RESEARCH ARTICLE Agricultural Science Digest, Volume 44 Issue 4: 679-683 (August 2024)

Incentivising Agroforestry Through Carbon Revenue: Augmenting Farmers' Income in India

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10.18805/ag.D-6066

ABSTRACT

Background: The present study explores and assesses the potential of carbon revenue to augment the financial returns of farmers from agroforestry plantations. Government of India aims at doubling the farmers' income and this study can go a long way in achieving this aim. The income from carbon revenue will be over and above the market value of farm-grown wood and hence will be an additional incentive.

Methods: Under the present study, the assessment of carbon stocks for Eucalyptus and poplar plantations was done in Yamunanagar district of Haryana using stratified random sampling and standard calculation tools explained under methodology. The results of this study and data from other existing studies, covering different parts of the country, were used for estimating the carbon credits and carbon revenue for total area under agroforestry in India *i.e*. 28.4 MHA.

Result: The findings suggest that agroforestry, if incentivized with carbon revenue, has a potential of increasing the income of farmers by 40-50% (upto Rs. 25,000/ha/year). It could be achieved by developing agroforestry based carbon finance projects for Voluntary Carbon Markets (VCM) and by promoting agroforestry plantations for net carbon emission neutrality of corporate using their CSR funds. The additional returns could also act as a buffer and as an alternative like minimum support price (MSP) for farmers in case of "price-crash" of agroforestry produce due to various reasons. The study indicates that there is urgent need to have a policy in India for registering agroforestry plantations under carbon finance projects thereby contributing to net neutrality of corporates, ultimately benefitting the farmers through financial incentives.

Key words: Agroforestry, Carbon credits, Carbon revenue, Carbon sequestration potential.

INTRODUCTION

Agroforestry is a dynamic and ecology based nature resource management system which diversifies and sustains production enhancing social, economic and environmental benefits at all levels (Roger Leaky, 1996). Agroforestry holds the key to sustainability and contributes to achievement of nine of the seventeen sustainable development goals (SDGs) like no poverty, zero hunger, climate action *etc*. set by UN, besides serving as major climate neutrality pathway. Regular research in agroforestry, upgradation in quality planting material (QPM), introduction of diversified tree species in agroforestry and policy support from government, especially the National Agroforestry Policy, (2014), has accelerated the pace of diversification of agriculture towards agroforestry.

During the last few decades, the "agrisilviculture system" has gained popularity with farmers owing to its higher economic returns per unit area. Plantation models (with different inter cropping patterns and spacing) and biomass productivity with Eucalyptus and Poplar based agroforestry have been evolving and improving as per changing requirements of industry and has been maximum up to 30 t ha^{-1} yr^{-1} (Chavan *et al*., 2023; Rizvi *et al*., 2011, 2020; Kulkarni, 2005).

The agroforestry plantations are open to market forces and at times face crash in prices. Additional financial support in the form of carbon revenue from the sale of carbon credits generated by agroforestry plantations could serve as the biggest motivation for promotion of agroforestry (Mahendra Singh *et al*., 2017) and it would also serve as a buffer for farmers to safeguard them from the vagaries of market. The report of Indian Timber Supply and Demand 2010 to 2030 (Kant and Nautiyal, 2023) estimated total production of round wood in India as 47 million cum per annum of which only about 2 million cum comes from state owned forests having restricted harvesting. About 80% of the remaining requirement comes from "Trees Outside Forests" and the rest is dependent on imports. The import of wood and wood products from the year 2011 onwards

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How to cite this article: Singh, N., Biswas, D., Gokhale, Y., Kapil Kumar, K. (2024). Incentivising Agroforestry Through Carbon Revenue: Augmenting Farmers' Income in India. Agricultural Science Digest. 44(4): 679-683. doi: 10.18805/ag.D-6066.

Submitted: 28-03-2024 **Accepted:** 06-06-2024 **Online:** 14-06-2024

has increased by more than 2.5 times reaching 457.22 billion Indian rupees in the year 2022 (statistica.com, accessed on 11-03-2024).

The potential available areas for expansion of agroforestry are agricultural lands and culturable wastelands suitable for agroforestry *i.e*. 140 MHA and 27 MHA (Directorate of Economics and Statistics, Ministry of Agriculture, Govt of India, Neelam Patel *et al*., GROW Niti Aayog, 2024). According to Vision 2050 report by CAFRI (2015), there is potential to expand the area under agroforestry to 53 MHA from current figure of 28.4 MHA (Arunachalam *et al*., 2022) by the year 2050. Enhancing agroforestry returns with additional incentive from carbon revenue can serve as a major catalyst in this direction. Table 1 gives current and projected demands for various commodities along with future projection of area under agroforestry.

MATERIALS AND METHODS

The total estimated area under agroforestry in India is 28.4 MHA (Arunachalam *et al*., 2022) out of which Poplars and Eucalyptus based agroforestry systems occupy 0.27 MHA and 4.0 MHA respectively (Chavan *et al*., 2023) having domination in Northern India with some exceptions of Southern regions of Andhra Pradesh, Telangana and Tamil Nadu. The area under Eucalyptus and Poplar based agroforestry in Yamunanagar district has been estimated as 16,300 ha (Rizvi *et al*., 2020). These data have been used for estimation of carbon credits and carbon revenue.

Furthermore, a study was conducted in Yamunanagar district of Haryana for assessment of carbon sequestration potential of Eucalyptus and Poplars. Carbon sequestration potential of the remaining area under agroforestry *i.e*. 24.13 MHA of a total of 28.4 MHA was assessed using other available studies covering different parts of the country. The results of present study as well as the data available from other existing studies were used to estimate the carbon credits and approximate carbon revenue per hectare based on prevailing international prices of carbon credits.

For conducting the study, the villages of Yamunanagar district having more than 5000 Poplar trees (8076 ha.) and 1000 Eucalyptus trees (1578 ha.) under agroforestry plantations were selected for Sampling (Tree Census 2023, Haryana Forest Department). It was followed by identification of strata, laying preliminary sample plots to estimate standard deviation, laying permanent sample plots for data collection and finally the data analysis.

Selection of strata, sampling plan and data collection

Based on the data of Tree Census, 2023, available records and field visits, the population in the study area was divided into three homogeneous strata based on prevalent girth classes *i.e*. 30-59 cm and 60-89 cm for Poplar and 30-59 cm for Eucalyptus. This categorization was made based on presence of majority of plantations within these specific girth classes in the field (source, field visits).

The prevalence of Poplar and Eucalyptus within different administrative units of Forest Department *i.e*. Forest Ranges, was taken into consideration for the purpose of sampling. Jagadhari Forest Range having 45% of total Poplar trees and Sadhaura range having 60% of total Eucalyptus trees were selected as study areas for Poplar and Eucalyptus respectively (Tree Census, 2023). To estimate the standard deviation within each stratum, five sample plots each having a size of 0.1 ha (31.62 m $\times$ 31.62 m) were laid randomly in each stratum (Carbon Stock in India's Forests, FSI, 2011). Using Pearson's (Pearson *et al* 2007) formula, statistically significant sample size for Poplar 30-59 cm, Poplar 60-89 cm and Eucalyptus 30-59 cm strata was calculated as 16, 8 and 9 sample plots respectively.

Stratified Random Sampling strategy using the rice grain method was used to identify the location of sample plots within each stratum separately. Nested Square sample plots with a dimension of 0.1 ha (31.62 m $\times$ 31.62 m), were laid for undertaking fieldwork. Measurement of the Girth at breast height (GBH) at 1.37m of individual trees having girths greater than or equal to 30 cm was done using linear tape. All measurements taken in field were recorded in standard proformas. Calculation of biomass and carbon stocks was done using standard tools given in Table 2.

RESULTS AND DISCUSSION

It was observed during field visits that agrisilvicultural system dominated by Eucalyptus and Poplars is producing straight timber under compact planting models meeting with requirements of plywood industry.

The Carbon sequestration rate for different strata *i.e*. Poplar 30-59 cm, Poplar 60-89 cm and Eucalyptus 30-59 cm was assessed as 7.29, 8.49 and 13.05 tha^{-1} yr^{-1} respectively, given in Table 3. These figures were used to calculate carbon credits and carbon Revenue for Yamunanagar district using current international price of carbon credits (@ $ 6 per carbon credit, ecosystemmarketplace.com). These calculations suggest that Eucalyptus and Poplar under suitable agroforestry models can generate carbon revenue

Table 1: Total domestic demand for various items versus agroforestry contribution, 2010-2050 (CAFRI, 2015).

Item	2010-2011	Projected for 2025	Projected for 2050	Contribution from Agroforestry in 2050
Fodder (Mt)	1061	1170	1545	154 (10%)
Fuel Wood (Mt)	308	479	629	308 (49%)
Timber (Mt)	120	171	347	295 (85%)
Agroforestry (MHA)	25.32		53.32	

Table 2: Formulas for calculation of biomass, carbon stocks and carbon credits.

Item	Description	Unit	Source	value
GBH	Girth at breast	M	Field work	Measurement from field in cms is divided by 100 to convert in units
D	Diameter at breast height	M	Field work	GBH/3.14
V	Volume	M^3	Volume equations	V=0.02894-0.89284D+8.72416D2 V= for Eucalyptus 0.81467- 1.063661D
			FSI Technical Information	+ 6.452918D2 poplar
			Series Volume 2 no. 1 2020	WD- 0.56 (Eucalyptus),
WD	Wood density	Gm/cm^3 or t/m^3	FAO	0.37 (Poplar)- ICRAF Data base
				0.57 for both species - by FAO
BEF	Biomass expansion factor	Constant	IPCC, GPG table 3 a.1.10	1.3
AGB	Above ground biomass	Tonnes	Calculated from field work	AGB=V* WD* BEF
BGB	Below ground biomass	Tonnes	Calculated from AGB	BGB=AGB* 0.27 (IPCC Default value)
C_{AGB} & C_{BGB}	Above and below ground Carbon stock density	Tonnes	Calculated from AGB and BGB	Default carbon fraction of 0.47 used (IPCC 2006)
CO_2 eq	Carbon dioxide equivalent	Tonnes	Calculated from carbon stock	Multification factor of 44/12 or 3.67 (Pearson *et al.*, 2007)

(additional earning for the farmer) worth up to Rs 25000/ ha/year. Using standard carbon fraction and multiplication factor for calculating carbon and carbon dioxide equivalents (Table 2), the carbon credits for current area under agroforestry in Yamunanagar district *i.e.* 16,300 ha (Rizvi *et al.,* 2020), @ average carbon sequestration potential of 10 t/ha/yr come at 0.6 million $tCO_2eq\ ha^{-1}yr^{-1}$ having a valuation of Rs. 290 million annually (@ $ 6 per credit), given in Table 3.

The carbon sequestration rate of agroforestry plantations from the present study done in Yamunanagar district and data from other existing studies covering different parts of the country have been tabulated in Table 4.

Assessment of annual valuation of carbon credits was made using current area under agroforestry in India and carbon sequestration rates given in Table 4. Carbon sequestration rates for area under Eucalyptus and Poplar (4 MHA 0.27 MHA, Chavan *et al.,* 2023) and for rest of India (24.13 MHA) were taken as 12 t $ha^{-1}\ yr^{-1}$, 7 t $ha^{-1}\ yr^{-1}$ and 3.9 t $ha^{-1}\ yr^{-1}$. These figures were further used to assess the total carbon revenue from agroforestry taking international price of carbon credits as $ 6 per credit and were then converted to rupees (source http://www. ecosyste mmarketplace.com, accessed on 10-3-2024). The annual valuation of carbon credits was estimated at Rs 250 billion per year, having annual potential of GHG emission reduction of 0.5 Gt $ha^{-1}\ yr^{-1}$ (half Giga tonnes) given in Table 5.

Discussion on policy initiatives promoting carbon financing

India became the first nation to adopt the National Agroforestry Policy in 2014 which yielded many positive outcomes. More than 20 states issued notifications relaxing felling and transit regulations for agroforestry produce. From a minimum of 6 species in Tripura to a maximum of 86 species in Gujarat have been brought under transit free regime. Major features of the National Agroforestry Policy, (2014) include creation of an institutional setup for agroforestry under Ministry of Agriculture, simplification of felling and transit regulations, developing Market Information System (MIS) for agroforestry, certification of nurseries and seeds, research and development for supply of Quality planting material (QPM), institutional budgetary provisions and insurance of agroforestry produce, involvement of industry for extension and supply of QPM *etc.*

Government of India aims to achieve net-zero carbon emissions by the year 2070. At COP-21, Prime Minister of India declared our Nationally Determined Contributions (NDCs) creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2eq through additional forest and tree cover by the year 2030. Top of Form Agroforestry based carbon finance projects have potential as well as opportunity to holistically address the issue of augmenting agroforestry based industrialization across India. The carbon finance provided for agroforestry plantations will not only generate the carbon revenue from the sale of the carbon credits but it will boost the furniture, paper and pulp and timber based

Table 3: Annual Biomass production, carbon credits and carbon revenue, Yamunanagar.

Strata/Girth cm	Year of planting	Biomass and carbon credits				
		Total biomass AGB+BGB	Biomass per year	Carbon seq per year	CO_2eq	Valuvation
Cm	Year	t ha^{-1}	t ha^{-1} Yr^{-1}	t ha^{-1} Yr^{-1}	t ha^{-1} Yr^{-1}	Rs ha^{-1} Yr^{-1}
Poplar 30-59	2021	31.04	15.52	7.29	26.77	12849.32
Poplar 60-89	2020	54.22	18.07	8.49	31.17	14962.83
Eucalyptus 30-59	2021	55.54	27.77	13.05	47.90	22991.03

16300 ha AF area @ Avg CSP of 10 t/ha/yr gives 0.6 mtCO_2eq per yr (worth Rs. 290 m @$ 6 per credit).

Table 4: Carbon sequestration rates of agroforestry assessed under different studies.

Trees/ha	Species	Carbon stock ha^{-1} yr^{-1}	Location	Study by
1000	Eucalyptus	12.7 t ha^{-1} yr^{-1}	Indo-Gangetic plain	Chavan, 2023
	Poplar		Indo-Gangetic plain	Chavan, 2023
300-800	Complex agroforestry	0.25-19 t ha^{-1}	All India	Dhyani, 2016; Nair, 2010
		0.58-113 t ha^{-1}	All India	CAFRI
		3.9 t ha^{-1}	Abondoned agricultural land	Gupta, 2017
2000	Eucalyptus	11.75 t ha^{-1} yr^{-1}	Andhra, Telangana	Kulkarni, 2005
1400	Eucalyptus	13 t ha^{-1} yr^{-1}	Haryana Yamunanagar	Results of present study 2023
	Poplar	7.6 t ha^{-1} yr^{-1}	Haryana	Rizvi *et al.,* 2020
500-700	Poplar	7.2-8.4 t ha^{-1} yr^{-1}	Haryana Yamunanagar	Results of present study 2023
500	Poplar	4.7 t ha^{-1} yr^{-1}	Haryana	Handa *et al.,* 2020
		2.6 t ha^{-1} yr^{-1}	40 MHA, Short rotation	Singh and Lal, 2000

Table 5: Projected annual potential of GHG emission reduction and valuation of carbon credits from agroforestry in India.

Study / Area	Projected annual valutaion of carbon credits, Pan India						
	Area under AF MHA	Carbon Stock per ha	Total C	CO_2eq	Current rate	Amount	Amount
	MHA	t/ha/yr	Mt/yr	Mt/yr	$	M $/yr	M Rs./yr
Eucalyptus, Chavan 2023	4.00	12.00	48.00	176.16	6.00	1056.96	84556.80
Poplar, Chavan 2023	0.27	7.00	1.89	6.94	6.00	41.62	3329.42
Rest of India	24.13	3.90	94.11	345.37	6.00	2072.24	165778.89
Total	28.40	22.90	144.00	528.47	6.00	3170.81	253665.12

0.528 GtCO_2eq GHG emission reduction per year, Annual Carbon revenue of Rs 250 billon.

industry due to assured supply of raw material resulting into enhanced income of farmers, augmenting livelihood opportunities across sectors and hence substantially contributing to sustainable development goals.

Options for carbon financing

Agriculture, forestry and other land use (AFOLU) sector carbon markets have evolved over past two decades. Due to expiry of Kyoto Protocol in the year 2020, Compliance Markets executed through UNFCCC are non-operational for the time being. Currently, Voluntary Carbon Markets (VCMs) are operational world over including India. But due to lack of awareness amongst stakeholders and policy makers, the response to VCM is still very limited. VERRA and Gold Standards are some of the important VCM standards which are operational in India and are having over 68 projects (data from websites of VERRA and Gold Standard). These projects are covering estimated area of 1.5 MHA (10% of total area under agroforestry) across India likely generating 17 million carbon credits which are at various stages of development. If these credits get issued then it would generate an amount of over Rs. 8000 crores with interval of every five years. This revenue from the sale of carbon credits will represent an additional incentive made available to farmers. India has an area of 28.4 MHA under agroforestry and there is a potential of adding another 29 MHA to this pool (Vision 2050, CAFRI, 2015). It means, there is an enormous potential left untapped for VCM to generate additional incentive for farmers across India since approximately only 1.5 MHA are under VCM as of now.

Similarly, the companies committed to carbon neutrality can engage directly with farmers to support carbon credits through intermediary organizations capable of developing carbon finance projects. The corporates will compensate farmers through their CSR funds for generating the carbon credits by paying the market price as an incentive to farmers and in return achieve net neutrality by neutralizing carbon emissions due to business/industrial activities. States like Haryana can take the initiative in this regard and develop a platform to create a pool of agroforestry plantations and associated credits and trade with the domestic industry to garner support for farmers as an incentive.

CONCLUSION

The Eucalyptus and Poplar plantations in Yamunanagar district of Haryana have potential to effect GHG emission reductions of 0.6 mtCO_2eq per year valued at Rs. 290 million. Under compact planting models these plantations have potential to generate additional carbon revenue of Rs 25,000/ha/year to farmers. This additional incentive can serve as chief motivation for promotion and extension of agroforestry in India, particularly in the state of Haryana. The current area under agroforestry in India has annual GHG emission reduction potential of 0.5 G t per year. If the area under agroforestry is increased to 50 MHA over the next two decades, even with the current productivity rates agroforestry can generate carbon credits of more than 1.0 Gt annually worth Rs. 500 billion. This entire stock of carbon credits is unused and requires immediate policy intervention through a carbon registry in India. The carbon registry at national and state levels can aim at efficient issuance of carbon credits through government-approved validation and verification systems. Opportunities to finance agroforestry through CSR for carbon projects can play a big role in achieving carbon neutrality in India. This strategy can help India achieve domestic carbon neutrality and meet international climate commitments, while also significantly increasing farmers' income.

Conflict of interest

All authors declare that they have no conflict of interest.

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