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Potential and Performance of Poplars under Short Rotation Agroforestry Models: A Case Study of Yamunanagar District of Haryana

Navdeep Singh and Yogesh Gokhale[1]

Kalinga University, Raipur, Chhattisgarh-492 101, India
[1]The Energy and Resources Institute, New Delhi-110 003, India
E-mail: navdeepifs@yahoo.com

Abstract: The biomass assessment of poplar (*Populus deltoides*) was done in Yamunanagar district based on different girth classes. The sample plots, each having a size of 0.1 ha were laid within each stratum for collecting the field data. The average biomass for 2.5 years old (30 to 59 cm girth class) and 3.5 years old (60 to 89 cm girth class) plantations was assessed (33.73 tha^{-1} and 49.16 tha^{-1}, respectively). This study concludes that agroforestry in the study area is passing through a transition phase and it is evolving to short rotation agroforestry models. Adapting to market dynamics, farmers prefer short rotation of less than 4 years over long rotation of 6 to 8 years. This study also gives useful information for planning various climate mitigation strategies as well as carbon sequestration projects through agroforestry which are directly dependent on biomass production besides giving a pathway for economy-driven planning and extension of agroforestry as well as wood based industries.

Keywords: Agroforestry models wood based industry, Biomass, Carbon sequestration, Mitigation

Successive reports of UNFCCC have been highlighting the importance and necessity of agriculture, forestry and other land use i.e., AFOLU sector as a mitigation tool to combat climate change. Forests, the reservoirs of carbon, which is proportionate to biomass production, are under various pressures due to ever-increasing demand for timber, fuelwood and various other products. The dependence on forests needs to be diverted to agricultural lands and to make agricultural lands also "productive and sustainable".

Rizvi et al (2022) reported an area of 28.4 MHA under agroforestry in India. The Forest Survey of India has estimated area under trees outside forests (TOF) as 29.3 MHA (ISFR 2021). The extent of area under agriculture in India is 141 MHA, out of which 78 MHA is irrigated, which is the potential area for extension of agroforestry. International Panel on Climate Change in 2023 summary for policy makers para A-3.2 and C-3.5 documents the potential adaptation options for forestry and agriculture sectors and identifies agroforestry under AFOLU sector as the ideal mitigation-adaptation mechanism. Poplar, a fast-growing agroforestry species, has an extent of 2,70,000 hectares in India (Chavan et al 2023), whereas in Yamunanagar district, it occupies an area of 12169.6 hectares i.e., 6.93% of geographical area (Rizvi et al 2020). The Indo-Gangetic plain is conducive for poplar cultivation, having 12,540 sq km (1.79%) currently under agroforestry, holds significant potential for expansion of agroforestry. The high productivity potential, availability of area under suitable agroclimatic zones i.e., Indo Gangetic Plain and plywood-friendly properties of poplars make it a preferred species for agroforestry. The objective of this study has been to assess the performance of poplar by recording their biomass productivity under short rotation agroforestry models in Yamunanagar district.

MATERIAL AND METHODS

Poplars occupy 6.93% of the geographical area in Yamunanagar district. The Haryana tree census 2023 conducted by the Haryana Forest Department, records Yamunanagar as a district having maximum area under agroforestry with 4.01 million poplar trees. The trees having a girth of 30 cm and above were measured and recorded under this study (GBH i.e., 1.37 m), which covered an area of 8126 hectares.

Yamunanagar district has Sandy-loam to loamy-sand soils (Agriculture Department, Haryana) with tubewell-based assured irrigation spread over 97% of its geographical area, suitable for poplar-based agroforestry. It is recognized as a focal point for wood-based industries (WBIs), housing a total of 1589 wood-based industries comprising 468 "Plywood and veneer units", 424 sawmills and 236 stand-alone presses, producing 50% of country's plywood. The prevalence of agroforestry in Yamunanagar district and its significance as a plywood industry hub of India formed the basis for selecting this district as area of study.

The prevalence of poplar within different administrative units of Forest Department i.e., Forest Ranges, were taken into consideration for the purpose of sampling included discussions with farmers as well as industrialists. Jagadhari Forest Range has 45% of the total poplar trees, hence the range was selected as study area (Fig. 1). Villages having more than 5000 poplar trees under agroforestry plantations were taken for sampling points. It was followed by selection of a suitable sampling plan, calculation of standard deviation, field measurements and finally the data analysis.

Selection of strata, sampling plan and data collection: Stratified Random Sampling strategy was used for the study. After conducting the field visits, the entire population in the study area was divided into two homogeneous strata based on girth classes i.e., 30-59 cm and 60-89 cm. This categorization was determined by the presence of plantations only within these specific girth classes in the field.

The variance of biomass within each stratum was calculated and a basis for determining the number of permanent sample plots was established using the standard statistical tool presented by Pearson et al (2007). To estimate the standard deviation in each stratum i.e., 30-59 cm and 60-89 cm girth classes, five sample plots each having a size of 0.1 ha (31.62 m x 31.62 m) were laid randomly in both the strata. Standard Deviation for both the strata having girth classes of 30-59 cm and 60-89 cm was calculated as 0.25 and 0.51, respectively based on which the number of sample plots calculated for these girth classes were 16 and 8, respectively.

Nested Square sample plots each having a size of 0.1 ha (31.62 m x 31.62 m), were laid for undertaking fieldwork. Stratified Random Sampling strategy using the rice grain method was used to identify the location of sample plots within each stratum separately. The rice grains were scattered on the map/toposheet of the selected area and the points where grains fell on the sheet were selected as the centre of sample plots. Measurement of the girth at breast height i.e. GBH (at 1.37m) of individual trees having girths greater than or equal to 30 cm was done using linear tape. GPS coordinates of all four corners as well as the central points of the sample plots were also taken using Google Maps. All measurements taken in field were recorded in standard proformas. Calculation of biomass was done using tools given in Table 1.

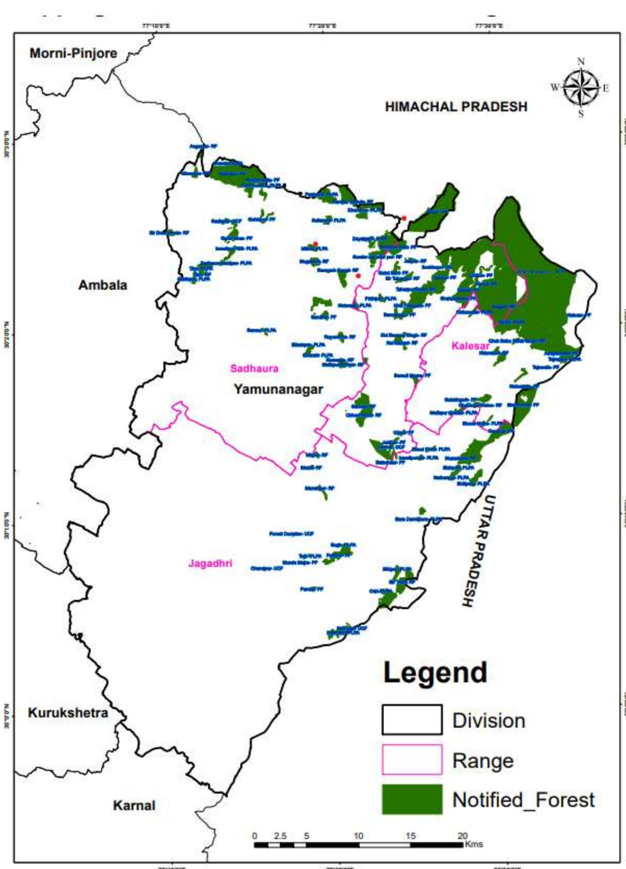

Fig. 1. Map of study area

RESULTS AND DISCUSSION

The assessment of biomass under the present study has been done for 2.5 years and 3.5 years old plantations having girth classes of 30-59 cm and 60-89 cm, respectively. Average tree density varied from 500 to 700 trees per hectare. The above ground biomass and below ground biomass i.e. AGB and BGB, respectively were calculated using standard values of wood density, biomass expansion factor and equations for volume as given in Table 2. AGB and BGB were then added to calculate the total biomass of each sample plot, which was further extrapolated to estimate the biomass per hectare.

The biomass was calculated for all sample plots under both strata. Sample plot wise calculation of biomass under the two selected strata has been given in Table 2 and 3. Using the year of plantation as base year, biomass production per ha per year was assessed as 16.8 $tha^{-1}yr^{-1}$ and 16.4 $tha^{-1}yr^{-1}$ under the girth classes of 30-59 cm and 60-89 cm, respectively. The assessed biomass productivity, rotation cycle and average tree density per hectare has been given below in Table 4.

It was confirmed during field visits that only two girth classes of poplar i.e., 30-59 cm and 60-89cm were available under agroforestry and further 75% of this crop was available in lower girth class only. The present study reports the biomass productivity of poplars under these girth classes having a reduced harvesting rotation cycle of less than four

Table 1. Dtandard values used for biomass calculation

Parameter	Description	Unit	Source	Value
GBH	Girth at breast heigh	m	Field work	Measurement from field in cms is divided by 100 to convert in mts
D	Diameter at breast height	m	Field work	GBH/3.14
V	Volume	m3	Volume equations FSI	V = 0.81467-1.063661D+6.452918D2 for Poplar, FSI Technical Information Series Volume 2 No. 1 2020, TOF
WD	Wood density	gm/cm3 or t/m3	FAO, ICRAF	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 - 3.4
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)

Table 2. Biomass calculation for all samples of 30-59 cm girth-class

Name of Site	Spacing (ft)	Year of plantation	Volume (cum)	AGB (tons)	BGB (tons)	Total biomass of each sample plot (tons)	Biomass for each sample plot (t ha^{-1})
Kazibans (P-I)	13' × 13'	January-21	4.25	2.04	0.55	2.6	25.97
Ismailpur (P-I)	12' × 13'	January-21	4.4	2.12	0.57	2.69	26.87
Nandgarh (P-I)	13' × 13'	January-21	4.42	2.12	0.57	2.7	26.97
Parwalo (P-I)	13' × 13'	January-21	4.63	2.23	0.6	2.83	28.27
Bhilpura (P-I)	14' × 14'	January-21	4.92	2.36	0.64	3	30.03
Nandgarh (P-I)	13' × 13'	January-21	5.25	2.53	0.68	3.21	32.09
Ismailpur (P-I)*	12' × 13'	January-21	5.42	2.6	0.7	3.31	33.08
Lkr M. Partappur (P-I)*	14' × 14'	January-21	5.53	2.66	0.72	3.38	33.81
Amadalpur (P-I)*	13' × 13'	January-21	5.61	2.7	0.73	3.43	34.27
Mukarampur (P-I)	12' × 12'	January-21	5.88	2.83	0.76	3.59	35.9
Hangoli (P-I)	13' × 13'	January-21	5.92	2.85	0.77	3.62	36.15
Sugh (P-I)	10' × 16'	January-21	6.07	2.92	0.79	3.7	37.05
Sugh (P-I)*	10' × 16'	January-21	6.29	3.02	0.82	3.84	38.4
Nathanpur (P-I)	14' × 14'	February-21	6.41	3.08	0.83	3.92	39.16
Amadalpur (P-I)*	8' × 16'	January-21	6.42	3.09	0.83	3.92	39.19
Mukarampur (P-I)	12' × 12'	January-21	6.96	3.35	0.9	4.25	42.54
Average volume & Biomass, t ha^{-1}			5.52	2.66	0.72	3.37	33.73

*Plots randomly sampled for estimating standard deviation

Table 3. Biomass calculation for all samples, 60-89 cm girth-class

Name of site	Spacing (ft)	Year of plantation	Volume (cum)	AGB (tons)	BGB (tons)	Total biomass of each sample plot (tons)	Biomass for each sample plot (t ha^{-1})
Bakarpur (P-II)*	10' × 18'	January-20	6.6	3.18	0.86	4.03	40.33
Nandgarh (P-II)	13' × 13'	January-20	7.47	3.59	0.97	4.56	45.63
Khadri (P-II)	14' × 14'	February-20	7.76	3.73	1.01	4.74	47.43
Parwalo (P-II)*	13' × 13'	January-20	7.79	3.75	1.01	4.76	47.61
Nathanpur (P-II)*	14' × 14'	January-20	8.41	4.05	1.09	5.14	51.39
Sugh (P-II)*	10' × 16'	January-20	8.54	4.11	1.11	5.21	52.14
Kazibans (P-II)	13' × 14'	January-19	8.73	4.2	1.13	5.33	53.33
Hangoli (P-II)*	16' × 16'	January-20	9.07	4.36	1.18	5.54	55.43
Average volume & biomass, t ha^{-1}			8.05	3.87	1.05	4.92	49.16

*Plots randomly sampled for estimating standard deviation

Table 4. Biomass productivity in study area

Girth class/ stratacm	Rotation cycle/age (Year)	Average tree density per hectare (Number)	Biomass production		
			Productivity range (t ha^{-1})	Average productivity (t ha^{-1})	Average annual productivity (t ha^{-1})
30-59	2.5 yr	500-700	25.9-42.5	33.73	16.8
60-89	3.5 yr	500-700	40.3-55.4	49.16	16.4

Table 5. Comparative chart of average annual productivity of poplar under different studies

Rotation cycle (yr)	Average annual productivity (tha^{-1} yr^{-1})	Assessment done by	Area of study
6	9	Handa et al (2020)	Haryana
7	4.5-11.5	Rizvi et al (2010)	Haryana & UP
6	30	Haque et al (2014)	Punjab
7	16.2	Rizvi et al (2019)	Haryana
6-8	21.9	Chavan et al (2023)	Indo Gangetic plain
2.5	16.4	Results of present study, 2023	Haryana
3.5	16.8	Results of present study, 2023	Haryana

years. With the introduction of spindle-less peeling machines and other technological advancements, the requirement of round timber in the plywood industry has reduced to a smaller diameter of 30-35cm, which previously required a diameter of 60cm. The harvesting rotation of poplars, as a result, which earlier used to be 6 to 8 years has come down to less than four years.

The comparison of productivity range of poplar under different studies with long rotation and the present study with short rotation has been given in Table 5. It shows that productivity under short rotation cycles is comparable with long rotations and there is no loss of biomass for the commercial use in the immediate scenario or in future.

Further, with the adoption of shorter rotations, farmers are also reducing the spacing from the current average of 13 ft x13 ft to 14 ft x 10 ft or 13 ft x 10ft. The number of plants to be planted per ha, consequentially, has also started increasing from 500-700 plants ha^{-1} under existing models to 850-900 plants ha^{-1} under new models. It will further result in increased biomass production per ha in the coming years as shorter rotations with increased density will be preferred. Short rotations with increased tree density will yield enhancement in biomass production though the outcome shall be ascertained in the coming years.

CONCLUSION

Keeping pace with the requirements of industry, farmers have switched over to plantation models with short rotation cycles of less than 4 years. The average annual productivity assessed under the present study for short rotations was found comparable with earlier assessments with long rotations. The findings of this paper auger well for the future of agroforestry as short harvesting rotations will support more plants per hectare and hence biomass production per unit area will also increase substantially.

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