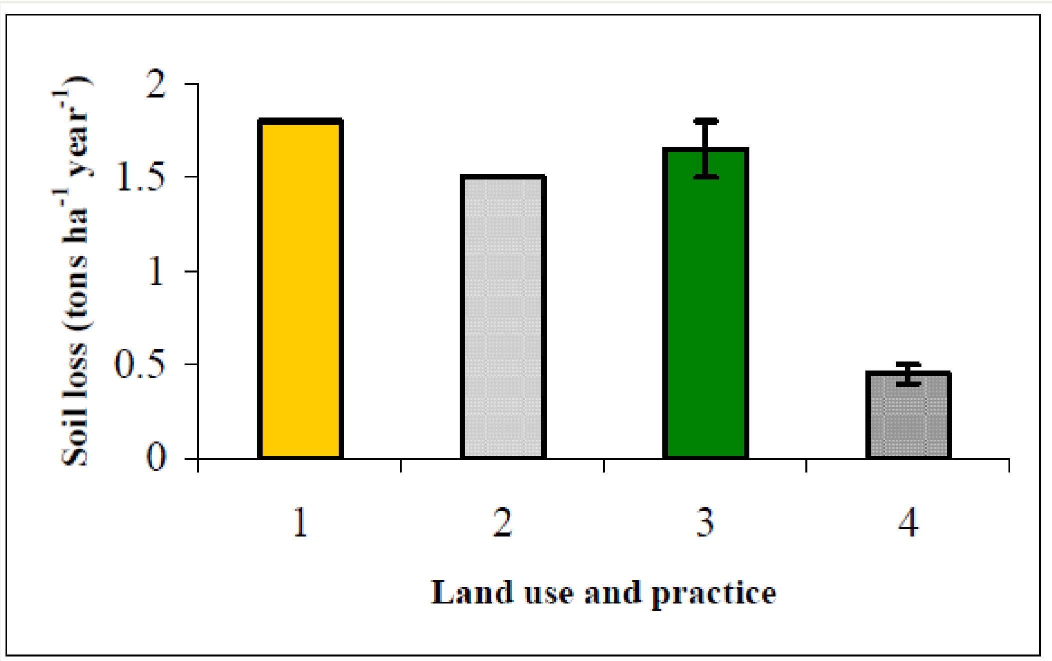

Fig. 1: The average soil loss from arable land as affected by land use and practice
1.Traditional arable cropping, no contouring 2. Traditional arable cropping, contouring
3. SAF, no contouring 4. SAF, contouring

Further the findings of Pellek[1], Bannister and Josiah[3] also suggested that hedgerow intercropping is one of the important aspects of agroforestry for the effective control erosion.

MAINTAINANCE OF SOIL ORGANIC MATTER

Soil organic matter (SOM) signifies the organic matter component of soil, consisting of plant and animal residues at various stages of decomposition. Soil organic matter affects many soil properties such as infiltration rate, physical properties (bulk density, aggregate stability), cation exchange capacity, nitrogen availability, and soil quality parameters[16]. Soil organic matter replenishment is the primary constituent for regenerating soil health and increasing soil organic matter which is prime goal of most agroforestry systems. Sharma[20] observed an increase of soil organic matter, different forms of the N and P up to 15 years old large cardamom plantation, thereafter, the decrease associated with decline in the litter accumulation and productivity in 20, 30, and 40-years plantation stand (Table-3). Findings of Upadhyaya *et al.*,[23] also suggested an increased amount of soil organic matter, available N and available K content in the mandarin orchards of Sikkim. In another study, Dhyani[6] also observed an increase of soil organic matter with different agroforestry systems at mid altitude of Meghalaya after 5 years of tree planting, thereafter decreased after 7 years on sloppy lands.

Table 3. Soil organic matter, different form of nitrogen and phosphorus in the different of *Alnus*-cardamom plantation

Indices	Stand age (years)					
	5	10	15	20	30	40
SOM (t/ha)	145±9	152±5	200±11	158±9	169±15	143±10
Total N (t/ha)	8.4±2.1	8.7±1.8	9.9±1.7	11.7±2.9	9.8±1.9	8.9±2.1
Inorganic N (kg/ha)	90±8	93±15	95±17	101±11	82±6	78±5
NAI (kg/ha)	21.9±4.2	30.8±5.0	38.0±9.4	28.9±8.0	26.6±7.4	17.5±4.1
Total P (kg/ha)	2285±105	2312±110	2554±121	2457±139	2255±129	2192±136
Inorganic P (kg/ha)	110±19	117±14	162±20	126±21	120±19	107±25
Avail. P (kg/ha)	135±17	137±19	182±26	147±16	143±16	130±13

IMPROVING SOIL PHYSICAL PROPERTIES

Soil physical properties include the interactive complex between particles, the volume and size distribution of pores and their degree of aggregation. Degree of aggregation and pore space determine structure, consistence, bulk density and porosity, which are related to water holding capacity, permeability, soil drainage (aeration) and resistance to soil erosion. Soils under natural forests have favorable effects on soil physical properties whereas physical properties degrade following forest clearance[11]. Improved water holding capacity (WHC) has been reported beneath *Acacia alhida* by Felker[7]. The degree of soil aggregation in four-year old plantations established on land cleared from natural forest in Brazil increased as compared to forest under *Pinus caribaea* but decreased under both oil palm and rubber[19]. Kashyap *et al*.[10] reported physico-chemical properties of the soil viz. organic carbon (OC) and available N, P, K, and Ca increased significantly in each type of block plantation of agroforestry species (Table-4). The highest OC contents (2.75 %) were observed under *Ulmus villosa* and *Albizia stipulata* syn. *A. chinensis*. Further, the highest available nitrogen kg ha^{-1} was under *Albizia stipulata* and *Dalbergia sissoo*, i.e., 458 and 459 kg ha^{-1}, respectively; available P in *Grewia optiva* (459 kg ha^{-1}) and exchangeable Ca in *Dalbergia sissoo* plantation (5880 kg ha^{-1}), whereas pH was observed near to neutral and EC was almost same as in the control in all the plantations. Yamoah *et al*.[26] also observed soil physical properties are highly improved with hedgerows.

Table 4. Effect of block plantation of agroforestry species on physico-chemical properties of the soil

Name of the species	OC (%)	pH	EC_2 (dSm^{-1})	Avail.N (kg ha^{-1})	Avail.P (kg ha^{-1})	Avail K (kg ha^{-1})	Ex Ca (kg ha^{-1})
Albizia stipulate	2.74	7.1	0.33	458	39	437	5337
Acer oblongum	2.13	7.1	0.36	415	30	422	5285
Bauhinia retusa	2.27	7.1	0.34	359	40	477	5477
B. variegate	2.55	7.2	0.34	386	29	370	5275
Bombax ceiba	2.29	7.0	0.35	317	38	438	5127
Celtis australis	2.01	7.1	0.35	307	33	448	5369
Dalbergia sissoo	2.51	7.1	0.34	459	32	409	5880
Grevillea robusta	2.27	7.0	0.30	329	31	337	5516
Grewia optiva	2.30	7.1	0.34	273	41	459	5409
Melia composite	2.21	7.2	0.36	250	40	357	5191
Robinia pseudoacacia	2.46	7.2	0.34	474	39	420	5673
Sapindus mukorossi	2.34	7.0	0.33	304	30	437	5275
Terminalia arjuna	2.38	7.0	0.35	275	28	388	4175
Toona ciliate	1.90	6.9	0.35	361	30	336	4873
Prunus armeniaca	2.06	7.1	0.36	329	30	443	5093
Punica granatum	2.38	7.1	0.33	292	29	392	4760
Paulownia fortunii	2.67	7.0	0.29	279	30	423	5182
Quercus leucotrichophora	1.93	7.0	0.36	319	27	349	5384
Ulmus villosa	2.75	7.0	0.35	321	29	431	4984
Control	1.83	7.1	0.36	251	24	315	3802

(Source: UHF[22])

BIOLOGICAL PROPERTIES

Soil organisms play an important role in nutrient turn over, organic matter transformation and also the key physical architect to improve soil structure. The soil fauna which are helpful includes both primary and secondary decomposers, ensures cycling of nutrients, breakdown of organic matter and the availability of essential nutrients particularly N-mineralization. In agroforestry systems microbes mostly concentrate to the top soil or surface. The dense network of fine roots of trees having capacity for plentiful mycorrhizal association increases the availability of nutrients to the participating crops.

Soil degradation associated with cultivation, depletion of organic matter, reduced floral diversity etc. leads to reduction of the population of soil micro-arthopods. Population density and composition of the fauna in soil are the indicators of condition and rehabilitation of ecosystem quality[5]. The population of micro-arthopods of natural re-growth and planted fallows in Nigeria are given in Table-6. It can be noted from the table that the population of soil micro-arthopods was higher in natural fallow and planted woody fallow species as compared to continuous cropping land. The favourable influence of earthworms, termites and ants on the physical, chemical and biological properties of soil has been studied by various researchers. Soil and crop techniques employed in agroforestry have favourable effect to enhance the activity of soil fauna[9], which positively affects the rates of soil turnover, mineralization and humification of soil organic matter, soil texture and consistency, porosity, infiltration rate and soil-water retention characteristics[12, 25].

Table 5. Effect of fallows on population of soil micro-arthopods over the years (May to March) in southwestern Nigeria[1]

Microarthopods	No. of population/m^2				
	Continous natural regrowth	**Leucaena**	**Acacia**	**Senna**	**Cropping**
Soil mites (Acari)					
Oribatids	7218	6662	8394	12014	2569
Actinedids	1216	1183	1568	1718	467
Gamacids	3525	2568	3754	3966	1174
Springtails (Collembola)	2483	1697	3098	3701	724
Others	248	104	207	659	43
Total	**18591**	**15911**	**22621**	**27004**	**7952**

CONCLUSION

Agroforestry is an ecologically based, natural resources management system that sustains production and benefits all those who use the land by integrating trees on farms and in the agricultural landscape. In addition to provide timber, fodder, fuel wood, medicines, etc., it conserves soil and enhances soil fertility. Less-developed countries of the tropics and subtropics, there is a large and growing problem of decline in soil fertility. This is caused both by erosion and by other processes of soil degradation but many agroforestry practices have the potential to control erosion through barrier and cover approach and maintain soil organic matter. Trees in agroforestry systems can help to maintain soil physical, chemical and biological properties, and promote efficient nutrient cycling as well as make a major contribution to soil conservation and sustainable land use.

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