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Agroforestry for Adaptation and Mitigation of Climate Change

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Agroforestry is one of the most conspicuous land use systems across landscapes and agroecological zones in India. Agroforestry is addressing the issue of ecologically sound and economically appealing strategies of adaptation and mitigation of climate change, being an intensive, integrated, intentional and interactive, which are creating favorable conditions in term of microclimate modification, biodiversity conservation, soil health improvement, windbreaks and shelterbelts. Scientist, policymakers, agriculture entrepreneurs and farmers need to realize the agroforestry importance in the context to adaptation and mitigation of climate change so that we can address the issues of backwardness in adoption of agroforestry and drawing new sustainable policy.

Introduction

The World Bank Report "Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience" published in June 2013, projects that a scenario of 4 ^{0}C rise in global temperature, would result in increased climate extreme events such as heat waves, sea level rise, more storm surges, droughts and flooding in the South Asian region including India. In addition to this, climate change is an additional threat that might affect a countries ability including the food security, population explosion, poverty, malnutrition and livelihood of small and marginal farmers of worlds. Nobel Prize Laureate, Wangari Maathai in second World Agroforestry Congress quotes, 'Trees have an important role to play, not only in climate change mitigation, but also in reducing vulnerability to climate-related risks'. The potential capacity of Agroforestry to adapt harsh climatic event is greater than agriculture because it's playing important role in ecosystems services and prevents land degradation which makes them to cope up in all type of climatic vagaries.

Agroforestry provides a unique opportunity to reconcile the objectives of enhancing the productivity and improving the soil health. The trees can also play important role towards adapting to the climate variability and mitigating carbon through sinks which helps to reduce pressure from natural forest. Realizing the importance of the agroforestry in meeting the twin objectives of mitigation and adaptation to climate change as well as making Indian agriculture more resilient, therefore keeping in view there is need to emphasize the potential of AFS for adaptation and mitigation.

Agroforestry in Context of Adaptation and Mitigation

Agroforestry has huge potential to adapt and mitigate climate change. Many of the time we talk about adaptation and mitigation strategies of agroforestry in context with global warming but we need to explain these key words. Agroforestry provides a unique opportunity to reconcile the objectives of mitigation and adaptation to climate change. Schoreneberger *et al* (2012) highlighted the adaptation and mitigation measures in Table 1.

Table 1. Measures of climate change adaptation and mitigation through agroforestry

Climate change activity	Major CC Functions	Agroforestry role
Mitigation		
Activities that reduces GHGs in the atmosphere or enhance the storage of GHGs stored in ecosystems	Sequester carbon	Accumulate C in woody biomass and in soil
	Reduce GHG emission	Reduce fossil fuel consumption: Reduce equipment runs in areas with trees Reduce farmstead heating and cooling Reduce CO_2 emission by C sink Reduce N_2O emissions: By greater nutrient uptake through tress By reducing N fertilizer consumption in tree systems Enhance forage quality, thereby reducing CH_4
Adaptation		
Action to reduce or eliminate the negative effects of CC or take advantage of the positive effects	Reduce threats and enhance resilience	Amelioration of microclimate to reduce impact of extreme weather events on crop production to maintain quality & quantity of forage to reduce livestock stress Provide greater habitat diversity to support organisms (e.g. native pollinators & useful insects) Provide greater structural and functional diversity to maintain and protect natural resources Create diversified production opportunities to reduce risk under fluctuating climate
	Allow species to mitigate to more favorable conditions	Provide habitat corridors for species migration

Adaptation

The IPCC lexicon defined adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. As adaptation emerges as a science, the role of agroforestry in reducing the vulnerability of agricultural systems (and the rural communities that depend on them for their livelihood) to climate change or climate variability needs to be addressed (UNFCCC, 2013). The adaptive measures of agroforestry considered as:-

- microclimate amelioration through increasing moisture and reducing temperature
- shading effect cut downs the evapotranspiration from crops
- high biodiversity which minimize pest and disease occurrence
- buffering agricultural crops against water deficiencies

Hence, agroforestry mainly consists woody perennials which have great potential to bear harsh climatic effects and make overall system sustainable with its coping mechanism. However, some of the adaptive strategies of agroforestry systems are explained in brief.

Microclimate amelioration: Agroforestry is ecologically dynamic, complex and sustainable system which provides opportunity to create "mimic" of natural forest in farm land with high

complementary benefits like economic and environmental. In such condition tree systems are having ability to improve microclimatic conditions by lowering temperature, evapotranspiration, moisture reduction acting as a filter and providing buffer against direct sunlight. Microclimatic amelioration is considered as one of the important role of trees in agroforestry systems to provide sustainability. As a method of adapting agriculture to climate change, agroforestry systems have been shown to increase on-farm production resilience to climate variability by buffering crops from the effects of temperature and precipitation variation as well as strong winds associated with storms (Lin, 2011). From the meteorological point of view agroforestry systems providing two key facts *viz.,* shade tree concept (radiation)and mechanic concept. For the first concept, shade will create microclimates with lower seasonal means in ambient temperature and solar radiation as well as smaller fluctuations. The shade tree reduces evaporative demands from soil evaporation and crop transpiration. Addressing issues of climate change adaptation in the scenario of microclimate improvement is important factor which reduces yield loss and drudgery of small farmers by agroforestry interventions in agriculture.

The mechanic concept of agroforestry is maintaining shelterbelts and windbreaks to minimize the impact of wind speed in arid, semiarid parts of country. These are providing crop assurance to farmers against extreme climatic events by modifying weather condition of the field. Windbreaks and shelterbelts reduce wind velocity, increasing moisture and decreasing temperature and also providing shelter against direct sunlight. Therefore it is considered as good adaptive strategies of climate change. Windbreaks are believed to reduce evaporative water losses from surfaces downwind, and thus conserve soil moisture, based on the notion that increased shelter from wind reduces evaporation.

Biodiversity conservation: Agroforestry is a system of complex and integrated approach which provides opportunity to intermingle trees, crops, pastures and animals in a managed aspect and providing shelter for soil flora & fauna, birds, insects and wildlife. Traditional agroforestry systems are best examples of agro-biodiversity conservations. The presence of trees further enhances diversity by providing shelter and habitat to a various diversified flora and fauna. It also helps in conserving genetic diversity of wild cultivars or landraces and trees that are in danger of loss and require priority conservation.

Mitigation Strategies

Mitigation refers to technological change and substitution that reduce input and emissions per unit of life (IPCC lexicon). Mitigation is nothing but remedial measure to cure the adverse impact which has occurred in limited extent like increased carbon dioxide concentration. Mitigation is nothing but preventing emission and allowing sinks of GHGs through carbon sequestration process. In simple language, adaptation can be carried out at local level but mitigation is at globally. Mitigation measure increases soil organic matter in the soil and ultimately improves soil health and quality so that it enhances crop yield in agroforestry systems and also enhance the adaptive capacity of soils, so is a ‘win–win’ option.

Carbon sequestration: The process of removing additional carbon from the atmosphere and depositing it in other "reservoirs" is principally known as Carbon sequestration. In practical terms, carbon sequestration occurs mostly through the expansion of tree plantation. Plethora of workers *viz.*, Kaushal *et al.,* 2014; Prasad *et al.,* 2012, Rizvi *et al.,* 2012; Swami and Puri 2005;

Chauhan *et al.*, 2010 and Ram Newaj *et al.*, 2008 are reported carbon sequestration from agroforestry. Different agroforestry systems sequestering varied amount of carbon based on type of system, species composition, soil and climate. In this way, the total potential of agroforestry in India to store carbon is about 2400 million tons. Carbon sinks potential of different agroforestry systems in India are shown in Table 3. Due to this innumerable benefits and potential of agroforestry, PKR Nair quoted that agroforestry is like "low hanging fruits" because of its mitigation potential of climate change and low sequestrating cost.

Table-3. Reported carbon sequestration potential (Mg C $ha^{-1}yr^{-1}$) of various agroforestry systems in India

Location	Agroforestry System	Tree species	No. of tree per hectare	Age (year)	CSP (Mg C $ha^{-1}yr^{-1}$)	References
Uttarakhand	Agrisilviculture	*D. hamiltonii*	1000	7	15.91	Kaushal et al., 2014
Himachal Pradesh	Agrihorticulture	Fruit trees	69	-	12.15	Goswami et al., 2014
Khammam, Andhra Pradesh	Agrisilviculture	*L. leucocephala*	4444	4	14.42	Prasad et al., 2012
			10000	4	15.51	
Uttarakhand	Agrisilviculture	*P. deltoids*	500	8	12.02	Singh and Lodhiyal, 2009
SBS Nagar, Punjab	Agrisilviculture	*P. deltoids*	740	7	9.40	Chauhan et al. 2010
Dehradun, Uttarakhand	Silviculture	*E. tereticornis*	2500	3.5	4.40	Dhyani et al. 1996
			2777*	2.5	5.90	
Kurukkhetra, Haryana	Silvipasture	*A. nilotica*	1250	7	2.81	Kaur et al. 2002
		D. sissoo	1250	7	5.37	
		P. juliflora	1250	7	6.50	
Chandigarh	Agrisilviculture	*L. leucocephala*	10666	6	10.48	Mittal and Singh 1989
Tripura	Silviculture	*T. grandis*	444	20	3.32	Negi et al. 1990
		G. arborea	452	20	3.95	
Tarai central devision Uttarakhand	Silviculture	*T. grandis*	570	10	3.74	Negi et al. 1995
			500	20	2.25	
			494	30	2.87	
Jhansi, Uttar Pradesh	Agrisilviculture	*A. procera*	312	7	3.70	Ramnewaj et al. 2008
Jhansi, Uttar Pradesh	Agrisilviculture	*A. pendula*	1666	5.3	0.43	Rai et al. 2002
Jhansi, Uttar Pradesh	Silviculture	*A. procera*	312	10	1.79	Rai et al. 2000
		A. amara	312	10	1.00	
		A. pendula	312	10	0.95	
		D. sissoo	312	10	2.55	
		D. cinerea	312	10	1.05	
		E. officinalis	312	10	1.55	
		H. binata	312	10	0.58	
		M. azaderach	312	10	0.49	
Hydarabad, Andhra Pradesh	Silviculture	*L. leucocephala*	2500	9	10.32	Rao et al. 2000
		E. camaldulensis	2500	9	8.01	
		D. sissoo	2500	9	11.47	
		A. lebbeck	625	9	0.62	
		A. albida	1111	9	0.82	
		A. tortilis	1111	9	0.39	
		A. auriculiformis	2500	9	8.64	
Hydarabad, Andhra Pradesh	Agrisilviculture	*L. leucocephala*	11111	4	2.77	Rao et al. 1991
			6666	4	1.90	
Raipur, Chhattisgarh	Agrisilviculture	*G. arborea*	592	5	3.23	Swami and Puri 2005
Coimbatore, Tamilnadu	Agrisilviculture	*C. equisetifolia*	833	4	1.57	Viswanath et al. 2004
Kerala	Home garden	Mixed treespp.	667	71	1.60	Saha et al. 2009

Conclusion

Agroforestry provides assets and income from carbon, wood energy, improved soil fertility and enhancement of local climate conditions; it provides ecosystem services and reduces human impacts on natural forests. Most of these benefits have direct benefits for local adaptation while contributing to global efforts to control atmospheric greenhouse gas concentrations. There is need to build a bridge between adaptation and mitigation measures for creating environmental secure options of carbon sequestration with multifunctional benefits from agroforestry.

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