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Circular Economy of Poplar-based Agroforestry in India

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ABSTRACT: *Poplar (P. deltoides), in India, is one of the ideal trees for integration with crop production in agroforestry and is grown in one of the most fertile agriculture land of North-western India. The tree supports numerous wood based industrial units with supply of wood raw material around its production locations and elsewhere. This symbiotic synergy between its land-use production systems and industrial manufacturing process is now mature and numerous economical activities are happening around the tree. This paper captures the circular economy around its nursery & plantation production and wood processing. Its nursery production is now revolutionized with mini cuttings which are made from the shoots collected from nursery grown saplings and is adding significant value with this new propagation material which earlier was a waste. Similarly, a huge economic activity is happening around its plantation production system right from planting saplings to their tending, harvesting and transportation of wood from fields to factory gates and during its further processing for manufacturing commercially important products. Improved nursery production from shoots is estimated to save Rs. 20 crores/annum. The current valuation of its wood trade is estimated to be Rs. 15225 million. Carbon trading of tree based production systems has started happening in India and there is a possibility of Carbon trade happening in future with a potential gain of Rs. 1530 million from poplar based agroforestry.*

Review Article

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1. INTRODUCTION

In India, agroforestry is contributing significantly towards land use and farm income diversification, natural resource management and meeting the demands of fuel, fodder, timber, thus helping in economic empowerment of farmers. The success story of Indian agroforestry is reflected in the form of its contribution in supplying about 90% of its industrial timber to the wood based industry (Pandey and Roy 2020). From the total availability of timber of about 83.5 million cum in India, less than 3 million cum, below 4% is from the Government forests and the rest from agroforestry that being now major source of wood raw material required for industrial purposes- Saw Mills, Ply & Veneer Mills and paper Mills.

Poplar is an ideal tree for planned and organized agroforestry wherein crops are grown throughout the retention of trees on agriculture land (Dhiman 2012a). It is one the main trees being grown under industrial agroforestry and is highly successful even on agriculturally most fertile and productive land of north-western states. It has created a large value chain around its nursery & plantation production and wood processing. This paper on circular economy of agroforestry grown trees is second in the series after the earlier one on eucalyptus (Dhiman *et al.* 2023). It captures value chain and economical activities around its different levels of nursery & plantation production systems and wood utilization processes *viz.*, nursery production, plantation production, plantation harvest and at wood processing levels.

Nursery production system

Recommendations of the Indian Forest Policy 1988 created an environment for managing government forests for ecosystem services whereas production forestry abruptly shifted to outside forests areas especially to farmland. This created a huge opportunity for non-government players' especially private sector, entrepreneurs, and farmers to venture into planting stock production and raising plantation on their land (Dhiman 2017a). Poplar plantations for matchwood production were initially promoted by private sector since late 1970's. In the starting phase of its growing, safety match WIMCO company controlled its nursery production which gradually spilled over to small private nurseries during 1990's.

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According to an estimate around 20 million poplar saplings were being planted annually during the first decade (Dhiman 2012b) which have now exceeded over 30 million during the last planting season of 2022-23 (Dhiman 2023) and the bulk of the planting stock for these plantations was grown by small nursery growers. The number of plants grown is gradually increasing with expansion in wood-based industry, though the periodical variation in plantations occurs due to variation in wood prices in the market.

Traditionally, poplar has been propagated using stem cuttings, whereas seed propagation is restricted to research work only. Initially, stem cuttings were collected from trees which were labour and other resource intensive besides these being not fully juvenile that affected the growth and productivity of produced clonal saplings. Later developments involve its propagation using cuttings made from juvenile fresh year nursery grown saplings. In costing process, the production cost of those saplings which are used for making cuttings for next nursery production cycle is accounted for as input costs in sapling production. Each sapling depending upon clone type and size could be multiplied to 6-7 standard size cuttings with adequate live buds for nursery production. With the sale price of around Rs. 25-40/sapling during the just concluded planting season of 2022-23, it would mean that Rs. 5/cutting is already added to the cost of next year sapling production based on cost of sale and Rs. 3/cutting based on cost of production. Further, these nurseries were usually established in January and February months, land for which is acquired for 3 cropping season *i.e.*, 1.5 years. The current average land leasing cost in poplar growing region is Rs. 50000 per acre/year. The leasing cost of land for new method nurseries (called Hi-tech hereafter) is reduced by 1/3rd from Rs. 75000/acre (for 3 crop seasons) to Rs. 50000/acre (for 2 crop seasons).

Around 50% poplar saplings are now grown using small/mini nodal and binodal cuttings in Hi-tech nurseries which are made from juvenile branch shoots collected from nursery grown saplings. The new improved system of poplar nursery production is based on a complete shift from standard size 9" stem cuttings to mini cuttings of nodal and bimodal cuttings made from healthy shoots (Dhiman and Gandhi 2010). These cuttings are first grown in containers and then planted late in nurseries during April, May and June months depending upon the size of sapling required in a particular location. The nursery preparation, planting and other operations have accordingly been modified to suit this technique making it economically more efficient and technically sound. This technique is now followed by large sized nurseries, whereas, smaller nurseries with low inputs still grow poplar saplings from standard stem cuttings.

Around 4000-acre poplar nurseries are currently established to grow over Rs. 3.25 crores saplings per annum. During 2022-23 planting season, the average sale price of poplar saplings was Rs. 30/sapling and the total volume of sale for 3 crores saplings was Rs.90 crores. Based on 50% of its nursery being grown with standard traditional stem cuttings and the remaining 50% using mini cuttings, the Hi-tech nurseries could save Rs. 10 crores (2 crore cuttings to produce 1.6 crore saplings at 80% survival) *Rs. 5 (cost of cutting)= Rs. 10 crores (A)) alone in term of cost of cutting material in nursery production. Further there is saving of around Rs. 5 crores (B) in land lease value (25000 (land lease value) *2000 (50% of nursery land). Cost of shoot handling, preparation of cuttings, their treatment and planting is considered same in both the production systems, though it is cheaper in the Hi-tech nurseries. There is added cost in the form of cost of containers (root trainers/polybags), their filling and growing the cuttings in them for 2-3 months before being planted in the open nursery beds. It is estimated that this activity would have additional cost of around Rs. 1 crores in growing 2000 acre nursery which get compensated in modified nursery preparation in Hi-tech nurseries. The old nursery production system involves making of small sunken beds which were more labour and time intensive and has now been totally replaced with tractor made ridges/furrows on which the plants raised in containers are directly planted. The additional cost of raising plants in containers is compensated with the less cost incurred on preparing ridge/furrow preparation and some other operations. Another major saving is in the production system wherein Hi-tech nursery production is spanned for 7-9 months compared to around 10-12 months in traditional nurseries. It is estimated that there would be an additional saving of around Rs. 5 crores (C) in Hi-tech poplar nurseries (50% of total) due to its less production period and less operations related therewith. Thus, the pruned material which earlier were a waste and were left in the fields has helped in generating increased monetary benefits of around Rs. 20 crores (A+B+C) annually.

Improving utility of culled /unsold nursery grown saplings

One of the standard operating procedures in poplar nurseries is to cull fully grown saplings and remove off-types, malformed, diseased and undersize saplings. At times, when nursery production is more than market demand, a fairly large number of saplings remain unsold in nurseries. Such fully grown saplings in open nurseries occupy large areas and if not

disposed off timely they become liability by holding the cultivated area for longer period. In such cases, these are uprooted, and locals have tried to find good use of them through converting waste into some usable material. They are used for fencing, props for crops, firewood and at times for making huts in rural areas. Their value addition and use in such items save in human cost in collecting the same material from far distanced areas and saving the alternate wood resources

Plantation management

The role of poplar plantation management in circular economy is more in providing labour employment and little on generating goods. The standard tending operation in poplar plantations is to prune trees for removing unwanted competing branches in order to improve the quality of timber on the main stem. Co-leaders or suppressed forked shoots are also removed during pruning to add wood volume on the main stem. The pruning of poplar plantations starts when they grow to around one year during winters and regularly thereafter. Sometimes, pruning is deferred by one year in that case the quantity of pruned wood yield is proportionally increased. Significant amount of wood that is obtained on pruning different aged poplar plantations is given in Table- 1 (Dhiman 2009).

Pruning poplar yields appreciable quantity between 3.8 to 25 t/ha fresh branch wood based on the age of the plantations. Two payment systems exist for pruning poplar trees. There are numerous specialized pruning teams throughout poplar growing region those charge pruning rates per tree depending on the age of trees and also in some cases pruning labour gets payment in kind i.e., pruned material is given to them *in-lieu* of labour cost. Large plantations produce appreciable quantity of pruned material; in that case farmers prefer to sell it in the market for higher appreciation, whereas in small plantations, it is disposed off to needy locals from the fields itself. The pruning material is either directly used as firewood or thereafter chipped or cut in rotary cutters to produce chip wood for getting higher value appreciation. The substitution of traditional fuels with pruned material from poplar plantations at least shifts the firewood value from one source to other source and this is another version of circular economy.

Table-1. Pruning yield from poplar plantations in Tarai Region, Uttarakhand

Age (Years)	Fresh weight (kg/tree)	Fresh weight* (qt/ha)
2	9.6	38.4
3	17.5	70
4	13.1	52.4
5	10.7	42.8
6	10.7	42.8
Total	61.6	246.4

Harvesting operations and transportation

Harvesting and transportation are some of the major costs in value chain of trees. The current rates for cutting trees, making standard size logs of tradable grades, segregating them grade-wise and loading on transportation lorries varies from Rs. 50 to 55/qtl. An additional Rs. 5/qtl is charged for excavation of roots if carried out along with harvesting. At times when the thinner logs are debarked for their supply to pulp mills for which labour charges Rs. 5/t. Smaller sections of firewood and foliage from harvested plantations are cut/chopped into small pieces/chips for onward supply to mills. Dhiman *et al.* (2023) reported 20% premium on sale of such material after cost of raw material and processing. In most chippers the composite material of locally available trees especially that of eucalyptus and poplar is processed together as its segregation is time consuming and is avoided. The current rate of such pulpwood is Rs. 650/qtl for debarked wood and Rs. 625/qtl with bark.

Poplar trees are felled by chipping the lateral roots with axe clearing the soil over them and then pushing the tree to fall with the remaining root system. This chipping of lateral roots generates around 7 kg chip wood per mature tree of 6-8 years age. A sample of 172 eight years old trees with around 85 cm girth felled in one of the farms generated 7.8 kg fresh chip wood per tree and this was sold at Rs. 70/qtl as firewood to the local vendor during 2008 (Dhiman 2009). Felling of 2 crores poplar trees/year therefore could generate 0.112 million t fresh chip wood. At times this chip wood is used by the labour for cooking while staying inside plantation sites for harvesting operations, sometimes collected and sold and at times left in-situ for degradation.

Dhiman *et al*. 2023 reported the costs of wood transportation from Yamuna Nagar to different locations those include Ambala and Bhiwani (Haryana), Bareilly, Agra, Lucknow, Prayagraj, Samastipur, Azamgarh, Chhapra (U.P.) and *vice-versa* as Rs. 2.32/km/t wood. The average distance for transportation of wood to Yamuna Nagar mandi is estimated to be around 50 km. According to Sapra (2022), the average annual wood consumption in Yamuna Nagar wood-based industry is reported to be 35-40 Lakh ton, major share being of poplar, and valued at Rs. 1500 to 1800 crores. The total money involved in transportation of wood to Yamuna Nagar mandi is worked out to be Rs. 46.40 crores (35*2.32*50).

Recycling process waste from polar wood based industries

Wastage in poplar wood

Poplar is used as a raw material for over three dozen products, of which the veneer industry comprising of panel products like plywood, plyboard, safety matches, ice cream spoons, and sticks, toothpicks, *etc.* are the main products (Dhiman 2023). Poplar wood processed in any of the wood-based industry produces process wastage during manufacturing of the main products. In a typical poplar-based factory, in North India, log procurement and their processing is happening almost day to day and week to week basis and units do not unnecessary lock money in a making large wood inventories. All factories avoid using old and dried logs and therefore fresh wood is used for making veneers. The wood use efficiency/wood wastage in plywood, safety matches and sports industry has been studied in detail and given below.

Sports goods industry

The traditional wood for making cricket bats has been willow imported from England and that grown in Kashmir Valley. Of late, poplar has substituted willow and emerged as the main wood raw material for making low value cricket bats in Meerut in Uttar Pradesh, Jallandhar in Punjab and in some units in Kashmir (Valley) in Jammu and Kashmir. Good and high-quality bats, used by star players, are still made from imported willow, and those of little low quality from Kashmir grown willow but the bulk of them used in local tournament and street cricket matches and those used for gifting during sport ceremonies, functions *etc.* are now made from poplar wood. It is estimated that around 80% of cricket bats in Jallandhar and Meerut clusters are made from poplar wood and hence the volume of semi and low-quality bats including small sized gift bats is very high. In addition to cricket bats, poplar wood is also used for making low-cost stumps and badminton handles and some other components of sports goods. In many cases small sections components of process waste generated from main sports goods are used for making components of other sports goods. Sports industry making cricket bats are integrated, multi-brand, multi-product and labour intensive making multiple sports goods and sports components. The sports industry thus effectively uses every possible piece of wood for one or another product to realize value of wood raw material. Except for sawing logs into bat look like wood pieces called clefts, on sawmills, all other operations are manually carried out and hence this industry is labour intensive that provides good employment to artisans.

The main specifications of standard cricket bats are for length of 38 inches (including handle length) and width 4.25 inches with variable thickness. Weight of the cricket bats vary widely depending on thickness and grade-wise. B2 and C grade bats with same width and thickness within each grade are further differentiated by 0.75" length. For example, the length of 4, 5 and 6 number bats in B grade is 22.50", 23.25" and 24" respectively, whereas, length of 0, 1, 2, 3 bats in C grade is 18.75", 19.50", 20.25" and 21" respectively. Small sized gift bats of different dimension are in addition to the above grades (Table 3).

Fresh good quality poplar logs are procured from local wood markets for making cricket bats. For example, logs over 21" mid girth thickness without defects like cracks, knots, *etc.*, are used for making A-grade bats. For other grades, even thin logs are also used. Logs are sawn into bat looking like shapes and sizes which are locally called as "Bagarh" (cleft in English terminology). The individual pieces are air dried and repeatedly compressed by moving them under increased compressing pressure of the machine by maintaining the shape of bats. The top middle of bat is cut into V notch to fix the composite handle. A classical good quality composite handle consists of three wood piece handle each of which is called as chapti. The outer chapties are made from poplar wood and the internal one of eucalypts/mango wood. Another sports product made from poplar wood wastage is handling for badminton rackets and is locally called as "Dakey". Its standard size is 7.5" length and 1" in thickness. Subsequent operations include cutting of the shoulders of the semi-finished bats, rounding off the toe, sanding of freshly processed surfaces, polishing by using a bee's wax compound to keep moisture out and let linseed oil in. Finally, the handle is bound by a string, rubber grip and market stickers are attached at appropriate place.

In a detailed study conducted in one of the Meerut sports industries (Table 4) by using 800 qtls fresh poplar logs, 14937 bats of different grades were made. Out of these, 2068 bats of A grade (103.40 qtls), 1754 of B1 grade (6.38qtl), 6034 of B2 grade (207.79qtls) and 5081 of C grade (86.38 qtls). In addition to cricket bats, 4200 handles of cricket bats (chapties) and 46000 handles for badmintons (dakeys) were also made from this wood.

Table 2. Three grades (including sub grades) of cricket bats made in Meerut sports industry.

Grade	Size (L x W x T)	Sub type
A	27" x 4.25" x 2.60"	Standard
B1	24" x 4.25" x 2.25"	Standard
B2	24" x 4.25" x 1.75"	4, 5, 6 number bats
C	21" x 3.50" x 1.50"	0,1, 2, 3 number bats

This study concludes that the wood use efficiency for making cricket bats was around 50%, around 5% more wood could be recovered for making handle for cricket bats and badminton handles. The rest was used as firewood.

Panel industry

Most plywood industrial units in North India are currently using poplar veneers. Battens (funties) for plyboard are largely made of poplar wood which being light in weight, sawing is easy and resin adhesion is good. Wood waste varies from product to product and the one given below is studied from the plywood industry.

Logs are debarked and further subject to trimming, peeling, clipping of veneers in appropriate sizes, veneer preparation, chopping, gluing, assembling, hot pressing, conditioning, quality check, sanding and sorting, repairing, preservative treatments, hand finishing, stamping, sorting and dispatching. Major operations for wood wastage in a plywood factory take place at debarking, end cutting, peeling, chopping, and trimming. Small units try to make use of maximum wood by manually converting even small sections to useable components, wood wastage is a little higher in large units and also in large sized product components. The wood wastage was studied in a plywood factory in, Bilaspur of Rampur District, Uttar Pradesh and is given in Table-5 (Suman 2003). This study was conducted around 2 decades back when the traditional peeling machines were using a little large thickness logs. Of late, most peeling units are now using hydraulic peeling machines using low girth logs in which turnout in the form of veneers is a little less and wastage a little higher.

Safety match industry

Manufacturing safety matches was the first established commercial use of poplar wood for which it was introduced and initially promoted in India. Wood is the main cost centre and raw material for making safety matches which is a low value wood-based product but involves highly complex and multiple processes and machinery in a mechanized sector. A match box contains three components *viz.*, match sticks (number vary with execution), inner (cardboard tray carrying match sticks) and outer (cover to hold inner with sticks) with two opposite rough surfaces to lit the match stick by sticking stick's head. The process of making safety matches in match factories passes through five operational sections, *viz.*, debarking in log yard, peeling and chopping in peeling section, drying, polishing waxing, head formation in splint processing section, stick filling in box filling section and box packing in packing section, all being under one roof.

Data presented for wood wastage at different sections of safety match manufacturing in Table-6 and Fig.-1 indicates significant differences between most of manufacturing sections (Dhiman and Dhiman 2015). Maximum wood wastage of 216.69 qtl per shift out of a total log consumption of 1000 qtl was recorded at peeling section which was significantly higher than that in all other sections *i.e.*, 115.22 qtl in splint processing, 111.42 qtl in debarking, 31.3 qtl in saw mill, 10.82 in box filling and 5.58 in packing. In percentage term wood wastage was maximum of 22.62%, 12.77%, 12.51%, 3.59%, 1.12% and 0.58% in peeling, debarking, splint processing, sawmill, box filling and packing sections respectively based on log

Table 3. Poplar wood wastage study in sports industry Meerut

Sr.No.	Items	Qtls(fresh)	Per cent
1	Weight of bats	404	50.5
2	Handle(chapti)	8	1.0
3	Dakay (handles for Badminton rackets	28	3.5
4	Side cuts(fararaa-bark and firewood)	240	30.0
5	Saw dust and freshening waste	75	9.4
6	Others	45	5.6

Table 4.Wood wastage in a plywood industry

Process	Before use (cft)	After use (cft)	Wastage (cft)	Wastage (%)
Debarking	45.014	39.31	5.708	12.68
Peeling	39.31	36.39	2.92	7.43
Core	36.39	33.98	2.41	2.82
Chopping	30.09	29.46	0.63	2.02
Trimming	29.46	26.66	2.80	9.50
Others	33.98	30.09	3.89	11.459

Table 5. Wood waste in safety match industry

Manufacturing process section	Wastage (qtls)	Per cent of Wood weight (without bark)	Per cent of Log weight (with bark)
Debarking	111.40	12.51	11.25
Sawmill	31.93	3.59	3.23
Peeling	216.69	22.62	20.33
Splint processing	115.22	12.77	11.48
Box filling	10.82	1.12	1.01
Packing	5.58	0.58	0.52
SE diff	5.61	0.56	0.622
CD0.05	15.21	1.52	1.686

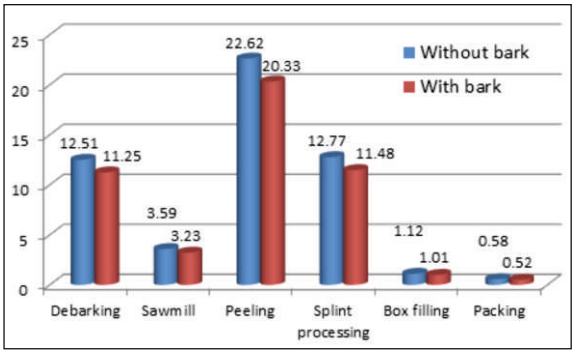

Fig.-1. Wood wastage (%) in different operations of safety match manufacturing

weight without bark; while; these figures were 20.93%, 11.48%, 11.25%, 3.23%, 1.02% and 0.52% percent respectively for the same processing sections based on log weight with bark.

The percentage wood wastage in log yard and peeling sections of safety match manufacturing is given in Fig. 2. In log yard section, end cuts had more wastage (1.79%) than saw dust (1.4%), in peeling section the percentage wood wastage were 10.07%, and followed by 9.93% in peeling section and 1.67% in chopping sections.

Three main wood wastage sections in processing section were pit (5.81%), sieving (2.55%) and polishing wastage (1.46%), In box filling section, stick dressing had 0.58%, & ROJ as 0.49% wastage whereas in packing section, the three major wastage components were mending (0.08%), sweeping (0.02%) and packing 0.01%) (Fig.- 3).

Debarking, sawmill and peeling sections together contributes for the maximum wood wastage in the match manufacturing processes. These are the sections where logs are processed to make into billets and then from billets to splints. Wastage in the form of centre ruler, peeling and end cuts is largely recycled as pulpwood in the paper industry. Bark and the remaining process wastage with chemical adhered to stick is used in-house boilers for generating steam.

Recycling the industrial waste

Wood is the costly raw material component and the main cost centre for making a very large number of its products. Every industry therefore tries to improve wood use efficiency by increasing wood conversion into main products, use waste/rejects for making secondary products. Wood wastage in the three case studies presented above indicates around 50% of the wood get transformed into main product for which wood is procured and the remaining 50% is generated as process waste. In all the poplar-based industry, wastage finds one or another use either as sale of pulpwood to pulp mills or used as firewood in the same or adjoining units. Even the central core left after peeling (using old machines leaving thick cores) has been used to make billets for filling in many block board manufacturing units. In main clusters of wood-based industry especially in Yamuna Nagar, Rampur,

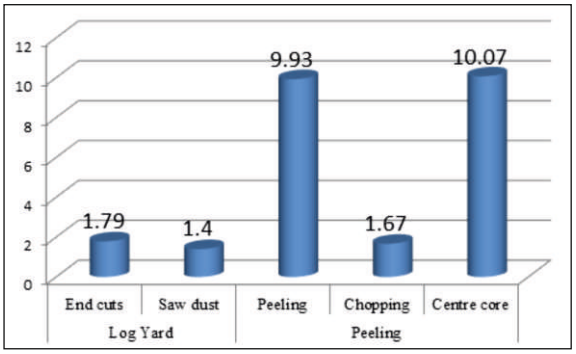

Fig.-2. Wood wastage (%) in log yard and peeling sections of match industry

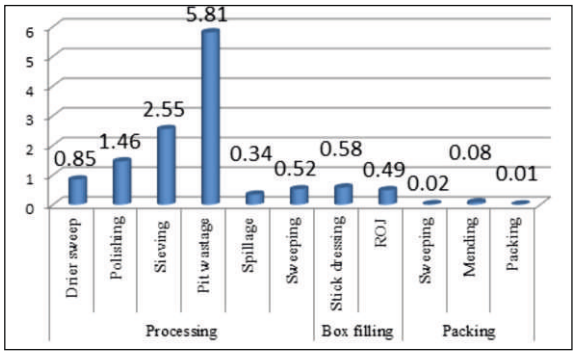

Fig.-3. Wood wastage in processing, box filling and packing sections of match industry.

Saharanpur and elsewhere where the cumulated wastage generation is huge a trading system has evolved wherein such wastage is collected and supplied to paper units. Some process waste also finds use in making packing cases, billets for making plyboard, firewood *etc.*

Paper factories in North India, in the past, were major user of eucalyptus pulpwood but have substituted a significant percentage of this with thin logs mainly of poplar and its wastage from various panel units in the vicinity due to its low cast. Another change in raw material is taking place in wood based industry near ports where they prefer low cost imported wood than costly indigenous raw material. A sizeable quantity of poplar and eucalyptus wood is imported each year and is used in units located around port cities. This clearly indicates that wood based industry balances the abundance and low supply by sourcing it from low value process waste and low priced locations including imports compared to locally available costly wood. Paper mills prefer recycling this wastage as it is cost effective, better efficiency as it does not contain bark component and has predictable and ensured supply. Dhiman (2017b) mentioned a survey report of 3 major paper factories located at Saharanpur (Uttar Pradesh), Yamuna Nagar (Haryana) and Lalkuan (Uttarakhand) which were earlier using raw wood for paper production have now quickly shifted to wood waste from industrial processing on its increased availability and low cost. During the survey period, all the three paper mills were using a higher share of recycled wood wastage as pulp wood. Century was additionally using baggase as well, whereas other two units were using only wood chips and recycled waste. The average share of recycled wastage as pulpwood in the three units was 61.22% with contribution of Bilts, Century and Star as 70.59%, 55.63% and 70% respectively. Collectively, poplar based wood wastage in the3 mills reportedly was 92.19% of total wastage used as these mills are located in the core poplar growing and wood processing region. Bilts paper mill at Yamuna Nagar has since been closed and the Star paper mill at Saharanpur is now in advantage of getting higher percentage of industrial process waste.

More than half of their raw material was from recycled wood with Bilts located in the core area of panel industry in Yamuna Nagar had maximum of 70.59% and star located very near to Yamuna Nagar cluster with 70%. Century was getting it from Rampur, and Rudrapur the other two prominent panel industry clusters in Uttar Pradesh and Uttarakhand, respectively.

Debarking of logs is carried out at plantation sites, factory log yards and at secondary processing points. Farmers avoid debarking at farm site as a significant volume of logs in the form of bark get underpaid. This is done by a few peeling units from their own plantations as it provides much leverage in transport cost and the bark is locally disposed off. There are numerous spots other than established wood markets where small and thinner logs/billets are debarked around the production sites or trading sites for their supply to paper mills and bark is disposed off to other traders and units.

Market valuation of poplar trade

We picked up some default values from the published literature and tried to capture the market valuation of poplar. Poplar is reported to occur over 0.312 M ha area in India out of which 0.3 M ha is under its plantation culture (NPC 2016) and the remaining area in natural forests. It is mainly grown for peeling logs and timber production in block and boundary plantations at low densities up to 600 trees/ha. With increased expansion in its wood consumption in wood based industry, its plantations on farm land are increasing at faster pace for quite some time now. Poplar is mainly grown on farm fields where its average wood productivity is repeatedly quoted as 50t/ha/year. We picked up very conservative figures of 35 t/ha/yr average fresh wood productivity for poplar for calculating its yearly market valuation given latter in this section.

For wood prices, we collected the wood sale prices of different grades of poplar from Yamuna Nagar wood market in Haryana for the month of July 2023 which is summarized in Table 9.

Wood prices in open market are highly dynamic which remain fluctuating on day to day basis depending upon demand and supply. Yamuna Nagar in Haryana was the first open wood market for farm grown wood in the country. Wood production and consumption significantly increased in different locations in due course as a result about 20 odd wood markets developed around its major production and consumption locations in the states of Uttar Pradesh, Haryana and Punjab in North India (Table 10). The rates are always high in Yamuna Nagar market which decreases in locations away from it especially towards eastern Uttar Pradesh. Wood of farm grown trees especially of poplar, eucalyptus, mango, kikkar, shisham, beri, drek, amrood *etc.* is traded without many regulations in these mandies.

Box-1. Strong synergy and relationship between market rates and poplar plantations

Poplar started finding visibility in plantation activities especially on farmland during late 1970's. It was originally promoted by safety match company WIMCO Ltd for production of match wood. Poplar culture is happening in a few select north western states, The utilization base of this tree has significantly

Table 6. Different components of wood used by the three paper mills (Dhiman 2017b)

Pulp wood	Waste type	BILT Yamuna Nagar			Century Lalkuan			Star Saharanpur			Total of 3 factories		
Species		Qty (t)	% of total	% of wood	Qty (t)	% of total	% of wood	Qty (t)	% of total	% of wood	Qty (t)	% of total	% of wood
Poplar	logs	140	24	24	1000	25	44	165	21	21	1305	24	36
	chips	-	-	-	-	-	-	165	21	21	165	3	5
	core	280	47	47	204	5	9	55	7	7	539	10	15
	veneer	140	24	24	1050	26	47	165	21	21	1355	25	37
Total		560	94	94	2254	56	100	550	69	69	3364	62	92
Eucalyptus	logs	35	6	6	-	-	-	75	9	9	110	2	3
	chips	-	-	-	-	-	-	75	9	9	75	1	2
	core	-	-	-	-	-	-	25	3	3	25	0	1
	veneer	-	-	-	-	-	-	75	9	9	75	1	2
Total		35	6	6	-	-	-	250	31	31	285	5	8
G. total		595	100	100	2254	-	100	800	100	100	3649	67	100
	Baggase	-	-	-	1800	44	-	-	-	-	1800	33	-

Table 7. Recycled waste used as pulpwood in three paper mills of North India (compiled from Table-7)

Pulpwood	Bilts	Century	Star	Total
Wood	175	1000	240	1415
Recycled wood	420	1254	560	2234
Others (Bagagse)		1800		1800
Total	595	4054	800	5449

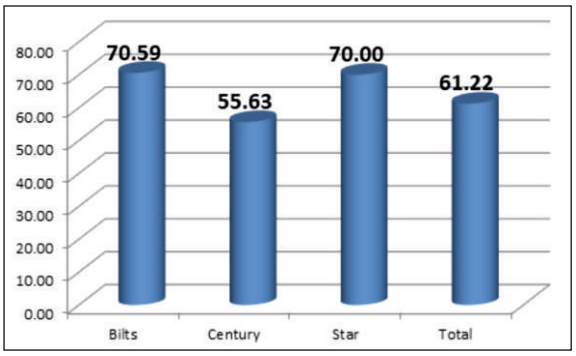

Fig. 4. Percent of recycled wood waste in select paper mills of North India

Table- 9.Current wood prices (Rs./qtl) for different grades of poplar in Yamuna Nagar wood market during July 2023.

Grade	Unit	Rs./Qtl
Over and under (mix)	>16 inches for poplar	1650
Sokta	8-14 inches	780
Pulpwood		670
Firewood		450
Roots		320

enlarged over the years and currently poplar is a life line for panel products, pencil making, paper pulp around locations of its culture.

Table- 8. Recycled waste used as pulpwood in three paper mills of North India (compiled from Table-7)

Pulpwood	Bilts	Century	Star	Total
Wood	175	1000	240	1415
Recycled wood	420	1254	560	2234
Others (Bagagse)		1800		1800
Total	595	4054	800	5449

Tree culture on farmland is largely based on the demand and supply for sale of their produce. Last year (2022-23), around 60 lakhs poplar saplings were planted in the state. Whenever, there is fall in wood prices, there is drop-in plantation activities and *vice-versa*. Poplar wood prices dropped to the low-end range three times around 1995, 2004 and 2017 and plantation activities were directly affected in those periods. Once the wood prices start increasing, plantation activity also start expanding with every incremental increase in wood prices.

Poplar wood is traded in different grades of logs, firewood and roots and/or in mixed lots in different markets. Dimensional limits of grades and their trade also change with demand and supply. Periodical fluctuation in wood prices in all wood markets is much higher than seasonal variation. For example, poplar wood log prices which are currently the highest at Rs. 1650/qtl in July 2023 (Table 9) were Rs. 1310/qtl in May 2022 (Table 10) and Rs. 740 during April 2021. They were minimum of around Rs. 400 during 2017 and are regularly increasing thereafter. The current trend of poplar wood trade shifted to lower dimension grade of over at 16 inches mid girth logs which also include earlier traded under log size as mentioned in Table- 9. Box- explains strong relationship between

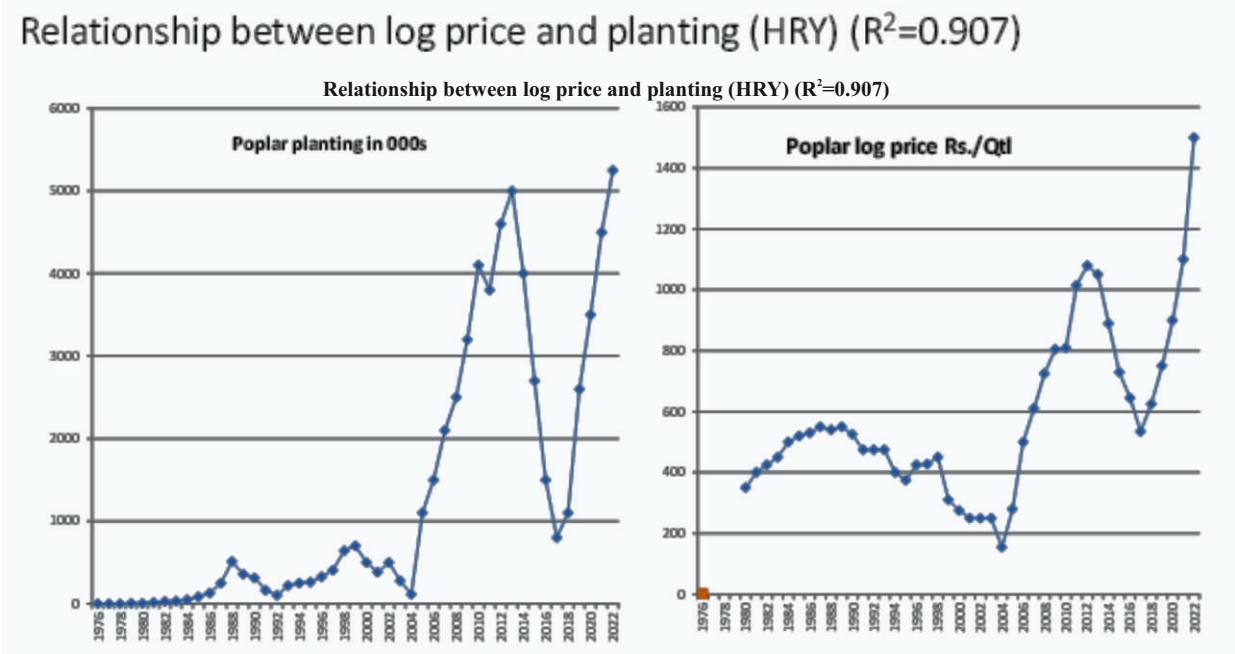

Fig.- 5. Relationship between log price and planting

Table-10. Poplar wood prices (Rs./qtl) (May 2022) for different grades in some selected mandies of Punjab and Haryana (Dhiman 2023).

Mandi	Oversize	Undersize	Sokta	Roots	Firewood	Mix
Amritsar				500	600	1050
Ludhiana	1200	1100	850	300	300	1150
Jalandhar				200	200	1150
Hoshiarpur				250	225	1200
Ropar	1200	900	650	350	350	1100
Yamuna Nagar	1320	750	640	325	325	
Jagadhari	1310	740	630	325	325	
Karnal	1050	800	600	250	250	900
Shaharanpur	1100	850	600	300	300	1000

expansion of poplar plantations and wood prices in the state of Haryana (Fig.-5).

Over logs are considered with >16" mid girth, Under 12-16" and Sokta 3-12". No commission on trade of poplar is paid in any money except in Jagadahri where it is currently 3% of sale proceeds. As seen from the Table-10, Yamuna Nagar is paying the maximum of Rs. 1320/qtl for oversize timber. However, the price of mix lot in Hoshiarpur is Rs. 1200/qtl which works out to be higher than that of Yamuna Nagar mandi for oversize wood. These rates are significantly higher than those recorded for different grades wood around one year back (Table-9).

It is inferred from the above information that valuation of the poplar wood trade changes seasonally and periodically (Table 11). The mix lot including all grades varied in a narrow margin on around Rs. 200/qtl in different mandies and less by the same margin from the oversize wood logs. Salable logs constitute around 80% of the total wood produced in this tree and accordingly the average wood price will tend towards higher grade price. We thus picked up Rs. 1450/qtl (Rs. 14500/t) for poplar wood trade for estimation of market valuation of these trees (based on July 2023 market pricing). Taking a very conservative values for poplar wood production at current mandi prices, the current market valuation of poplar wood trade from 0.3 million ha is estimated to be Rs. 15225 million . The wood value get a multiplier factor of X2 when it is converted into product and a multiplier factor of 4X when it is sold and used by the consumers (Dhiman *et al.* 2023) An additional gain of Rs. 1530 million could be generated from the CO_2 trade if that become reality in the near future. (Table-12).

The payment of ecosystem services from growing trees has now started happening. The potential of financial gains against CO_2 sequestration from 25 million ha agroforestry in India has been estimated to be Rs. 127480 million (TERI 2020). Poplar based agroforestry is practiced over 0.3 million ha and hence the potential financial gains from this activity

Table-11.Poplar wood prices in different mandies of North India during April 2021 (Dhiman 2023)

Sr. No.	Place/mandi	State	Over	Under	Sokta	Roots	Mix
1	Amritsar	Punjab	-	-	-	200	410
2	Ludhiana	Punjab	655	545	435	200	550
3	Jalandhar	Punjab	600	500	-	200	-
4	Hoshiarpur	Punjab	800	700	450	210	650
5	Ropar	Punjab	-	-	-	170	550
6	Jagadhari	Haryana	800	650	525	185	-
7	Yamuna Nagar	Haryana	740	650	550	185	-
8	Karnal	Haryana	-	-	450	170	550
9	Bhagwanpur	Uttrakhand	650	470	-	130	-
10	Rudrapur	Uttrakhand	575	480	150	90	-
11	Jaspur	Uttrakhand	550	475	150	-	-
12	Bilaspur	U.P.	540	355	130	85	-
13	Rampur	U.P.	550	370	140	90	-
14	Bareilly	U.P.	550	410	150	-	-
15	Sahjahnpur	U.P.	500	350	140	-	-
16	Hapur	U.P.	575	415	160	-	-
17	Meerut	U.P.	-	-	160	-	550
18	Bijnor	U.P.	560	400	130	-	-
19	Muzafarnagar	U.P.	-	-	150	-	550
20	Lucknow	U.P.	450	270	120	-	-

Table- 12. Current valuation of poplar culture in India.

Sr. No.	Item	Unit	Poplar (0.3 Mha)
1	Fresh wood (inc. firewood)	35t/ha/yr (poplar)	1.05 million t
2	Dry weight	Half of 1 above	0.525 million t
	OM addition in soil	3 t/ha/yr	0.9 million t
3	C sequestration in trees*	46% for poplar	0.2415 million t
4	Employment generation	Person days	100 million
6	Carbon credit trade value	(projected)	Rs. 1530 million
7	Present wood trade value (Rs.)	14500/t (poplar)	Rs. 15225 million
8	Total		Rs. 16775

*46% Carbon content in poplar wood picked up from literature scan for these species.

are estimated to be Rs. 1530 million. The total wood trade value and potential gains from CO_2 sequestration from poplar are estimated to be Rs 16755 million (1530+15775) per annum at the current market prices of its wood. Trade value of trees is decided by the market prices of different tradable tree components gardes at a particular time Dhiman (2013) while quantifying the trade value of commercially grown trees in India reported that Industrial agroforestry in India is spread over 5 million ha and was estimated wood trade value Rs. 10000 billion per annum during 2012 (Dhiman 2013). The trade value of eucalyptus has been estimated to be Rs. 500397 million per annum (Dhiman *et al.* 2023)

CONCLUSION

Poplar has established industrial agroforestry in North India around which numerous economical activities developed. Being grown by thousands of farmers on agriculturally fertile and productive Indo-gengetic plains demonstrated its vast potential in improving economical conditions of many of them. It also acted as an example for replication of industrial agroforestry with other species in other regions of the country. The tree originally promoted for production of match wood is now finding use in around 3 dozen products and its usage is still expanding with developments of new techniques and products. Circular economy around its production-utilization base is gradually expanding to new activities and improving its social, economic, and industrial footprint.

References

Dhiman R.C. (2009). Carbon footprint of planted poplar in India. ENVIS Forestry Bulletin, 9(2): 70-81.

Dhiman R.C. (2012a). Diagnosis of intercrops in poplar based agroforestry. Indian Forester 138(7): 600-609.

Dhiman R.C. (2012b). Status of poplar culture in India. ENVIS Forestry Bulletin. Vol. 12(1):15-32.

Dhiman R.C. (2013). Status and impact of commercial agroforestry in India. Indian J. Agroforestry 15(2):55-67.

Dhiman R.C. (2017a). Evolving production-supply chain of nursery plants to sustain farm grown commercial wood production in India. Presentation made in the XIX Commonwealth Forestry Conference, 3-7 April, ICFRE Dehradun, India.

Dhiman R.C. (2017b). Development of synergy between private sector and farmers for wood raw material production. In Souvenir of NAU-ISTS National Seminar on Forest and Tree based land use systems for livelihood, Nutritional and Environmental Security. COF, ACHF, Navsari Agriculture University, Navsari Gujarat. Pp. 157-167.

Dhiman R.C. (2023). Poplar wood marketing and trade. In: Poplar Farming (Eds. Anita Tomer and Sanjay Singh), Forest Research Centre for Eco-rehabilitation, Prayagraj, Uttar Pradesh (ICFRE), Biotech Books. Pp.189-214.

Dhiman R.C. and Dhiman D. (2015). Deepak**:** Quantification of wood wastage in mechanized match manufacturing. International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869, 3(2): 51-57.

Dhiman R.C. and Gandhi, J.N. (2010). Innovations in nursery production for enhancing field performance and acceptability of poplar saplings. In: (eds. Giuseppe Scarascia-Mugnozza and Brian J. Stanton). Poplars and willows: from research models to multipurpose trees for a bio-based society. IPS-V, Session 4: Innovative production systems for low input tree crops, pp. 113. 20-25 September, 2010 Palazzo dei Congressi,Orvieto(Italy).http://www.sisef.it/IPS-V/data/material/IPSV%20Book%20of%20Abstracts.pdf

Dhiman R.C., Arunachalam A., Shiv Kumar Dhyani , Aqeel H. Rizvi , Archna Singh , Raj Kumar Singh , Chandrashekhar M. Biradar and Javed Rizvi. 2023. Circular economy of eucalyptus-based agroforestry in India. Indian Journal of Agroforestry 25(2): 12-21 (2023).

NPC (2016). India- Country Report on Poplars and Willows (Period 2008-2011), National Poplar Commission of India, Forest Research Institute, Dehradun, Uttarakhand, India.

Pandey C.N. and Sumit Roy (2020). Plywood and panel industry in India: Current scenario and key issues. Wood Is Good 1(1):15-17.

Sapra R.K. (2022). Haryana- A potential hub for export of wooden panel products. Ply Insight May 2022.

Suman S.K. (2003). Project Report on Minimization of wood wastage in Plywood industry. Submitted to FRI Dehradun for partial fulfillment of the requirement for the Award of M.Sc. degree in wood Science and Technology, FRI (Deemed University) Dehradun.

TERI (2020). Policy brief on innovative financial mechanisms to achieve additional 2.5–3.0 billion t of Co^2e through additional forest and tree cover in India by 2030. The Energy and Resources Institute, New Delhi.