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REVIEW ON BENEFITS OF AGRO FORESTRY SYSTEM

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ABSTRACT

Agroforestry is a land use option that increase livelihood security and reduce vulnerability to climate and environmental change. According to Planning Commission report "Greening India", that 33% forest cover can only be achieved through agro-forestry. Agro-forestry has many potential, such as enhance the overall (biomass) productivity, soil fertility improvement, soil conservation, nutrient cycling, micro-climate improvement, carbon sequestration, bio drainage, bio energy and bio fuel etc. Nowadays agro-forestry has gained popularity among farmers, researchers, policy makers and other for its ability to contribute significantly in meeting deficit of tree products, socio-economic and environmental benefits.

KEYWORDS: Agro Forsetry, Bio Drianage, Bio Fuel.

INTRODUCTION

Land-use options that increase livelihood security and reduce vulnerability to climate and environmental change are necessary. Traditional resource management adaptations such as agro-forestry systems may potentially provide options for improvement in livelihoods through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change.

AGROFORESTRY DEFINITION

There are several definitions of agroforestry given by the experts and scientists working on agroforestry. Looking to the available definition of agroforestry, there is a consensus that agroforestry is a land use system which involves trees with agricultural crop/grass and/or animals simultaneously or sequentially. The most commonly used definition is "Agroforestry is a collective name for land use system in which woody perennials (tree, shrubs etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in spatial arrangement, a rotation or both; there are usually both ecological and economic interactions between the trees and other components of the system" (Lundgren, 1982).

COMPONENTS OF AGRO-FORESTRY

In general there are 4 or 5 basic sets of components which are managed by human beings in all agro-forestry systems. Structurally, the system can be grouped as:

Agri-silviculture system

Agri-horticulture system

Silvipastoral system

Agri-silvipastoral system

On the basis of nature of components the following are common agroforestry systems found in different agroecological regions of India:

Agrisilviculture (trees + crops)

Boundary plantation (tree on boundary + crops)

Block plantation (block of tree + block of crops)

Energy plantation (trees + crops during initial years)

Alley cropping (hedges + crops)

Agri-horticulture (fruit trees + crops)

Agri-silvihorticulture (trees + fruit trees + crops)

Agri-silvipasture (trees + crops + pasture/animals)

Silvi-olericulture (tree + vegetables)

Horti-pasture (fruit trees + pasture or animals)

Horti-olericulture (fruit tree + vegetables)

Silvi-pasture (trees + pasture/animals)

Forage forestry (forage trees + pasture)

Shelter-belts (trees + crops)

Wind-breaks (trees + crops)

Live fence (shrubs and under- trees on boundary)

Silvi-horti-sericulture (trees/fruit trees + sericulture)

Horti-apiculture (fruit trees + honeybee)

Aqua-forestry (trees + fishes)

Homestead (multiple combinations of trees, fruit trees, vegetable etc).

INTERACTIONS IN AGRO-FORESTRY

In agroforestry, complementary or competitive effects depends upon (i) age and size of the trees, (ii) nature of the tree species, (iii) nature of the agricultural crops, (iv)availability of water, nutrients and light etc. In an intercropping system involving a legume and non-legume, part of the nitrogen fixed in the root nodule of the legume may become available to the non-legume component which is an example of complementarity (Soundararajan and Palaniappan, 1979). The complementarity in resource capture under mixed cropping/ intercropping system may be spatial or temporal. In temporal complementarity, the leaf canopies of component crops may occupy different vertical layers with taller component tolerant of strong light and high evaporative demand and shorter component favoring shade and high relative humidity. Multistoreyed cropping in coconut and planting shade trees in cocoa and tea plantation uses this principle. In similar manner under agro-forestry system, exploitation of different layers of soil by the root systems of trees and crops may lead better utilization of resources with much less competition. In temporal complementarity, the yield advantages provided by the mixture cannot always be explained by more effective use of growth resources at specific times. Indeed, there are substantial opportunities for temporal complementarity if species make their major demands on available resources at different times, thereby reducing the possibility of competition.

BENEFITS OF AGRO FORESTRY

ENHANCED PRODUCTIVITY

In agroforestry, the potentially higher productivity could be due to the capture of more growth resources *e. g.* light or water or due to improved soil fertility. Several studies in different parts of the country suggested that agroforestry is more profitable to farmers than agriculture or forestry for a particular area of land (Tokey, 1997 and Samra *et al.*, 1999).

National Research Centre for Agroforestry has been working since 1989 on agri-silvi-horticulture system which included 4 varieties of *aonla viz.*, Chakaiya, Kanchan, Krishna and NA 7 as fruit trees, *Leucaena* as multipurpose tree and blackgram as intercrop in rainfed areas. The *Leucaena* was planted on both sides of the fruit trees at 2 m distance. The *aonla* was planted at 10 m x 6 m and 5 m x 6 m spacing but 10 m x 6 m spacing was proved an ideal spacing among these and it was considered for calculating the yield and economics of the system. The cost of cultivation in first year which includes planting of fruit trees and *Leucaena* as multipurpose trees and cultivation of crop was Rs 8,666/ha but during next year the cost of cultivation was reduced and it was again increased with subsequent increase in the cost of input during different years. The gross income from the system was less during initial year but when fruiting started in *aonla*, the gross income was increased and it went up to Rs 60,712/ha at age of 13 years. Similarly the net income was positive in all the years except at first, third and six years when *aonla* had no fruiting/or less fruiting. In age of 13 years, the B: C ratio from the system was 3.28 and on discounted rate it was 2.61 which indicated that *aonla* based agroforestry system is a profitable enterprise in marginal lands under rainfed conditions (Ram Newaj and Rai, 2005).

ENHANCING SOIL FERTILITY

The primary objective of soil conservation is to improve / maintain soil fertility. To achieve this, control of erosion, maintenance of organic matter and physical properties, organic matter addition, maintenance of nutrient is necessary. In this way agroforestry system constitute sustainable land use and helps to improve soils in the number of ways. Maintenance and enhancement of soil fertility is vital for global food security and environmental sustainability. Although currently India is self-sufficient in terms of food production, for a population expected to rise further, the country will need to enhance both food production as well as tree biomass. Ecologically sound agroforestry systems such as intercropping and mixed arable-livestock systems can increase the sustainability of agricultural production while reducing on-site and off-site consequences and lead to sustainable agriculture. Alternate land-use systems such as agroforestry, agro-horticultural, agro-pastoral and agro-silvipasture are more effective for soil organic matter restoration (Manna, *et al*. 2003).

Samra and Singh (2000) observed in increase in soil organic carbon status of surface soil 0.39 % to 0.52 % under *Acacia nilotica* + *Saccharum munja* and 0.44% to 0.55% under Acacia nilotica+ Eulaliopsis binata after 5 years and suggested that Acacia nilotica + Eulaliopsis binata are conservative but more productive and less competitive with trees and suitable for eco- friendly conservation and rehabilitation of degraded lands of Shivalik foot hills of sub-tropical northern India. Ram Newaj *et al.* (2008) observed that in agri- silviculture growing of Albizia procera with different pruning regimes, the organic carbon of the soil increased by 13-16 % from their initial values under different pruning regimes which was 5 to 6 times higher than growing of either sole tree or sole crop.

Soil fertility can also be regained in shifting cultivation areas with suitable species. For instance, a field experiment to study N_2 fixation efficiency suggests that planting of stem-cuttings and flooding resulted in greater biological N_2 fixation, 307 and 209 kg N ha^{-1} by Sesbania rostrata and S. cannabina respectively. Thus, S. rostrata can be used as a green manure by planting the stem-cuttings under flooded conditions (Patel et al., 1996).

SOIL CONSERVATION

Agro forestry system on arable lands envisage growing of tress and woody perennials on terrace risers, terrace edges , field bunds as intercrops and as alley cropping in the shape of hedge row plantation. Integrating trees on the fields act as natural sump for nutrients from deeper layers of soil, add bio-fertilizer, conserve moisture and enhance productivity of system. The alley cropping with leguminous trees *viz*., subabul (Leucaena leucocephala) has been most widely used on the field bunds for producing mulch material for moisture conservation and nutrient recycling. Alley cropping with Leucaena leucocephala was effective for erosion control on sloping lands up to 30%.

Suitable alternate land use systems involving agriculture, horticulture, forestry and agroforestry has been designed with the support of local natural resources for almost identical hydrological behaviour as under the natural system. The model land use suggests utilizing slopes below 50% towards lower foothills and valley lands for agricultural crops and pisiculture, middle slopes between 50 and 100% for horticulture and top slopes over 100% for forestry / silvipastoral establishment. Under agri- horti -silvi-pastoral systems, the reduction in runoff was 99 % and in soil loss 98% (Singh, 1988). Combining fine root system of grasses and legumes, such as *Stylosanthes guyanensis, Panicum maximum, Setaria* etc. and deep-root system of fodder trees, such as alder (*Alnus nepalensis*) in a silvi- pastoral system stabilizes terrace risers and provides multiple outputs. Silvipastoral system comprising Alnus nepalensis, pineapple and forage crops like Panicum maximum or Setaria sphacelata coupled with S. guyanensis in 1:1 ratio was found to be a sustainable agroforestry practice in soils having 30-60% slopes. Forage yield of 13.5 t/ha was obtained from the combination of Stylo and Setaria. In addition, 2.3 t/ha litter from Alnus nepalensis and 4,000 fruits / ha from pineapple were obtained. This system also restored the fertility of these soils (Chauhan *et al.*, 1993).

ENHANCING WATER USE EFFICIENCY

Through a combination of mulching and water conservation, trees in agro-ecosystems may directly enhance crop yields of coarse grains. For instance, in the arid region of Haryana, the effect of *Prosopis cineraria, Tecomella undulate, Acacia albida* and *Azadirachta indica* on the productivity of *Hordeum vulgare* (barley) was found to be positive. *P. cineraria* enhanced grain yield by 86.0%, *T. undulata* by 48.8%, *A. albida* by 57.9% and *A. indica* by 16.8% over the control. Biological yield was also higher under trees than that in the open area. Soils under different tree canopies were rich in organic carbon content, moisture availability and nutrient status (Kumar *et al.* 1998).

There is robust evidence that agroforestry systems have the potential for improving water use efficiency by reducing the unproductive components of the water balance. Examples from (run-off, soil evaporation and drainage) India and elsewhere show that simultaneous agroforestry systems could double rainwater utilization compared to annual cropping systems, mainly due to temporal complementarity and use of run-off in arid monsoon regions. For example, a combination of crops and trees uses the soil water between the hedgerows more efficiently than the sole cropped trees or crops, as water uptake of the trees reached deeper and started earlier after flood irrigation than that of the *Sorghum* crop, whereas the crop could better utilize top soil water (Lehmann *et al*. 1998). Integration of persistent could better utilize topsoil water perennial species with traditional agriculture also provides satisfactory drainage control to ameliorate existing out breaks of salinity. Agroforestry systems can also be useful for utilization of sewage-contaminated wastewater from urban systems.

MICROCLIMATE IMPROVEMENT

The use of trees as shelterbelts in areas that experience high wind or sand movement in well-established example of micro climate improvement that resulted in improved yields. Establishment of micro – shelterbelts in arable lands, by planting tall and fast growing plant species *viz*., castor on the windward side and shorter crop such as vegetables in the leeward side of tall plants helped to increase the yield of bhendi yield by 41 % and of cowpea by 21 % over the control (Venkateshwaralu, 1993). Experimental shelterbelts of *Acacia nilotica* and *Dalbergia sissoo* were established over 120 km in square block at the Central Mechanized Farm of Central Arid Zone Research Institute at Suratgarh, Rajasthan. Reduction in wind speed was greater during monsoon (July- September) than before the monsoon period (April – June). There was a 5-14 % reduction in evaporation from April to July. In general, the use of shelterbelts brought about a 50% reduction in the magnitude of wind erosion. In the *Cassia siamea* shelterbelts, the loss was 184.3 kg /ha while in bare soil (*i.e.* without any shelterbelts) it was 346.8 kg / ha. The evidence for the beneficial effects of shade trees depends on the nature of the understorey crops. The clear effect is reported for crops that require shading for normal growth *e.g.* black pepper, turmeric, cacao.

BIODIVERSITY CONSERVATION

Over exploitation of natural resources is a major challenge for sustainable production and livelihood security. Deforestation is that major cause which affected the bio-diversity of an ecosystem. Agroforestry with components like trees, agricultural crops, grasses, livestock etc. provides all kinds of life support. However, agroforestry may not entirely reduce the deforestation (Angelsen and Kaimowitz, 2004) but in many cases it acts as an effective buffer to deforestation. Trees in agroforestry system act as a refuse to biodiversity after catastrophic events such as fire (Griffith, 2000). The traditional society of coastal belts and tropics of the country practicing homegardens and sacred groves help in bio- diversity conservation.

BIO-DRAINAGE

The biodrainage technique is eco-friendly as the biodrainage plantations purify our environment by absorbing greenhouse gases from the environment and releasing oxygen into the environment. The biodrainage technique does not require any disposal of drainage effluent as the biodrainage plantations drain out the filtered fresh water into the atmosphere by using their bio-energy. Commonly drainage effluent has been disposed of into rivers. This practice is progressively becoming problematic as the drainage effluent contains drained nutrients, salts and residues of agro-chemicals and affects the health of reservoirs, rivers and inland seas into which it is discharged. The salinity of most inland seas is known to increase over time because of the continuing inflow of saline drainage water. The Aral Sea Basin, the Indus basin in Pakistan, various river systems in India and the Murray-Darling Basin Catchment in Australia are suffering the consequences of river water pollution as a result of the discharge of polluted drainage effluent from irrigated lands (Heuperman *et al.*, 2002).

Rise in ground water table followed by water logging and secondary Stalinization of soils has become a serious problem in canal irrigated areas located in arid and semi-arid regions of the world. To combat the problem, an agroforestry model of biodrainage was tested in waterlogged area of Haryana state (north-west India) in which 10% area (0.44 million ha) has already become waterlogged resulting in reduced crop yield and abandonment of agricultural lands. In this model, four parallel strip-plantations of clonal *Eucalyptus tereticornis* (Mysure gum) were raised in December 2002 on four ridges constructed in north-south direction in 4.8 ha waterlogged area. The strip-plantations were spaced at 66 m and each strip-plantation contained 2 rows of plants at a spacing of 1 m x 1 m resulting in a density of 300 plants/ha. Levels of ground water table were measured over 3 years (April 2005 to April 2008) in 22 observation wells installed in 2 transects across the strip-plantations. The ground water table underneath the strip-plantations remained lower than the ground water table in the adjacent fields and the drawdown in ground water table during a period of 3 years was 0.85 m. Rate of transpiration (May 2008), measured with sap-flow meter, was 50 litres/day/plant which was equal to 438 mm/annum against the mean annual rainfall of 212 mm. Benefit-cost ratio of first rotation (5.4 years) of strip-plantations was 3:1 against

1.3:1 of agricultural crops in Haryana and it would be more than100:1 for next 3 to 4 rotations due to negligible cost of maintenance of coppiced Eucalyptus. Wheat yield (April 2007) in the inter-space of strip-plantations was 3.34 times the yield in adjacent waterlogged areas without plantation. This agroforestry model of biodrainage has proved a low-cost, socially-acceptable and environment-friendly technique for the reclamation of waterlogged areas and during 2008-09. This agroforestry model of biodrainage has proved a low-cost, socially-acceptable and environment-friendly technique for the reclamation of waterlogged areas and has been implemented on 2500 ha farmer's waterlogged areas of Haryana during 2008-09.

CARBON SEQUESTRATION

Tree components in agroforestry systems can be significant sink of astmospheric carbon (C) due to their fast growth and high productivity. By including trees in agricultural production systems, agroforestry can, arguably, increase the amount of C stored in lands devoted to agriculture, while still allowing for the growing of food crops (Kursten, 2000). In agroforestry system, tree components are managed, often intensively by pruning of minimizing competition and maximize complementarity. The pruned materials are mostly non- timer products. Such materials are often returned to soil. Besides, the amount of biomass and therefore C that is harvested and exported from the system is relatively low in relation to the productivity of the tree. Therefore, unlike in tree plantations and other mono culture systems, agroforestry seems to have unique advantage in terms of C sequestration.

In India, evidence is now emerging that agroforestry systems are promising land use system to increase and conserve aboveground and soil C stocks to mitigate climate changes. The average potential of agroforestry has been estimated to be 25 t C / ha over 96 m ha (Sathaye and Ravindranath, 1998). In this way the total potential of agroforestry in India to store C is about 2400 m.t. In other estimate, the under agroforestry is 8.2% of total reported geographical area (305.6 m ha) and it contribute 19.3 % of total C stock under different land uses (2755.5 m. t C). Although there is variation in the estimation of area under agroforestry and C stock made by scientist involve in this area but there is good indication of agroforestry for gaining popularity for mitigating climate change because desired tree cover can only be achieved including tree in farm field / bunds. The C storage capacity varied from region to region and also depends upon the growth and nature of tree species involved in the system (Table 1).

Table -1Total C storage under agro-forestry systems in different regions of the country

Region	Agroforestry system and components	Total C storage (t C / ha)	References
Semi- arid region	Silvi-pastoral system (age 5 years) *Acacia nilotica* + natural pasture *A. nilotica* + established pasture *Dalbergia sissoo* + natural pasture *D. sissoo* + establed pasture *Hardwickia binata* + natural pasture *H. binata* + established pasture	 9.5-17.0 19.7 12.4 17.2 16.2 17.0	Rai *et al*. (2001)
North- western India	Silvipastoral system (age 6 years) *Acacia/ Dalbergia/ Prosopis + Desmostacya* *Acacia/ Dalbergia / Prosopis + Sporobolus*	 6.8-18.5 1.5-12.3	Karur *et al.* (2002)
Central India	Block plantation (age 6 years) *Emelina arborea*	 24.1-31.1	Swamy *et al.* (2003)
Arid region (Rajasthan)	Agri- silvicultural system (age 8 years) *Emblica officinalis + Vigna radiate* *Hardwickia binata + vigna radiate* *Colophospermum mopane + Vigna radiata*	12.7 -13.0 8.6 - 8.8 4.7 - 5.3	Singh (2005)
Semi – arid region	Agri-silvicultural system (age 11 years) *Dalbergia sissoo* + crop	26.0	NRCAF (2005)
North-western Himalayas	Silvi-pastoral system Agri- horti- pastoral Horti -pastoral	2.17 1.15 1.08	AICRAF (2006)

A study on C sequestration potential of *Albizia procera* under agri-silviculture was carried out during 2005 in a well established tree having 5 years- age with three pruning regimes (70% canopy pruning, 50 % canopy pruning and un-pruned) with 2 crop rotations (blackgram-mustard and green gram-wheat) at NRC for agroforestry, Jhansi. After 3 year, the system sequestered 23.58 to 24.79 t C / ha under different crop rotations irrespective of pruning regimes and the amount of C sequestered under pruning regimes was 27.97, 22.96 and 21.33 t C/ ha in unpruned tree, 70 % canopy pruning and 50 % canopy pruning, respectively. The C sequestration in pure tree and pure crop was 40 and 84 % less, respectively than agri-silviculture. It indicates that agro forestry system have more potential to sequester C than either growing pure tree or pure crop. Tree without pruning can sequester more C but same time it does not allow cropping after 2-3 years of planting. Canopy pruning of tree gives advantages of C sequestration as well as allow cropping for desired period (Ram Newaj *et al.*, 2008).

AGROFORESTRY FOR BIO-FUEL AND BIO-ENERGY PRODUCTION

In rural areas 70-80% energy comes through biomass from trees and shrubs. Due to the agroforestry initiatives large amount of woods are now being produced from outside the conventional forest lands. The fuel wood potential of indigenous (*Acacia nilotica*, *Azadirachta indica*, *Casuarina equisetifolia, Dalbergia sissoo, Prosopis cineraria* and *Ziziphus mauritiana*) and exotic (*Acacia auriculiformis, A. tortilis, Eucalyptus camaldulensis* and *E. tereticornis*) trees revealed that calorific values ranges from 18.7 to 20.8 MJ/ kg for indigenous tree species and 17.3 to19.3 MJ/kg for exotics. Species such as *C. equisetifolia*, *Prosopis juliflora*, *Leuceana leucocephala* and *Calliandra calothyrsus* have become prominent due to their potential for providing wood energy at the highest efficiency, shorter rotation and also their high adaptability to diverse habitats and climates. In India the energy demand is expected to grow at 4.8%. Further, increasing gap between demand and domestically produced petroleum the dependence on import of oil will increase in the near future.

Biofuels are renewable liquid fuels coming from biological raw materials and has proven to be good substitute for oil in the transportation sector as such biofuels are gaining worldwide acceptance as a solution for problems of environmental degradation, energy security, restricting imports, rural employment and agricultural economy. The potential tree borne oilseeds (TBOs) holding promise for biofuel are *Jatropha curcas*, *Pongamia pinnata*, *Simarouba*, *Azadiracta indica*, *Madhuca* spp., etc. In agroforestry system, *Jatropha curcas* has been intercropped with annual crops such as cowpea, sesame, sunflower, French bean, black gram, green gram and groundnut etc. at various places. The promotion of the use of oils could also provide a poverty alleviation option in the rural areas. Farmers can use vacant, waste and marginally used land for growing such trees and benefit from the annual produce, which will add as their income. With the increased green cover the environment will also benefit greatly. The use of oils is also CO2 neutral, which would mitigate green house effect. But the economics and viability of the *Jatropha* plantation and bio-fuel production are still at initial stage and will be governed by international market prices of crude oil as well as government policies (NRCAF, 2007).

CHALLENGES AND OPPORTUNITIES

Due to increasing demands of food, fodder, fuel, timber and for environmental security, the Indian agriculture is facing with lot of challenges and these are: inclusive growth and sustainable livelihoods, energy security, agricultural growth and food security and environmental security and climate change.

Agroforestry provides great opportunities to link water conservation with soil conservation; hence, the major focus has to be on this aspect (Dhyani *et al.,* 2003).

The opportunities offered by agroforestry are as mentioned here.

- Gives diversification
- Provide opportunity for growth and also mechanism for better equity
- Agroforestry provides societal continuum
- Agroforestry is multifunctional system at the same time and thus, fulfills various demands simultaneously
- Generate fresh water harvesting potential and ground water recharge
- Agroforestry creates green cover for carbon sequestration
- Regenerate biomass and nurtures depleted soil

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