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Carbon modeling of agroforestry systems at farmers' field in Indo-gangetic plains of India

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Introduction

The Indian Green revolution region **"**Indo-Gangetic Plain" (IGP) comprises of four agro-climatic zones namely lower, middle, upper, and trans gangetic plains covering West Bengal, Bihar, Uttar Pradesh, Delhi, Uttarakhand, Chandigarh, Haryana, Punjab, and some part of Rajasthan state. It covers 169 districts with total geographical area of 43.70 million ha. The Indo-Gangetic plains are one of the most populous regions with its area covering nearly 13% of the total geographical area of the country. It produces about 50% of the total food grains to feed 40% of the population. The continuous cropping of rice-wheat system has degraded the soil health dramatically over the years. Hence, the incorporation of trees in agriculture would be a better option to improve the soil as well as livelihood of the farmers in IGP.

Agriculture is the major enterprise of the region that is most vulnerable to climate changes particularly owing to the inadequacy of resources with the smallholder farmers. While, agroforestry has the potential to play a significant role in mitigating the atmospheric accumulation of greenhouse gases (GHG), it also helps smallholder farmers adapt to the changes. These are the reasons for recognizing agroforestry as a viable alternative to prevent and mitigate climate change (Ram Newaj *et al.*, 2014). A considerable proportion of agroforestry area located in IGP and some of the promising tree species like *Populus deltoides*, *Eucalyptus tereticornis*, *Melia azadirach*, *Mangifera indica*, *Dalbergia sis*soo, and *Acacia nilotica* are very common in the farmer's fields. Keeping this in view, the field survey was carried out to estimate the carbon sequestration potential at a farmer's field in IGP.

Materials and Methods

The carbon sequestration potential of agroforestry system existing on farmer's field was studied under National Initiative on Climate Resilient Agriculture (NICRA), ICAR project in various district of Indo-Gangetic Plains, for which a field survey was conducted through transect walk in the districts (Table 1). Field survey was done as per methodology described by Ram Newaj *et al*., 2014. The general information's like total net sown area, total area of districts, climatic parameters were collected from Agriculture Department at each districts. All the primary data used to run carbon accounting model CO2FIX v3.1 model to estimate biomass, carbon (C) stock and carbon sequestration. It developed as part of the Carbon Accounting data were used in Forest Ecosystem (CASFOR II), project, Wageningen, The Netherlands. The detailed working procedure of CO2FIX v3.1 model was described in the bulletin "Methodologies for Assessing Biomass, Carbon Stock and Carbon Sequestration in Agroforestry Systems published by ICAR-CAFRI.

Results and Discussion

The major crops of Punjab, Haryana, Uttar Pradesh and Bihar are wheat and rice. In West Bengal, jute is a dominant crop (Table 1). The Punjab, Haryana and western part of Uttar Pradesh are pioneer in practicing poplar and eucalyptus based commercial agroforestry. Major wood based industries are located in Yamunanagar and Jagadhri of Haryana states having about 470 agroforestry based industries and bestowed as the most important timber market in India.

The total carbon sequestered under AFS comprises of three C pools *viz.* biomass carbon (tree+ crop), leaf litter and soil carbon. Since most of the crop biomass is exported from the system and only crop residue accounts in CSP under AFS. The survey results indicates that tree density in trans-Gangetic plains is maximum (12.50 trees ha^{-1}) and lowest under Lower Gangetic Plains (5.60 trees ha^{-1}). The tree density on farmer's field ranges from 11 to 12 tree ha^{-1} in the Upper and Middle Gangetic plains. The tree + crop biomass in different agro-climatic zones of IGP varied from 9.90 to 17.51 t ha^{-1} during baselines (2013), which clearly indicate that, those agro-climatic zones where higher number of trees exits in agroforestry system have more biomass. It is also predicted that the tree + crop biomass in Indo-Gangetic Plains would range from 14.58 to 20.48 t ha^{-1} after 30-years (Table 2). The crop productivity may vary in different year but tree biomass will increase gradually, if situation is as usual.

Table 1: Major trees and crops in agroforestry systems existing on farmer's field

Indo-Gangetic plains (states)	Districts	Trees	Major crops
Lower Gangetic plains (West Bengal)	Bardhman and North Dinajpur	*Albizia procera, Terminalia arjuna, Mangifera indica, Eucalyptus tereticornis, Dalbergia sissoo*	*Oryza sativa, Corchorus capsularis, Triticum aestivum, Vigna mungo, Brassica juncea, V. radiata,*
Middle Gangetic Plains (Uttar Pradesh and Bihar)	Gorakhpur, Mirzapur, Nawada, Darbhanda, Purnia	*Mangifera indica, Tectona grandis, Eucalyptus tereticornis, Azadirachta indica, Madhuca indica, Dalbergia sissoo*	*Oraza sativa, Triticum aestivum, Saccharum officinarum, Lens esculentus, V. radiata*
Upper Gangetic Plains (Uttarakhand and Uttar Pradesh)	Sultanpur, Faizabad, Bulandsahar	*Eucalyptus tereticornis, Populus deltoides, Mangifera indica, Madhuca indica, Tectona grandis, Dalbergia sissoo*	*Oraza sativa, Triticum aestivum, Saccharum officinarum, Lens esculentus, Cicer arietinum, Mustard, Vigna mungo and V. radiata*
Trans Gangetic Plains (Punjab, Haryana, Rajasthan and Delhi)	Faridkot, Ludhiana, Nawansahar, Hisar, Kurukshetra	*Eucalyptus tereticornis., Populus deltoides, Dalbergia sissoo, Melia azedarach, Acacia nilotica*	*Oraza sativa, Triticum aestivum, V. radiate, Saccharum officinarum,, Cicer arietinum, V. mungo,*

Table 2: Biomass, soil carbon and carbon stock available in agroforestry system existing on farmer's field

Indo-Gangetic Plains (trees ha^{-1})		Total biomass (tree + crop) (t ha^{-1})	Total C (tree + crop) (t ha^{-1}) A	Soil C(t ha^{-1}) B	Total C (A+B) (t ha^{-1})	Net CS over simulated period (t ha^{-1})
Lower Gangetic Plains (5.60)	Baseline	9.90	4.75	9.96	14.71	3.68
	Simulated	14.58	7.00	11.39	18.39	
Upper Gangetic Plains (11.03)	Baseline	10.84	5.20	9.46	14.66	5.52
	Simulated	20.48	9.83	10.35	20.18	
Middle Gangetic Plains (12.45)	Baseline	11.10	5.33	14.67	20.00	5.17
	Simulated	20.15	9.67	15.50	25.17	
Trans-Gangetic Plains (12.50)	Baseline	17.51	8.40	9.90	18.30	5.67
	Simulated	19.21	9.22	14.75	23.97	
Average	Baseline	12.34	5.92	11.00	16.92	**5.01**
	Simulated	18.61	8.93	13.00	21.93	

Note: Baseline, 2013 and Simulated for 30-years (2042) Parenthesis is tree density per hectare

The soil organic carbon (SOC) was estimated in agroforestry systems existing on farmer's field in IGP and it varied from 9.46 to 14.67 t C ha^{-1} in baseline (2013) and after 30-years of simulation period, the SOC would increase up to 15.50 t C ha^{-1}. The total carbon stock available in different agro-climatic zones of IGP during 2013 (baseline) varied from 14.66 to 20.00 t C ha^{-1} and corresponding values will increase up to 20.18 to 25.17 t C ha^{-1} after simulation period of 30 years. Similarly, C sequestered in agroforestry system after a period of 30-years varied from 3.68 to 5.67 t C ha^{-1} in different agro-climatic zone of IGP (Table 2). These results are in line with the report of Post and Kwon (2000), who reported that

the average rate of soil carbon sequestration under tree based systems ranged between 0-3 Mg C ha^{-1} yr^{-1} (with 0.3 Mg C ha^{-1} yr^{-1} as the average value). Since, C sequestration in agroforestry is a dynamic process and during establishment phase there is a loss of C and N from vegetation and soil. After establishment, a quick accumulation begins and tons of C is stored in the boles, stems, roots of trees and in the soil. At the end of the rotation period, when the trees are harvested and land returned to cropping (sequential system), part of the C would be released back to the atmosphere. Therefore, effective sequestration can only be considered, if there is a positive net C balance from an initial stock (baseline) after a certain period.

Conclusion

The carbon sequestration potentials of AFS under IGP with 10 trees ha^{-1} was estimated as 0.17 Mg C ha^{-1} yr^{-1}. The average SOC was 11.0 t C ha^{-1} in baseline (2013) and it would be 13.0 t C ha^{-1} after simulation period of 30-years. Generally CSP dependents on tree density, rainfall and management practices etc. and it is a dynamic process in which during establishment phase there is a loss of C and N from vegetation and soil. Therefore, effective sequestration can only be considered if there is a positive net C balance from an initial stock (baseline) after a certain period. A large extent of agroforestry is distributed on farmers field which contributes to mitigation and adaptation to climate change.

References

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