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Mitigating climate vagaries through adoption of agroforestry land use in Maharashtra, India

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ABSTRACT

Climate change is the leading ecologic, economic and geopolitical issue of the 21st century and has even the potential to rewrite the global equation for prosperity, development and peace. Adoption of agroforestry land use offers viable option for reducing some of the vagaries arising due to climate change especially the elevated level of CO_2 and global warming. The realistic estimates of area and C-sequestration potential of agroforestry are essential for assessing its contribution of agroforestry in climate change mitigation. This has more relevance in current scenario when Maharashtra is facing drought condition especially in Marathawada region. The modern technologies like satellite remote sensing can provide spatially explicit information on land covers and natural resources like water. In the present study, estimation of area under tree cover and agroforestry has been done in Latur, Wardha, Nashik, and Thane districts of Maharashtra. The combination of remote sensing technique and CO_2FIX model were applied to estimate agroforestry area and carbon sequestration in selected districts. Dynamic CO_2FIX model v3.1 was used to assess the baseline carbon, i.e. year of survey (2013) and to estimate the carbon sequestration potential (CSP) of agroforestry systems for a simulation period of 30 years. Estimated area under agroforestry was in the range of 2.84% in Thane to 5.17% in Latur district and C-sequestration potential ranged from 0.06 to 0.41 Mg C/ha/yr. Study concluded that agroforestry has potential for carbon sequestration vis-à-vis climate change mitigation and a viable solution for coping the climate vagaries like drought.

Key words: Agroforestry, Climate change, CO_2 FIX model, Natural resources, Remote sensing.

Agroforestry is a sustainable land-use system that maintains or increases total yields by combining food crops (annuals) with tree crops (perennials) and/or livestock on the same unit of land, either alternately or at the same time, using management practices that suit the local social, cultural, economic and ecological conditions of the area. Agroforestry is key path to prosperity for millions of farm families leading to extra income, employment generation, greater food and nutrient security, and meeting other basic human needs in a sustainable manner. Carbon sequestration is the process that involved in carbon capture and the long period storage of atmospheric carbon dioxide. Vegetation plays an important role in sequestration of the atmospheric carbon and agroforestry not only have potential of carbon sequestration but also helps in reducing greenhouse gas emissions.

In India, an average C-sequestration potential in agroforestry has been estimated to be 25 Mg C/ha over 96 million ha (Sathaye and Ravindranath 1998), but there is a considerable variation in different regions depending upon the biomass production (Newaj and Dhyani 2008, Dhyani *et al*. 2009) and method of estimation. Finally, more stringent emission reductions are required to achieve the 2°C global warming target, which may require more rapid and tremendous changes in socio-economic conditions (Edenhofer *et al*. 2010, Luderer *et al*. 2011, Rogelj *et al.* 2011, 2013). Land use refers to the way in which land has been used by humans and their habitats, usually with accent on the functional role of land for economic activities. Land cover refers to the physical characteristics of earth's surface, natural vegetation, water bodies, soil/rock, artificial cover and others resulting due to land transformation.

Remote Sensing has become an effective tool for mapping and monitoring agriculture, forestry and natural resources. In India, preliminary estimates of agroforestry area through remote sensing were attempted by Rizvi *et al*. (2013 and 2014). Statistical evaluation and identification of potential villages for agroforestry development was done by Ahmad *et al*. (2010) using GIS. A strategy of forest/non-forest cover mapping based on remotely sensed data and GIS was demonstrated by Maurya *et al*. (2013). Remote sensing technique has been used for crop forecasting (Chaudhary 1999), crop inventory (Salman and Saha 1998), and calculating carbon sequestration (Tripathi *et al*. 2010).

In present study, area under agroforestry using

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remote sensing data and carbon sequestration potential of agroforestry systems was estimated in selected districts of Maharashtra. This will be useful in assessing the contribution of agroforestry in reducing atmospheric CO_2, a major constituent of greenhouse gases.

MATERIALS AND METHODS

Four districts of the Maharashtra namely Latur, Wardha, Nashik, and Thane were selected for this study. Nashik district is known for its ghats and mountain ranges. The western Ghats which are popularly known as Sahyadru ranges are bordered from north to south of Nashik. District has extreme climate with maximum temperature of 42.4° C and lowest of 0.6° C. The weather is very humid with 43 to 62% humidity. Thane district is the third largest industrialized place in the Maharashtra. The geographical area of the district is 9558 sq km. Thane district lies between 18°42' to 20°20' N latitude and 72°45' to 73°48' longitude. Latur is situated in the south-eastern part of Maharashtra. It is ancient city lying on the bank of Panchganga river. Latur experiences moderate temperature. Temperature ranges from 39.6° C to 28° C during summers and between 34°C to 13.9° C during winters. Annual rainfall in the district ranges from 600 to 800 mm.

Maharashtra frequently experiences drought conditions, which effects agricultural production and economy. Latur district was severely affected by drought in 2016 and there was acute shortage of drinking water.

For mapping agroforestry area in four selected districts, Resourcesat-2/ LISS III remote sensing images (spatial resolution 23.5 m) were taken for the years 2011-12. These images were visually and digitally interpreted using ERDAS 2015 and ArcGIS 9.3 software and analyzed for land uses and land covers (LULC) classification. Ten mostly found LULC classes viz. agroforestry, cropland, plantation, forest, degraded forest, wasteland, grassland, water bodies, built-ups, and sandy area were selected. Classification accuracy was obtained with the help of more than 100 GPS points collected from farmers' fields and thematic maps were finalized.

The methodology developed and standardized by Rizvi *et al*. (2016) for mapping agroforestry at district level was adopted. Maximum likelihood method of supervised classification was applied for assessment of LULC of study districts. Then sub-pixel classifier was applied on agricultural land obtained from LULC to identify the land feature if it present in fraction of pixel. To get virtually tree cover within the pixel in the range of 20 to 100%. The total sum total of these pixels gives an estimate of area under agroforestry in a district.

The dynamic carbon accounting model CO_2FIX v3.1 (Masera *et al*. 2003, Schelhaas *et al*. 2004) was used to assess the baseline carbon and simulating the CSP of agroforestry systems in the district. CO_2FIX model has been developed as part of the CASFOR II project. It is a user-friendly tool for dynamically estimating the carbon sequestration potential of forest management, agroforestry and afforestation projects. This model consists of six modules viz. biomass module, soil module, products module, bioenergy module, financial module and carbon accounting module.

The primary data used for CO_2FIX model includes tree species existing on farmlands and their number, diameter at breast height (DBH), crops grown by farmers on farmlands along with their productivity, area coverage etc. Whereas the secondary data included the growth rates of tree biomass components (stem, branch, foliage, root) for various species on annual basis.

Field survey in selected districts was conducted in year 2013 (baseline) and data on existing tree species on farmlands, their number and DBH were recorded. The tree species were grouped into fast, medium and slow growing trees on the basis of their rotation period.

RESULTS AND DISCUSSION

Remote sensing images of selected districts of Maharashtra were classified by maximum likelihood method into ten LULC classes. Agroforestry area was obtained by applying sub-pixel classifier on agricultural land (cropland + fallow land). The estimated area under agroforestry was highest in Latur district (5.17%) followed by Nashik district (4.69%).Total area under agroforestry was estimated to be 167754.19 ha (4.31%) in these districts (Table 1). Quite reasonable accuracy of 82.5-83.3% was obtained in agroforestry classification in the selected districts.

Average number of trees/ha were found to be 13.53, 11.98, 11.60 and 2.11 in Wardha, Nasik, Thane and Latur district, respectively. Tree species found on farmlands during field survey in these districts were grouped into fast, medium, and slow growing trees (Table 2). The secondary data on district wise crop production and productivity was obtained with the help of NIC, Government of India, New

Table 1 Estimated area under agroforestry in selected districts of Maharashtra

District	Geographical area (ha)	Area under agroforestry	
		ha	%
Latur	722913.16	37388.85	5.17
Nashik	1570349.61	73638.09	4.69
Thane	968903.10	27540.06	2.84
Wardha	631426.30	29187.19	4.62
Total/ Average	3893592.17	167754.19	4.31

Table 2 Number of trees and their observed DBH in surveyed districts of Maharashtra

District	Average number of trees/ha				Observed DBH of existing trees (cm)		
	Slow	Medium	Fast	Total	Slow	Medium	Fast
Latur	0.20	1.87	0.04	2.11	44.39	22.81	17.37
Wardha	1.35	12.06	0.11	13.53	40.74	24.77	18.77
Nashik	1.99	8.74	1.24	11.98	40.52	31.86	11.37
Thane	1.28	9.68	0.63	11.60	50.34	30.82	14.81

Table 3 Estimated biomass carbon and carbon sequestered by trees in agroforestry

Parameter			Selected districts			
			Latur	Wardha	Thane	Nashik
Total biomass (tree+ crop) (Mg DM/ha)	Baseline	Biomass	14.69	23.92	26.91	28.22
	Simulated		17.69	42.18	39.89	44.44
Soil carbon (Mg C/ha)	Baseline	Carbon	18.65	16.87	17.60	14.82
	Simulated		19.2	20.80	19.23	17.63
Biomass carbon (Mg C/ha)	Baseline		6.76	11.00	12.39	12.98
	Simulated		8.14	19.40	18.35	20.44
Total carbon (biomass + soil) (Mg C/ha)	Baseline		25.41	27.87	29.99	27.80
	Simulated		27.34	40.20	37.58	38.07
Net carbon sequestered in AFS over the simulated period of thirty years (Mg C/ha)		Carbon sequestered	1.93	12.33	7.59	10.27
Estimated annual carbon sequestration potential of AFS in different districts (Mg C/ha/yr)			0.06	0.41	0.25	0.34

DM - Dry matter; Mg - million gram

Delhi and the respective District Statistical Offices. This secondary data is given as input to the CO_2FIX model for calculation of biomass carbon in a district.

Total biomass (tree + crop) for baseline come out to be 23.92, 28.22, 26.91 and 14.69 Mg DM/ha in Wardha, Nasik, Thane and Latur districts, respectively. The soil carbon is expected to increase from 16.87, 14.82, 17.60 and 18.65 Mg C/ha to 20.80, 17.63, 19.23 and 19.2 Mg C/ha in Wardha, Nasik, Thane and Latur districts in thirty year simulation. Total carbon (biomass + soil) in baseline was estimated to be 27.87, 27.80, 29.99 and 25.41 Mg C/ha. Both total biomass and total carbon was lowest in Latur district because number of trees/ha in this district are very less (2.11) as compared to other three districts. Highest total biomass (42.18 Mg DM/ha) and total carbon (40.20 Mg C/ha) was found in Wardha district due to highest tree density (13.53 trees/ha). Net carbon sequestered was estimated to be 12.33, 10.27, 7.59 and 1.93 Mg C/ha with an average of 8.03 Mg C/ha in four districts. Considering an agroforestry area of 167754.19 ha, net carbon sequestered in 30 years would be 1.347 million tonnes. Annual CSP of existing agroforestry systems in Wardha, Nasik, Thane and Latur districts come out to be 0.41, 0.34, 0.25 and 0.06 Mg C/ha/yr, respectively (Table 3).The CSP can be increased considerably by increasing tree density from present 2-14 to 40-50 trees/ha.

In this way, long term storage of carbon in tree biomass as well as in soils by agroforestry systems have significant contribution in reducing atmospheric CO_2 and mitigation of climate change. Agroforestry provides the resilience to agricultural production under current climate variability as well as long term climate change through intensification, diversification and buffering of tree in farming systems (Newaj *et al*. 2016). Singh *et al*. (2016) proved that even with deficit rainfall by about 32%, water crisis in drought prone Bundelkhand region can be averted by adopting agroforestry and watershed interventions as it will recharge the weatheed zone by 86% which will serve the purpose of drinking and irrigation.

Agroforestry systems whether traditional or commercial have potential of carbon sequestration in the form of tree biomass and soil carbon. They can play a vital role in mitigating the effects of climate change through sequestration of atmospheric CO_2. Present study demonstrated how agroforestry systems have significant contribution in reduction of atmospheric CO_2 through carbon sequestration in selected districts of Maharashtra. With suitable agroforestry interventions like planting fruit trees with crops, any loss in crop yield can be compensated by fruit production. Hence with the adoption of agroforestry on farmers' fields, the climatic vagaries like drought may be tolerated.

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