SOIL CARBON MANAGEMENT THROUGH SUSTAINABLE LAND USE

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Land degradation is rampant everywhere, that poses serious threat to ecosystem functioning and services it provides to the society. Climate change has aggravated the situation both locally and globally with wider level of consequences. Global warming and climate change effects such as variable rainfall pattern, increased incidence of extreme weather events like floods and droughts, rise in sea level, heavy and intense storms, decline in crop yields etc. started challenging the survival of communities live in the climatically vulnerable regions of the world. To avoid more consequences of global warming it has become inevitable to reduce the emission of greenhouse gases (GHGs) by 50-80% globally in next 20-25 years.

CLIMATE CHANGE MITIGATION AND ADAPTATION

At the face of intensified land use pattern to achieve global food requirement, energy and water security, and management of soil health to enhance and sustain the carbon (C) stock are crucial. The soil C pool includes soil organic C (SOC) estimated at 1550 Pg and soil inorganic C approx. 950 Pg (Batjes, 1996). These together constitutes 2500 Pg C worldwide (Eswaran et al., 2000), and thus being the third largest global reservoir/pool of C after marine C and fossil fuel reservoirs (Zamanian et al., 2016; Siegenthaler and Sarmiento, 1993). Hence, sustainable land management practices are the need of the hour particularly to ensure the conservation of natural resources for the future generations. Agroforestry system is one of such beneficial land use systems that are known for more C sequestration potential than pastures and annual cropping systems (figure 1) mainly due to the potential of trees for C sequestration through the above as well as below ground portions.

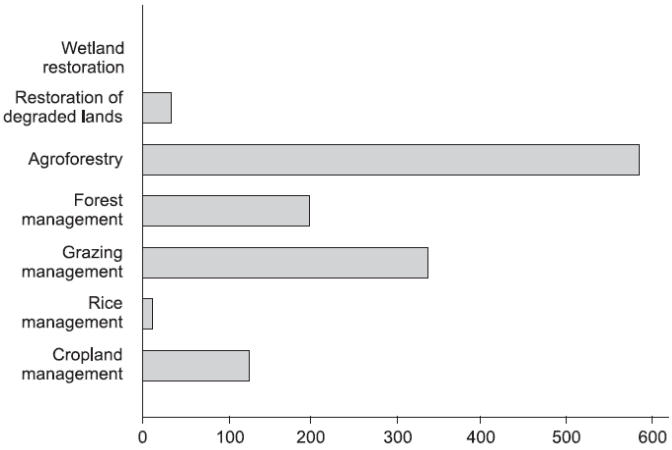

Figure 1: The potential of carbon sequestration through various land use systems and management options (IPCC, 2000)

LAND USE SYSTEMS & CARBON SEQUESTRATION

Agroforestry: Adoption of agroforestry serves the twin objectives of climate change adaptation and mitigation. The leaf litter and pruned biomass adds organic matter to soil. This in turn improves the chemical, physical and biological properties of soil. The below ground biomass of trees in the form of roots roughly comprise of 1/4th to 1/5th or of the total living biomass and also the carbon being added continuously to the soil through decaying of roots. Apart from carbon sequestration, agroforestry is a great means of additional income for small and marginal farmers of tropics.

Grassland: Grassland soils is a significant source of C pool in the order of 200-300 Pg (Scurlock and Hall, 1998). Global grasslands are important part of terrestrial C cycle as they can store to an extent of 343 Gt C in the top 1m soil (Conant *et al*., 2017). Proper grassland management practices such as pruning; root sloughing and regeneration help to continue the contribution indefinitely to the soil C stock. Since these practices improve soil C sequestration rate of grasslands @ 0.5 tonnes C/ha/year (Conant *et al*., 2017). Compared to forests, which store a significant amount of C in the biomass, grasslands store more of C in the soil pool. If the management practices that deplete soil organic C will be reversed, then C stocks through perennial ecosystems could be rebuilt.

Table 1. Effect of land use change on soil organic carbon (SOC) at different soil depths

CHANGE IN LAND USE PATTERN	% CHANGE IN SOC	
	0-15 cm	15-30 cm
Forest to agroforestry system	-26	-22
Forest to agri-silviculture system	-12	-24
Forest to silvi-pastoral system	-44	
Pasture to agroforestry system	N.S.	+9
Pasture to agro-silvo-pastoral system	N.S.	+13
Agriculture to agroforestry system	+25	+20
Agriculture to agri-silviculture system	+25	+40
Uncultivated to agro-silvo-pastoral system	N.S.	+7

*(+) sign denotes increase in SOC; (-) sign denotes decrease in SOC; NS-Non significant change

(Source: De Stafano and Jacobson, 2017)

Table 2. Soil carbon storage potential of different agroforestry systems of India.

REGION	AGROFORESTRY SYSTEMS	SOIL C STORAGE POTENTIAL (t ha^{-1})	SOURCE
Northern India	Agri-silviculture	27.50 - 92.65	Goswami *et al.* (2014); Sarvade *et al.* (2016); Singh *et al.* (2015); Saha and Jha (2012); Rizvi *et al.* (2016)
	Agri-horticulture	35.93 - 90.07	
	Agri-horti-silviculture	29.05 - 84.14	
	Agri-silvi-horticulture	35.73 - 95.46	
	Silvi-pasture	34.27 - 115.45	
Central India	Agri-silviculture	23.38	
	Alley cropping	2.38	
South India	Agri-silviculture	24 - 35	
	Homegardens	119.3	
North east India	Agri-silviculture	65.27 - 106.00	

(Source: Adapted from Chaturvedi *et al.*, 2016)

Table 3. Effect of various range legumes on forage yield and soil organic carbon build up.

TREATMENT	FORAGE DRY-MATTER YIELD (mg/ha)	TOTAL ORGANIC C (g/kg)	SOC BUILD UP RATE (g/kg/yr)
Natural grassland	3.3	7.78	0.74
Alysicarpus rugosus	4.2	7.55	0.67
Atylosia scarabaeoides	4.1	9.22	1.22
Clitoria ternatea	4.4	7.47	0.64
Dolichos lablab	4.7	10.07	1.51
Desmodium tortuosum	4.2	9.72	1.39
Glycine javanica L.	3.8	8.58	1.01
Macroptilium atropurpureum	4.1	7.99	0.81
Macroptilium lathyroides	4.9	11.05	1.83
Mimosa invisa	3.7	8.91	1.12
Stizolobium deeringianum	4.0	8.10	0.85
Stylosanthes guianensis	4.2	10.53	1.66
Stylosanthes humilis	4.0	8.22	0.89
Vigna luteola	4.2	9.15	1.20

Source: Rai *et al.* (2013)

LAND USE AS PER SUITABILITY

Land use systems are an effective economic utilization of land without hampering resource base of the region as per the land capability classification. They mostly have a perennial component that has the potential to tolerate aberrations due to natural or anthropogenic activities, thus add stability to the production system. Sustainable land management integrates technologies, activities, strategies and policies in such a way that cater issues of environment, socio-economics, nutrition etc. so s to address together issues of

- protecting and preventing the natural resource degradation.
- improving the soil fertility and crop productivity through improved land management practices.
- enhancing the system resilience and resistance (offered by the soil) against any sort of disturbance.
- building an economically viable and socially acceptable land use pattern.

Examples of selective trees and their uses listed below:

- for strong roots and conservation with well-developed root system: *Prosopis juliflora, Azadirachta indica* & *Albizzia lebbeck*
- for fodder and fuel: *prosopis juliflora, prosopis cineraria* & *acacia nilotica*
- for fruits and income: *Zizyphus mauritiana, Punica granatum* & *Phoenix dactylifera L.*
- for salt affected areas: *Prosopis juliflora, Prosopis cineraria, Azadirachta indica, Terminalia arjuna, Eucalyptus etc.*
- for waterlogged soils: *Terminalia arjuna, Bambusa spp., Syzygium cumini etc.*

C SEQUESTRATION: CHALLENGES

Perennial systems like pastures and agroforestry act as sinks of atmospheric CO_2. In undisturbed ecosystems, the C balance tends to be positive as C uptake through photosynthesis exceeds C losses through respiration. Thus, grasslands have similar nature of basic processes that govern the C balance similar to other ecosystems: the photosynthetic uptake and subsequent assimilation of CO_2 into organic compounds and release of gaseous C through respiration (primarily CO_2 but also CH_4). However, biomass in grasslands, being predominantly herbaceous, is a small, transient C pool (compared to forest) and hence soils constitute the dominant C stock. Further, while planning to increase C stock of degraded and substandard soils through agroforestry utmost care needs to be taken because, growing trees in these soils may have establishment problem. This results lower biomass and lead to low C sequestration. Also, if the target is highly intensive biomass production, proactive action is required to manage pests and diseases.

SUMMARY

To promote sustainable land use, development of agri-pastoral, silvi-pastoral and horti-pastoral models ideal for different agro-climatic regions particularly, for waste lands as per the land use classification, is required. It should be identified in semi-arid and sub-tropical environments focussing on C sequestration potential. Similarly, management of grasslands with improved grazing practices, choice of species, and integration with other production system components may result a win-win situation. Development of high energy plantations of perennial nature having deep root systems and high SOC sequestration potential reduces nutrient losses through leaching, runoff, erosion etc. and helps to sustain soil health. Total SOC sequestration potential through restoration of degraded and desertified soils in India is estimated to be 10-14 Tg C/yr and agroforestry can play great role to achieve this along with soil health restoration, environmental protection, providing ecosystem services and ensuring livelihood security.

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