Conservation of natural resources in tree based systems

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Agroforestry is a collective name for land use systems in which woody perennials (trees, shrubs, etc.) are grown in association with agricultural plants (crops, pastures) and/or livestock, in a spatial arrangement, a rotation or both, in which there are both ecological and economic interactions between the tree and non tree components of the system. The important aspect of this land use system is that it includes a combination of trees with plants or animals and that there must be interactions between the tree and non-tree parts. It is the ecological interactions that are the most distinctive feature, which differentiates agroforestry with social forestry.

a) Conservation of soil and water: One of the major advantages of agroforestry in terms of improving or conservation of natural resources and sustaining soil productivity is through its effect on soil and water conservation. Erosion is regarded as one of a number of forms of soil degradation, including deterioration of physical, chemical and biological properties, all of which require attention. It has been recognized that the consequences of erosion are by no means limited to soil depth; its major adverse effects are loss of organic matter and plant nutrients, with consequent degradation of soil physical properties and decline in crop yields. Trees and shrubs can contribute directly through enhancing soil cover, provide live or dead barriers and enhances soil's resilience to erosion through maintenance or build up of organic matter and desirable physical properties. When trees are planted on erosion control structures including grass strips, bunds and terraces, they gets strengthened resulting in improving their longevity and efficiency towards reducing runoff and erosion. Barrier hedges such as in alley cropping are effective in limiting runoff. Alley cropping can be a very effective means of controlling soil erosion. Common tree based systems that can be used for erosion control in the tropics are given in Table no. 1.

Vegetative barriers with rows of trees, shrubs, perennial grasses, hedges, windbreaks and shelterbelts etc. on contours are cheap and effective barriers as compared to mechanical measures in reducing/controlling erosion on mild slopes (Narain et al 1998). The barrier function is operative by reducing wind speed, checking runoff and suspended sediments. The cover function involves reducing raindrop impact and wind action on soil particles by increasing soil cover through litter and pruning. In black soils, leucaena keylines established at 0.25 m vertical interval recorded minimum runoff and gave maximum net monetary returns under pigeon pea+sorghum and pigeon pea+soyabean system in sloping land at Parbhani (Jadhav et. al. 2006). At Kanpur, Leucaena based wider alley width (6.5m) and intra row spacing of 0.5m proved very effective in arresting erosion and contributed to higher sorghum yields (Haider et al. 2005). Vegetative barriers influence redistribution of sediment in the catchments resulting in deposition of sediment on contours and forming terraces/ bunds naturally. Live fencing with tree species such as *Acacia caesia*, *A. concinna*, *A. nilotica*, *Agave sisalana*, *Annona squamosa*, *Borassus flabellifer*, *Carissa carandus*, *Lawsonia inermis* and *Murraya koenigii* around fields and homesteads is an important indigenous practice in eastern ghats region of India which can control erosion (Chaudhury et. al. 2005).

Agroforestry practices also effects soil physical properties and influences the soil erodibility factor. It has been widely observed that soil structure is of a higher grade under forest than under cultivation, which includes increased stability, lower detachability and higher infiltration capacity. In tree based systems the soil cover formed of living and dead plant material including herbaceous plants and perennial cover crops, crop residues and tree litter and prunnings can effectively check raindrop impact and runoff and the potential of this cover approach for reducing erosion is greater than that of the barrier approach. Agroforestry can contribute to maintenance of such effective ground covers for longer periods of time in a number of ways. In addition to providing living or dead plant materials on the surface the presence of multiple layers of canopy as in plantation crop combinations, multi layer tree gardens and home gardens can considerably reduce the velocity of falling raindrops and thus reduce the severity of their impact. Some recorded erosion rates under agroforestry practices and other relevant forms of land use are shown in Table:2. For classifying the systems the rates of erosion is taken as low (< 2 t/ ha/ year), moderate (2-10 t/ ha/ year) and high (>10 t/ ha/ year). Among agroforestry practices, only multi storey tree gardens are by their nature always likely to control erosion, and other practices notably planted tree fallows, alley cropping, plantation crop combinations, multipurpose wood lots and reclamation forestry have the potential to reduce erosion to acceptable levels with appropriate management levels.

Table 1: Agroforestry practices for with potential for soil erosion control

Agroforestry practice	Environments in which it is applicable	Notes
Plantation crop combinations	Humid to moist sub humid climates	Densely planted combinations of agricultural plantation crops with multipurpose tree species appear to control erosion effectively on at least moderate slopes
Multistorey tree gardens including home gardens	Mainly distributed in humid and moist sub humid climates, but possible potential in drier regions	Possess inherent capacity to control erosion through combination of herbaceous cover with abundant litter
Hedge row intercropping (alley cropping) and barrier ridges	Humid, sub humid and possibly semi arid climates	Considerable potential to combine erosion control with arable use on gentle to moderate slopes, high potential on steep slopes
Trees on erosion control structures	Any	Supplementary use of trees stabilizes earth structures and gives production from land they occupy
Windbreaks and shelterbelts	Semi arid zone	Proven potential to reduce wind erosion
Silvopastoral practices	Semi arid and sub humid climates and humid climates	Opportunities for inclusion of trees and shrubs as part of overall programmes of pasture improvement
Reclamation forestry leading to multiple uses	Any	Potential for planned design and development
Combination of the above in integrated watershed management	Any	Substantial opportunities to include agroforestry with other major kinds of land use in integrated planning and management

Table 2: Rates of soil erosion in tropical eco systems

Land use system	Erosion (t/ ha/ year)		
	Minimum	Median	Maximum
Multi storey tree gardens	0.01	0.06	0.14
Natural rain forest	0.03	0.30	6.16
Shifting cultivation, fallow period	0.05	0.15	7.40
Forest plantation, un disturbed	0.02	0.58	6.20
Tree crops with cover crop or mulch	0.10	0.75	5.60
Shifting cultivation, cropping period	0.402.78	70.05	
Taungya, cultivation period	0.63	5.23	17.37
Tree crops, clean weeded	1.20	47.60	182.90
Forest plantations, litter removed or burned	5.92	53.40	104.80

Windbreaks and shelterbelts are long multiple rows of trees and shrubs usually along coasts to protect agricultural fields from inundation by tidal waves. Where wind is a major cause of soil erosion and moisture loss, windbreaks can reduce the velocity of the wind and thus its ability to carry and deposit soil and sand and can improve microclimate of the protected area.

In western Kenya, the World Agroforestry Centre, together with various partners, has tested the potential of improved fallow systems for controlling soil erosion, using fast-growing shrubs such as Crotalaria spp. and Tephrosia spp. These species showed great promise in reducing soil losses (Boye and Albrecht 2005). At the same time a significant improvement in soil water storage has been observed in the improved fallow systems optimizing the use of increasingly scarce rainwater through agroforestry. The parkland farming system, in which trees are encouraged to grow in a scattered distribution on agricultural land, is one example. Successful and well-managed integration of trees on farms and in agricultural landscapes often results in diversified and sustainable crop production, in addition to providing a wide range of environmental benefits such as erosion control and watershed services. When designing tree fallow and agroforestry systems for erosion control, the primary aim should be to establish and maintain a ground cover of plant litter.

b) Nutrients: Nutrient cycling occurs to varying degrees in all land use systems. Agroforestry systems and other tree-based systems are commonly credited with more efficient nutrient cycling than many other systems because of the presence of woody perennials in the system. These woody perennials have theoretically more extensive and deeper root systems and have a potential to capture and recycle a larger amount of nutrients. Their litter contribution to the soils surface is greater than that of herbaceous plants. About 20 to 30% of the total living biomass of the trees is in their roots and there is a constant addition of organic matter to the soil through dead and decaying roots. In a moist tropical forest the net annual contribution of dead roots was to the tune of around 2600 kgs/ ha. In addition the addition of soil organic matter during active root growth in the form of sloughed off tissue much of it coming directly from the roots without the intervention of microfauna. The deep rooting ability of trees, helps trees to absorb nutrients from the soil depths that crop roots can not reach and recycle them to the surface soil layers through addition of litter. The extent of litterfall in some of the systems and the quantities of nutrients recycled is furnished in Table:3. Forest eco systems represent closed and efficient nutrient cycling systems, meaning that they have higher rates of turnover, and lower rates of losses from the system and they are self sustaining. The major difference between agroforestry and other land use systems lies in the transfer or turn over of nutrients with in the system from one compartment to the other and the possibility of managing the system or its components to facilitate increased rates of turnover without affecting the overall productivity of the system. In alley cropping systems, some species are capable of supplying 100-200 kg N/ ha/ year if all the prunnings are left on the soil. In coffee and cacao plantations with shade trees the return from litter and prunnings is 100-300 kg N/ ha/ year, which is much higher than the amount removed during harvest or derived from nitrogen fixation. Prunnings, which consist mostly of leaf but also some woody tissues, of many of the woody perennials used in agroforestry systems, especially alley cropping generally contain large quantities of nitrogen. These prunnings when applied to crops will make available nitrogen for the associated crops. However the rates of decomposition of the leaves vary widely.

Table 3: Dry matter and nutrient inputs via litterfall/ prunings in various production systems in the humid tropics

System	Dry matter t/ ha/ year	Nutrient inputs kg/ ha/ year				
		N	P	K	Ca	Mg
Fertile soils- Alley cropping						
Leucaena	5-6.5	160	15	150	40	15
Gliricidia	12.3	358	28	232	144	60
Erythrina	8.1	198	25	147	111	26
Shade systems						
Coffee/ Erythrina	17.2	366	30	264	243	48
Cacao/ Erythrina	5.8	95	11	57	108	43
Cacao/ mixed shade	8.4	52	4	38	89	26
Infertile soils- Alley cropping						
Inga edulis	5.6	136	10	52	31	8
Erythrina spp.	1.9	34	4	19	8	4

c) Carbon: The role of soil organic matter in soil fertility maintenance is very well known and trees help maintain soil organic matter through the provision of litter and root residues. Agroforestry systems not only provide a great opportunity for sequestering carbon, and helping to mitigate climate change, but also enhance the adaptive capacity of agricultural systems in tropical and subtropical regions. The potential carbon storage of some of the tree based systems is presented in Table 4. There has been a major emphasis on improving the productivity of agricultural systems, leading to an increase soil carbon stocks in degraded lands. A wide range of studies (Albrecht and Kandji 2003, Palm et al. 2005) have substantiated the fact that agroforestry systems, even if they are not primarily designed for carbon sequestration, present a unique opportunity to increase carbon stocks in the terrestrial biosphere. Agroforestry provides a unique opportunity to reconcile the objectives of mitigation of, and adaptation to, climate change.

Table 4**:** Potential carbon (C) storage of agroforestry systems in different ecoregions of the world.

Ecoregion	Climatic region	System	Mg C ha–**1**
Africa	Humid tropical high	agrosilvicutural	29–53
South America	Humid tropical low	agrosilvicutural	39–102
	Dry lowlands		39–195
Southeast Asia	Humid	agrosilvicutural	12–228
	Tropical dry lowlands		68–81
Australia	Humid tropical low	silvopastoral	28–51
North America	Humid tropical high	silvopastoral	133–154
	Humid tropical low	silvopastoral	104–198
	Dry lowlands	silvopastoral	90–175
Northern Asia	Humid tropical low	silvopastoral	15-18

Several agroforestry practices have potential for erosion control, soil fertility improvement and climate change mitigation potential and many of them are being used in several countries throughout the world. Often times, either erosion control, or soil fertility enhancement or mitigation of climate change is the main objective of the practice. For different situations, different types of agroforestry technologies have to be designed. Best results can be obtained if agroforestry technologies are combined with other relevant land use technologies, even for a single farm or land management unit, in accordance with the bio physical conditions of the farm, the farmers' production objectives and the prevailing market opportunities.

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