Emulating Indian agroforestry-based wood value chain for improving the wood-based economy in Central Asian Countries

Aqeel Hasan Rizvi[1], Ramesh Chand Dhiman[1], Shiv Kumar Dhyani*[1], A. Arunachalam[2], Archna Singh[1], Dilfuza Yuldasheva[3], Martin Welp[3], Bonu Azizova[4], Guzal Eshchanova[5], Mirzaev Bakhadir Suyunovich[5] and Javed Rizvi[1]

ABSTRACT: *Central Asian Countries (CACs) namely Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan are forest scarce and wood deficit countries as such they largely depend on wood imports for meeting their domestic demand. The region has mainly extra-continental climate with generally low rainfall which makes suitable conditions for forests rare. Historically, their forest resources have been subjected to significant exploitation, and the current wood production remains low. The wood value chains in CACs are in the early stage of development and the current forest development programmes for required plantation could benefit from further enhancements. India, on the other hand, is a large country and has fairly large forest area of 72.69 M ha, forest cover of 71.53 M ha (21.76%), and tree cover of 1.12 M ha (3.41%). However, most of its forests are under conservation plans and the total wood harvests from them are less than 2 M m^3 against a demand of around 100 M m^3. Its carefully crafted domestic wood production strategy from agroforestry based plantations and well-developed wood value chains are enabling major wood availability for the bulk of its domestic consumption and some for exports as wood products. Currently 92% of the wood production is produced from agroforestry plantations and small share from other Trees Outside Forests (TOFs). Farmers are increasingly growing trees with agriculture crops in agroforestry for sale of wood. Currently the Poplar-based agroforestry is generating around INR 0.2 M/acre/year (1US$=INR 86) and that of Eucalyptus up to INR 0.1 M/acre/year. Such initiatives of massive agroforestry plantations for wood production are missing in CACs. India and CACs have some commonalities in term of a few similar geographical locations, and tree resources; and common agriculture based economies. The paper identified some potential and successful case studies of Poplar and Willow agroforestry based wood value chains from India and suggests their emulation to increase the wood based economy in CACs.*

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1. INTRODUCTION

Central Asian Countries (CACs) and India are important countries in the Asian Region with many similarities and contrasts. All five CACs, namely Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan; and India are located above the equator in the northern hemisphere and have overall diverse weather conditions and seasons. India, being near the equator, is largely a tropical country with its extreme northern region having subtropical and temperate conditions. CACs are located at higher latitudes and are largely arid, semi-arid, semi-desert and temperate countries (Fallah *et al.*, 2024) with hot summers and cold weather conditions similar to the ones existing in the Indian Himalayan Region. Forests are scarce in all of them, which are appropriately managed and sensibly conserved in the best interest of the respective country. Each country regularly promotes tree plantations to expand forests to meet the much needed greenery and wood. Like any other country, CACs depend on their limited forest and tree resources for a large number of goods and services. They have variable wood consumption patterns based on their population size, forest resources, wood processing infrastructure, lifestyle, economic health, and historical trends. All of them face similar challenges of wood deficit as such their wood demand is largely based on imports.

Worldwide, wood supply chains are centred around their local availability, imports, wood product manufacturing and utilisation ecosystem, geo-

S.K. Dhyani[1]
s.dhyani@cifor-icraf.org

[1] CIFOR-ICRAF Asia Continental Program, World Agroforestry, New Delhi, India

[2] ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh

[3] Eberswalde University for Sustainable Development, Germany

[4] Technical University of Berlin, Germany

[5] Tashkent Institute of Irrigation and Agricultural Mechanization Engineers- National Research University, Uzbekistan

climatic conditions, and affordability of users. Wood value chain is a holistic concept that includes different ingredients, from growing plantations and their management for wood production to harvesting, transportation, distribution, and consumption (Schure *et al.* 2014). Wood-related supply chains are generally long and more complex as they involve multiple stakeholders and multiple processing channels until wood and its products are finally used. The intermediary steps of wood value chains may include all or some of them. In countries with strong linkages between wood production and consumption, intermediary steps of wood value chains are easily developed due to the economic activities around them. India, with its estimated 1458.8 million persons, is the most populous country in the world; as such, its annual wood demand is exceedingly high, at around 100 million m^3. CACs are relatively smaller countries, and so are their relatively lower wood demands (Dhiman 2025b). The existing forest resources in India and CACs have largely been placed under conservation. Therefore, wood value chains in all of them have developed alternate wood sourcing routes for meeting their respective demand. In India, the wood value chain has developed hugely from agroforestry-produced plantations with strong linkages between its processing and end-use. The wood value chains in CACs largely depend on imported wood from neighbouring countries, especially from Europe and Central Asian Countries (E&CACs).

This paper discusses various aspects of wood value chains between India and the CACs, identifies some of the successful case studies from India and explores their emulation in CACs to improve their economy through increased wood production and consumption. Variation in data sets of many parameters in CACs is noticed due to their variable origins and timelines. Some of them, namely, reported forest area (FA) and population, usually show high variation. We therefore used the data sets from a couple of websites, namely the "Worldometer" website for forest area (Worldometers website) and population (Worldometers Population). The data sets in these websites are regularly updated, were retrieved on 24th of February 2025 and used to present their status in CACs. For India, the population data was also retrieved from the same website, whereas the FA is cited from the recently released India State of Forest Report (ISFR) (2023).

2. BACKGROUND INFORMATION OF CACs

The Central Asian Region comprises 5 countries, is situated in the heart of the Eurasian continent, forming a trade link between East Asia and Europe (Liu 2011). This region shares borders with Russia in the north; China in the east; the Caspian Sea in the west; and Iran and Pakistan in the south. The geographical coordinates of CACs generally fall within the range of 35-52° North Latitudes and 46-87° East Longitudes. These countries collectively cover an area of approximately 4 million km^2 with a total population of approximately 65 million (Hamidov *et al.*, 2016). Kazakhstan is a relatively large country with 68.06%, and Tajikistan is a relatively small country with 8.57% of the total geographical area (GA) of the region. All these countries became independent in 1991 and thus had a similar way of life, policy framework, administrative network, and socio-economic interdependence within the erstwhile centrally administered Soviet Union.

Each CAC has specific geographical, ecological, social, anthropological, historical, economic and political systems, which together have a bearing on the natural resources, their extent, management and usage. In the undivided Soviet Union, natural resources, including forests, were plentiful and viewed from a broader perspective. Each country at that stage had access to surplus wood and wood-related products existing in that large country, which, on their independence, are now restricted to small GA and forest resources in the respective CAC. Some of the critical factors, which decide the wood demand and its current use are population size, extent of native forest and tree resources, forest conservation and management programmes, plantation programmes, commercial wood production within and outside designated forests, and import & export of wood & wood related products in each of them. Agriculture is a major activity and means of livelihood for the majority of the population. Agricultural land covers approximately 2.8 million km^2 or 70 % of the GA of the region (Lal 2007). Approximately 2.5 million km^2 or 63% of the total land is in rangeland and approximately 0.3 million km^2 or 7% is cropland (Mueller *et al.* 2014). Agriculture sector employs 20 to 50% of the labour force (Qushimov *et al.* 2007) and account for 5 to 22% of their gross domestic product (GDP). In individual CACs, agriculture is contributing 4.8% to the GDP in Kazakhstan, 12% in Turkmenistan, 18.2% in Uzbekistan, 17.6% in Kyrgyzstan, and 22% in Tajikistan (https://data.worldbank.org/).

The topography of CACs is a mix of plains, mountains and valleys. Most areas of Kazakhstan, Turkmenistan, and Uzbekistan are steppe and desert and semi-desert, whereas Kyrgyzstan and Tajikistan are largely mountainous with some of their mountains rising

above 6000 m amsl. Conifer forests are largely dominated by spruce (*Picea schrenkiana*) and are restricted to the mountains between 1,800 m and 2,800 m amsl, and Juniper, *Picea schrenkiana,* still at higher elevations up to 3,200 m amsl. Broadleaved forests are dominated largely by Walnut (*Juglans regia*) and Pistachio forests. Arid areas are dominated by White Saxaul (*Haloxylon persicum*) and Black Saxaul (*Haloxylon aphyllum*) forests. Tugai forests in the mountains have Elm, Poplar and Willow species which are restricted along the rivers where groundwater levels are high. In the dry regions, Tugai forests consist of Willow species, *Populus pruinosa*, *P. euphratica* and Russian Olive (*Elaeagnus angustifolia*). Willows are distributed along the riverbanks, whereas *P. pruinosa* and Russian Olive are restricted to sites with groundwater levels not deeper than 4 m. *P. euphratica* grows on sites with groundwater levels as deep as 12 m.

The forestry sector in CACs has been facing multiple challenges due to heavy fuelwood removal, charcoal production, overgrazing, salinity, illegal wood harvest, diversion of forest land and others. Each country has been doing forest development activities to expand and restore forests (Table 1).

3. COMPARISON OF RESOURCES AMONG CACs AND INDIA

The status of CACs and India in terms of their GA, land area, water bodies, FA and population are given in Table 2. All CACs are located at higher latitudes and longitudes than India. Geographical coordinates significantly affect the occurrence and distribution of plant species, including trees. For example, the lower limits of poplar (*P. deltoides*) in natural distribution range are 28° N latitudes and there have been difficulties in growing this tree below 28°N latitudes in many countries. Among the 5 CACs, Kazakhstan is the largest country with 2,724,910 km^2 GA followed by Turkmenistan (488,100 km^2), Uzbekistan (447,400 km^2), and Kyrgyzstan (199,949 km^2). Tajikistan is the smallest country in terms of its GA of 144,100 km^2 among the CACs. India, on the other hand, is a large country with 3,287,263 km^2 GA. Each country has water bodies within its territories, which affect the land availability for plant production systems. All the CACs have a higher percentage of land area (GA minus area under water bodies) of >95%, with Kazakhstan having 99.07%, Tajikistan 98.2%, Turkmenistan 96.28%, Kyrgyzstan 95.92% and Uzbekistan 95.08%. In comparison, it is only 90.45% in India, indicating that it has comparatively much less land area for plant and tree production systems.

All the CACs have low FA with Turkmenistan having a high of 4,1270 km^2 followed by 33,090 km^2 in Kazakhstan, 6210 km^2 in Kyrgyzstan, 4128 km^2 in Tajikistan and a very low of 3196 Km^2 in Uzbekistan. On percent basis, Turkmenistan has a high of 8.46% FA to GA and other countries have less than 3% of their GA under forests. Conversely, India has a large area of 22.11% (726,928 km^2) of its GA under forests. There is

Table 1. Forest Development and restoration programme undertaken in CACs

Country	Proposed efforts
Kazakhstan	Create 300,000 ha of wooded lands and forests by 2030. In addition, it is planned to establish plantations of fast growing trees, create green belts around cities, plant 10,000 ha of shelterbelts and set up protected areas for Saxaul woodlands on 962,021 ha by 2030.
Kyrgyzstan	Create plantation over 83,000 ha by 2025
Tajikistan	Plant new forests on 15,000 ha by 2030 and rehabilitate 30,000 ha of forests by 2030. Support natural forest regeneration on 120,000 ha by 2030.
Turkmenistan	Plant 4 M trees as shelterbelts around cities and field plots by 2020
Uzbekistan	Plant 42,000 ha annually until 2021

(Source: Compiled from UNECE 2019)

Table 2. Comparison for area and population among CACs and India

Country	GA	Population		Land area		Water bodies	Forest area		
	Km^2	No.	GA ha/ head	Total	GA (%)		Km^2	% of GA	ha/head
Kazakhstan	2724910	20747182	13.13	2699700	99.07	25202	33090	1.21	0.16
Kyrgyzstan	199949	7253078	2.76	191800	95.92	8150	6210	3.11	0.09
Tajikistan	144100	10711309	1.35	141510	98.20	2590	4128	2.86	0.04
Turkmenistan	488100	7570979	6.45	469930	96.28	18170	41270	8.46	0.55
Uzbekistan	447400	36786997	1.22	425400	95.08	22000	3196	0.71	0.01
India	3287263	1458835700	0.23	2973190	90.45	314070	726928	22.11	0.05

a significant tree resource outside the recorded FA in all these countries. In India, it is around 3.5% of the total GA and is a substantial resource for the bulk of wood production. Yin *et al.* (2017) reported the collective forest cover in CACs as 1.24% of the GA, with Kazakhstan as 1.45%, Kyrgyzstan 3.3%, Tajikistan as 1.05%, Turkmenistan as 0.06% and Uzbekistan as 0.29%. The addition in the forest cover was estimated by considering the planting area of 5 thousand hectares (Th. ha) in Kazakhstan, 57 Th. Ha in Kyrgyzstan, 0 Th. ha in Tajikistan, 12 Th. ha in Turkmenistan and 300 Th. ha in Uzbekistan.

Kazakhstan has comparatively large GA/person (13.13 ha) compared to other CACs. It was lower of 6.45 ha in Turkmenistan, 2.76 ha in Kyrgyzstan, 1.35 ha in Tajikistan and 1.22 ha in Uzbekistan. India also has a very low of 0.23 ha GA/person as it is the top populated country with 1458.8 M persons on a GA of 3,287,263 km^2. FA/person is dismally low in almost all the CACs and India. Among all these countries, Turkmenistan has a reasonably high FA of 0.55 ha/person. India has a low of around 0.05 ha FA/person.

India, with 2% of the world's total GA, and ranks 7th globally, whereas Kazakhstan, with a 1.8% share and ranks 9th of the GA of the world are close to each other on this land parameter. All other CACs are smaller in terms of population and GA. Their world ranking for GA varies from 53 for Turkmenistan to 95 for Tajikistan, whereas Kyrgyzstan (87) and Uzbekistan (57) are ranked between the former 2 countries. The world ranking for population is 107, 104, 91, 64 and 43 for Kyrgyzstan, Turkmenistan, Tajikistan, Kazakhstan and Uzbekistan, respectively. The current estimated population indicates that the population of 1458.8 million in India is 70 times larger than that of Kazakhstan with 20.7 million persons and 200 times larger than the less populated Tajikistan with 7.25 million persons among the CACs. Based on an index of ratio between area and population, India, with just a 0.11 ratio, is the worst placed in comparison to all the CACs. Kazakhstan has this ratio high of 7.2 and Turkmenistan as 3.3. Lower area: population ratio indicates higher dependence of people on fewer land resources. Livestock in all these countries has increased dependence on land and forest resources. Livestock population in CACs during 2016 indicates that Uzbekistan had a maximum of 12.7 million livestock population, followed by 9.75 million in Tajikistan, 7.9 million in Kazakhstan, 6.77 million in Kyrgyzstan, and 6.34 million in Turkmenistan. India's livestock population was huge of 536.76 million and was 11.6% of the world population during 2015.

Agriculture is the main occupation, and it employs a large workforce, especially in rural areas in CACs and India. Among CACs, the share of the agriculture sector to the GDP is maximum in the case of Tajikistan (22%), followed by Uzbekistan (17.6%), Kyrgyzstan (14.9%), Turkmenistan (12%) and a minimum of 4.8% in Kazakhstan. The Indian agriculture sector contributes 18.2% to its GDP (https://data.worldbank.org/).

All the above parameters presented and discussed for

Table 3. Ranking and share of area and population of CACs in the world (https://www.worldometers.info/geography/largest-countries-in-the-world/)

Country	Geo. Area		Population		Ratio: Area/ population (%)
	Share (%)	Ranking	Share (%)	Ranking	
Kazakhstan	1.8	9	0.25	64	7.20
Kyrgyzstan	0.1	87	0.09	107	1.11
Tajikistan	0.1	95	0.13	91	0.77
Turkmenistan	0.3	53	0.09	104	3.33
Uzbekistan	0.3	57	0.45	43	0.67
India	2	7	17.78	1	0.11

Table 4. Trade and growth related parameters of CACs and India

Country	GDP US$ M	GDP per capita US$	GDP growth annual	HHI index
Kazakhstan	220623	11244	3.2	0.07
Kyrgyzstan	10931	1607	7.02	0.14
Tajikistan	10492	1054	8	0.15
Turkmenistan	2905	2905	5.47	0.29
Uzbekistan	80392	2256	5.67	0.17
India	3385090	2389	7	0.06

(Source: IMF World Economic Outlook).

CACs and India directly and indirectly affect their economic and social health. This is reflected in the form of GDP, growth and their trade with other countries. Among CACs, Kazakhstan is the largest economy with 220,623 million US$ followed by 80,392 million US$ in Uzbekistan, 10931 million US$ in Kyrgyzstan, 10,492 US$ in Tajikistan and a low of 2,905 US$ in Turkmenistan (Table 4). India has a very high GDP of 3,385,090 million US$. This also has a bearing on GDP/person, which was a maximum of 11,244 US$/person in Kazakhstan and a minimum of 1,054 US$ in Tajikistan. In India, the GDP/person is a nominal of 2,389 US$. High GDP growth of around 8% is reported for Tajikistan, followed by 7.02% for Kyrgyzstan and a low of 3.2% for Kazakhstan. India has been maintaining a growth rate of over 7% for the last few years.

Trade is a norm worldwide to balance the demand and supply of different products. The export of the country is determined by the HHI index (Herfindahl-Hirschman Market Concentration Index), which is the degree of product concentration in the trade. A high index value indicates the presence of barriers for trade to different export markets. Turkmenistan has a high of 0.29 HHI, followed by 0.17 in Uzbekistan, 0.15 in Tajikistan, 0.14 in Kyrgyzstan, and a low of 0.07 in Kazakhstan. India has the lowest HHI of 0.06 among the targeted countries, indicating that its product range in exports is wide, and also there are many export destinations.

4. WOOD VALUE CHAIN INCLUDING ITS TRADE IN CACs

CACs are located in the close vicinity, have common borders among most of them and strong business ties among each other. Each of the CACs has a specific and peculiar status in terms of geo-physical, agro-ecological, weather and climate, socio-economic, natural and man-made resources, political and governance systems, population structure, economic well-being, literacy and some other elements. Each country heavily depends on their own natural resources in addition to the import and export of certain products to balance its demand and supply.

The World Integrated Trade Solutions (WITS) website provides a comprehensive database for various traded products, including wood products (https://wits.worldbank.org//CountryProfile/en/Country/). The data sets were retrieved on 26th February, 2025, for the total trade including import and export destinations. The data sets were available till 2022 for 4 CACs, whereas for Turkmenistan, it was only for 4 years, namely 2000, 1999, 1998 & 2017, which are not in sync with the rest of the CACs. The data sets of wood products for old years in Turkmenistan are thus given as indicative values to see their trends along with other CACs. In volume terms, Kazakhstan's total trade was worth 107,092 M US$, followed by 43,551 M US$ in Uzbekistan, 12,058 M US$ in Kyrgyzstan, and 6,852 M US$ in Tajikistan during 2022, whereas that in Turkmenistan it was 4,294 M US$ during 2000. The imports and exports (M US$) for Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan were 30,952 and 76,140, 9,803 and 2,255, 5,183 and 1,669, and 28,264 and 15,287, respectively, during 2022. Further, Kazakhstan had 125 and 174, Kyrgyzstan 134 and 99, Tajikistan 101 and 55 and Uzbekistan as 148 and 115 trade partners for import and export, respectively, during 2022. Turkmenistan had 1788 million US$ imports and 2506 million US$ exports with 75 and 58 partners respectively during 2000. The major trade of CACs has been with Europe & Asian countries (E&AC), including the Russian Federation (RF), and a

Table 5. Import of wood products in CACs between 2018-2022 (1000 US$)

Country/year	2022	2021	2020	2019	2018	Average
Kazakhstan	1346238	1234222	978329	1081002	1012745	1130507
Kyrgyzstan	2570689	196861	132721	204973	165650	191455
Tajikistan	297350	221300	180794	191462	186512	215484
Turkmenistan	51533	40482	15464	24665	-	33036
Uzbekistan	1406903	1103191	88267	941696	880003	884012

Table 6. Share (%) of Top 5 region and countries in wood supplies to CACs during 2022

Country	Total(Th.US$)	1	2	3	4	5
Kazakhstan	1346238	E&CA(89)	RF(68)	EA&P(10)	China(10)	Belarus (5)
Kyrgyzstan	257068	E&CA(85)	RF(60)	EA&P (15)	China (14)	Kazakhstan(7)
Tajikistan	297350	E&CA(94)	RF(73)	Turkmenistan(9)	Uzbekistan(5)	EA&P(4)
Turkmenistan	51533	E&CA(91)	Turkmenistan(53)	RF(16)	ME&NA(7)	France(5)
Uzbekistan	1406903	E&CA(89)	RF(71)	EA&P(10)	China(9)	Turkmenistan(5)

small share with distant countries like China, India and some others.

The major wood trade (including wood products) of CACs is primarily with neighbouring countries, including immediate neighbours and others in E&CA. Kazakhstan had 89%, Kyrgyzstan 85%. Tajikistan 94%, Turkmenistan 91% and Uzbekistan, with 89% of their wood imports from E&CA. The details of wood products are not available on the website. The imports mainly consist of wood, and exports consist of wood products manufactured from imported wood. RF was the major supplier of wood to CACs with 68% of total imports of Kazakhstan, 60% of Kyrgyzstan, 73% of Tajikistan, and 71% of Uzbekistan during 2022 and 16% of Turkmenistan during 2000.

The data on value (1000 US$) of import and export of wood for CACs were retrieved from the WITS website. Kazakhstan and Uzbekistan were the 2 large importers of wood products compared to 3 other CACs. Kyrgyzstan overtook 1st position from Kazakhstan and Uzbekistan during 2022. It is reported in certain quarters that the recent trade sanctions imposed on Russia due to Ukraine war has helped Kyrgyzstan to take advantage of diverted wood products trade from Russia. The remaining 3 CACs had comparatively less imports of wood products, which also include notional comparisons with those of Turkmenistan for the old years (1997 to 2000).

Five major import sources with value inside parentheses (1000 US$) of wood products for each of CAC during 2022 (2000 for Turkmenistan) are given in Table 6. Europe & Central Asian Region was the top source for wood supplies to all the 5 CACs and the per cent share of total wood values varied from 85% to 94% during 2023, Kyrgyzstan imported wood products primarily from RF ($60.2 million), Belarus ($8.79 million), Kazakhstan ($3.84 million), Uzbekistan ($2.59 million), and Poland ($2.33 million). The wood product was Kyrgyzstan's 18th most imported product (https:// oec.world/en/profile/bilateral-product/wood-products/reporter/kgz).

Among CACs, Uzbekistan and Kazakhstan were the 2 lead exporters of wood products throughout the 5 years reported period (Table 7). This was followed by that of Kyrgyzstan in the 3rd position, and Turkmenistan had the lowest wood exports among the CACs. Figures for Turkmenistan are old and just notional ones.

Like imports, exports from CACs have been mainly to E&CA, which was in the top 1st position for supplies of wood products. 97% of wood products exported by Kazakhstan were to E&CA, including RF, and these figures were 97% for Kazakhstan, 99% for Kyrgyzstan, 95% for Tajikistan and 71% for Uzbekistan during 2022 whereas it was 100% for Turkmenistan during 2000. RF among E&CA was the top 1st wood products receiver country from Kazakhstan with 49% of its total wood supplies. These figures of wood products from other countries were 35% for Kyrgyzstan, 47% for Tajikistan and 9% for Uzbekistan during 2022.

The gap in value (1000 US$) between the import and export of wood products was negative for all the reported years and for all the CACs. It was a maximum of 1,251 million US$ for Uzbekistan, followed by 1206 million US$ for Kazakhstan and a minimum of 232 million US$ for Kyrgyzstan during 2022. The value for Turkmenistan was low of 51.5 Tho.US$ for the year 2000. Both Uzbekistan and Kazakhstan had higher gap deficits between imports and exports for all the reported years.

The average gap between higher imports and lesser exports for the reported 5 years between 2018 and

Table 7. Export of wood products in CACs during 2018-2022 (1000 US$)

Country/year	2022	2021	2020	2019	2018	Average
Kazakhstan	140510	69082	51602	91937	88392	88305
Kyrgyzstan	24331	15680	15029	10803	5598	14288
Tajikistan	4246	1021	743	1364	1166	1708
Turkmenistan*	26	18	31	149	-	56
Uzbekistan	155643	76009	45144	40396	43424	72123

Table 8. Share (%) of Top 5 region and countries receiving wood from CACs during 2022

Country	Total(Th. US$)	1	2	3	4	5
Kazakhstan	140509	E&CA(97)	RF(49)	Poland(11)	Kyrgyzstan(9)	Uzbekistan(8)
Kyrgyzstan	24331	E&CA(99)	RF(35)	German(19)	Kazakhstan(13)	Uzbekistan(12)
Tajikistan	4267	E&CA(95)	RF(47)	Kazakhstan(29)	Uzbekistan(18)	SA(3)
Turkmenistan	25.79	E&CA(100)	Uzbekistan(98)	Kazakhstan(1)	Germ(1)	-
Uzbekistan	1553643	E&CA(71)	Kyrgyzstan(34)	EA&P(23)	RF(9)	Tajikistan(8)

2022 indicates that the wood imports worth the mentioned values were additionally used for domestic consumption in addition to their own domestic product manufacturing within each CAC. The average negative gap in value terms of wood products for the 5 reported years was worth 1,042 million US$ in Kazakhstan, followed by 812 million US$ in Uzbekistan, 177 million US$ in Kyrgyzstan and 214 million US$ in Tajikistan (Table 9). The average deficit gap of 33 M US$ was for Turkmenistan from 1997 to 2000.

Some data on wood trade for Uzbekistan is also available for 2023 year in another website (https://wits.worldbank.org//CountryProfile/en/Country/KGZ/Year/2022/TradeFlow/Import/Partner/ALL/Product/44-49_Wood), which mentioned a trade deficit in wood products worth 815.9 million US$ during that year. According to the website data, Uzbekistan was the 111th largest wood exporter of wood products worth of 21.1 million US$ during 2023 mainly to Tajikistan ($7.29million), Estonia ($6.77 million), Kyrgyzstan ($2.59million), Latvia ($1.26 million), and Germany ($1.04 million). During the same year Imports of wood products were worth of 837 million US$ from Russia ($620 million), Belarus ($126 million), China($46.6 million), Turkey ($15.5 million), and Kazakhstan ($11.8 million) making Uzbekistan to be 33rd largest wood importer in the world.

Some data sets of wood volume production, import and export in the form of round wood (RW), sawn wood (SW), veneers (Ven.) and plywood (PW) for CACs is also available in the Resource Assessment 2020 report (FRA 2020) (https://www.fao.org/forest-resources-assessment/fra-2020) and ITTO (https://www.itto.int/2023) (Table 10). According to these data sets; Kazakhstan and Uzbekistan produce, import and export more wood than the other 3 countries. All the CACs have higher imports compared to their local production and some of their volume appears to have been traded among each other. The data also indicates that Turkmenistan does not produce any RW and SW in the country, whereas Tajikistan's value is very low (1000 m^3). Further, Kyrgyzstan, Turkmenistan, and Tajikistan do not have any manufacturing base for veneer and plywood within each of them and their entire requirement of these two industrial wood components is met from imports. Kazakhstan has had higher volumes of veneer and plywood (PW) manufacturing than Uzbekistan. Sawn wood, Ven. and PW were converted to RW equivalent by applying standard multiplication factors used in India, namely 1.285 to SW and a factor of 2 to Ven. and PW. It can be seen that the estimated RW consumption in Uzbekistan was 3,944 Th.m^3, followed by 2,731 Th.m^3 in Kazakhstan, 922 Th.m^3 in Kyrgyzstan, 770 Th.m^3 in Tajikistan and a very low of 161 Th.m^3 in Turkmenistan. Wood consumption in each CAC is likely to be high compared to the reported figures as much of it used in the fragmented and unorganized sector, including by the local inhabitants, may be unaccounted.

5. TRADE IN WOOD PRODUCTS AMONG THE CACs

Trade in wood products has been happening regularly among all the CACs. The Import figures of wood products (1000 US$) for the years 2022 (2000 for Turkmenistan) are given in Table 11. The only exception was Turkmenistan, which did not import wood products from Tajikistan during 2000. The average import trade/CAC was a high of 4,887 Th.US$ for Kyrgyzstan followed by 3,885 Th.US$ for

Table 9. Gap (1000 US$) between Import and export of wood products in CACs between 2018-2022

Country/year	2022	2021	2020	2019	2018	Average
Kazakhstan	-1205728	-1165140	-926728	-989065	-924352	-1042203
Kyrgyzstan	-232737	-181181	-117693	-194170	-160052	-177167
Tajikistan	-293104	-220279	-180051	-190098	-185346	-213776
Turkmenistan	-51508	-40464	-15433	-24515	0	-32980
Uzbekistan	-1251260	-1027182	-43123	-901300	-836578	-811889

Table 10. Production, import and export of Industrial wood (1000 m^3) in CACs

Country	Production				Import				Export				Wood
	RW	SW	Ven.	PW	RW	SW	Ven.	PW	RW	SW	Ven.	PW	consumption
Kazakhstan	750	210.3	2	170	237	820	30.7	60.6	1.8	3.75	20.5	53	2731.5
Kyrgyzstan	250	158	0	0	47.8	293	4.5	17.7	2.7	5.2	0.2	0.03	921.7
Turkmenistan	0	0	0	0	0	117	0	5.2	0	0	0	0	160.7
Tajikistan	1	0	0	0	0.6	551	0	30	0.03	0.01	0	0	769.6
Uzbekistan	310	195	2.7	0.08	323	2290	1	63	0	3.4	0	7.8	3944.2

(Source: FRA 2020)

Kazakhstan, 3,034 Th.US$ for Tajikistan and 1,523 Th.US$ for Uzbekistan during the 5 reported years.

Export metrics of wood products (Table 12) indicate that Kazakhstan and Uzbekistan exported their wood products to all other 3 CACs, whereas exports from Kyrgyzstan, Tajikistan and Turkmenistan were to only Kazakhstan and Uzbekistan. In volume terms, Kazakhstan had a high average export volume of 5,000 Th.US$ compared to 1,210 Th.US$ to Kyrgyzstan and 398 Th.US$ to Tajikistan during 2022.

6 AGROFORESTRY BASED WOOD VALUE CHAIN IN INDIA

India is situated north of the equator between 8°-37° North Latitudes and 68°-97° East Longitudes. India, with a total GA of 3.288 million km^2 and over 1458.8 M persons, is the 7th largest and the 1st top country respectively in the world. India's livestock population was 536.77 million during 2015. India is the world's 5th largest economy by its GDP and the 3rd largest by purchasing power parity (PPP). It has 72.69 million ha area administered as forest land and 179.982 million ha as agricultural land, with 154.20 million ha cultivated area. The agricultural land area was reported to be 58.69% and under forest land to be 22.11% of GA during 2022-23 (MA&FW 2024). The net irrigated area in the country is 79.31 million ha. Food production during 2023-24 was a record high of 332.22 million t in the country. According to the ISFR 2023, the total forest and tree cover is 8,27,357 km^2, which is 25.17% of the GA of the country. The forest cover has an area of about 7,15,343 km^2 (21.76%), whereas the tree cover is 1,12,014 km^2 (3.41%). The top 5 tree species reported inside forests are *Shorea robusta* (GS of 11.43% of total), *Tectona grandis* (4.46%), *Pinus roxburghii* (4.43%), and *Terminalia tomentosa* (3.59%), whereas under Trees Outside Forests (TOFs) are *Mangifera indica* (13.25%), *Azadirachta indica* (7.00%), Madhuca spp. (4.37%) and *Cocos nucifera* (4.16%). The total growing stock (GS) of wood in the country is estimated as 6,429.64 million m^3, which comprises of 4,478.89 million m^3 in recorded forests and 1,950.75 million m^3 in TOFs. Total tree green cover under agroforestry at the country level was estimated at 1,27,590 km^2 in the 2023 report.

Wood production and supply chain based on agroforestry-based wood production has fully developed and completely transformed in India during the past few decades. A major part of the government forests has been placed under conservation after the enactment of the Indian Forest Policy 1988. As such, the major wood production has gradually shifted to non-FAs mainly to the agroforestry grown plantations. Each year, millions of farmers make plantations of fast-growing trees, harvest them at very short production cycles and supply wood to the wood-based industry (WBI) and other market channels. The volume of wood produced and supplied from agroforestry is vast and is meeting the bulk of the demand for domestic and industrial consumption. This has created an alternate wood resource and breathed new life into WBI, which otherwise was facing an acute shortage of raw material and was on the verge of closure. This significant development, by any means, in a mega country like India is unparalleled by any standard anywhere in the world.

The process of growing agroforestry plantations was started around 5 decades back with the growing of the first ever farmland plantation of Poplar in 1975, which went on to become a highly successful decentralized, diversified, economical, and effective model of wood production in wood deficient India. Currently, there

Table 11. Country-wise Import matrices of wood products among the CACs during 2022 (1000 US$)

Country	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan	Average
Kazakhstan	-	6582	1249	12.48	11333	3835
Kyrgyzstan	16948	-	84.51	2.27	7400	4887
Tajikistan	916	440	-	69	13745	3034
Turkmenistan*	261	124	-	-	192	144
Uzbekistan	4161	2009	737	710	-	1523

Table 12. Country-wise export matrices of wood products among the CACs during 2022 (1000 US$)

Country	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan	Average
Kazakhstan	-	12699	1069.47	173.25	11058	5000
Kyrgyzstan	3182	-	-	-	2869	1210
Tajikistan	1234	-	-	-	758	398
Turkmenistan*	0.26	-	-	-	23.33	5
Uzbekistan	11142	52628	12970	2142	-	15776

are around 3300 panel based industries, 900 paper mills, and around half a dozen large & medium mechanized, and numerous cottage scale safety match industries in the country. These and other sector WBI were totally dependent on government forests for forest raw material earlier, and are now virtually getting it from agroforestry-grown plantations. Agroforestry-grown wood production has progressively increased with a corresponding increase in demand from the ever-expanding WBI. Wood availability from government forests has gradually declined from a high of 10 million m^3, 4 million m^3, 3.175 million m^3 and 1.75 million m^3 during 1970s, 1990s, 2017 and 2019 respectively to 1.56 million m^3 during 2019-20 (Bansal 2022), whereas, the potential industrial wood production from TOFs (mainly agroforestry) has progressively and gradually expanded from 69.04 million m^3, 74.50 million m^3, 85.16 million $m^3$and 91.51 million m^3 during 2011, 2017, 2019, and 2023 respectively (ISFR 2023). The current wood demand in India is estimated to be around 100 million m^3 and its sourcing indicates 92% of it being procured from non-forest land sources (mainly agroforestry), forests are supplying <2%, and the remaining 6% is from imports.

Wood from TOFS is currently grown from around a dozen fast-growing trees, namely Eucalyptus, Poplar, Casuarina, Leucaena, Melia, Bombax, Ailanthus, Acacia, Neolamarckia (Syn. *Anthocephalus*) and a couple of others. The area under commercial agroforestry grown wood production was reported to be on 5 million ha a decade back, which included Eucalyptus on 2.0 million ha, Poplars on 0.3 million ha, Acacias on 0.7 million ha, Casuarina 0.5 million ha, and others on 1.5 million ha (Dhiman 2013). The acreage under it has undoubtedly expanded further since then. Eucalyptus for chip wood and Poplar for peeling and sawing logs are two main trees grown in agroforestry in India. Poplar now finds utilization for manufacturing 3 dozen products, and similarly, Eucalyptus base has expanded from its original utility as firewood to a multiple utility tree for numerous applications. Other species are grown over specific geographical locations for wood production and have varied utilities. Agroforestry grown plantations of some trees like Poplar, Eucalyptus, Casuarinas and Melia, are highly productive with an average of 20-30 m^3/ha/year productivity, which at times is reported up to 50 m^3/ha/year by applying good management on matching soil-sites.

The country has had imports of wood and wood based products worth INR 771,690 million during 2022-23 and is estimated to be around 6% of the total wood used in the country (Dhiman 2025a). The imports of wood and wood products are happening to meet the demand for solid wood use in different sectors, including housing, furniture, etc. and also some substitution for the industrial wood deficits. The primary function of agriculture land is to produce food grains, however, its additional contribution of 92% of country's wood requirement from the same land-use if substituted with the potential wood imports, this value is translated to potential foreign exchange savings worth of INR 11,832,580 million (771690/6)*92) to the exchequer during 2022-23 alone. Many of these monetary benefits of wood values are now transferred to millions of farmers who grow these trees in agroforestry.

In addition to producing much-needed wood and food, this transformed integrated wood production in agroforestry is significantly contributing to resolving many of the economic, social, environmental, industrial and financial issues, which the country has been facing with an ever-increasing population and

Table 13. Shift of wood raw material production from native trees to agroforestry grown trees for major products

Industry	Major Native trees	AF/FF grown trees
Paper pulp	Softwoods, Bamboos	Eucalyptus, Casuarina, Leucaena
Panel products	*Dipterocarpus* spp., *Swietenia macrophylla*, *T. grandis, Michelia champaca, Ailanthus* spp, *Bombax ceiba, N. cadamba* and some other	Eucalyptus, Poplar, Melia, Casuarina, Rubber wood, *Grevilea robusta*
Safety matches	*Ailanthus* spp, *Canarium euphyllum, Sterculia companulata, Trewia nudiflora, B. ceiba, N. cadamba,* and some others	Poplars, *Ailanthus* spp., *B. ceiba*
Poles	Bamboos, conifers, Shorea spp.	Eucalyptus, Casuarina, Bamboos
Construction	*T. grandis, Shorea* spp., *D. sissoo* and others	Engineered product made from agroforestry grown wood
Furniture	*T. grandis, D. sissoo, Acacias* and others	*T. grandis, D. sissoo,* Eucalyptus, Melia, Acacias and others

industrialization. The country, being the 7th largest in terms of its GA in the world, is a land-scarce country for its large population of over 1458.8 M persons. The carefully crafted national strategy of progressive wood and food production from agroforestry in consonance with climate resilient and sustainable natural resource management has produced the largest ever food grain production of 332.22 million t during 2023-24 and 91.15 million m^3 of wood production during the same time. Food production has increased from 50 million t during 1950-51 to 332.22 million t during 2023-24. This is despite the fact that the forest land, which was 14.24% of its GA during 1950-51, has increased to 22.11% during 2022-23, and the agriculture land, which was 66.70% during 1950-51, has reduced to 58.69% in 2022-23. The pressure on land and natural resources has significantly increased during this period, as there were only 361 million persons in 1951, which increased to over 1458.8 million. The country has thus been able to maintain the bulk of its wood and food security from its limited land resources by integrating the growing of trees and crops together in agroforestry.

Other goods and services generated from integrated wood and food production includes enhancing diversity of intensive agriculture farming system, improving and sustaining farmland productivity by recycling nutrients through trees integrated with crops, expanding green cover, economic transformation of rural landscape through wood trade and other economic activities associated with tree culture, better economical returns to growers, employment generation in rural areas, ameliorating environment and some others. This production model provided much needed relief to the country and a space for better conservation of natural forest and tree resources by shifting the wood production base to fast grown trees outside natural forests. Table 13 provides an overall picture of how the usage of traditional and native tree species has now shifted to a few selected agroforestry grown trees.

This practice of agroforestry for collectively growing wood and food is a low cost model and ideal approach for many countries, which are facing similar social, environmental and economic challenges. It does not involve heavy economic burden on government exchequers and the tree culture in agroforestry is providing direct economic benefits to the growers leading to the improvement in their economic condition. There are huge economic activities taking place around their value chains, which are transforming lives and localities in a big way (Dhiman 2012b).

7. EMULATING INDIAN SUCCESS STORIES IN CACs

Agroforestry based wood value chain is well developed and highly successful in India. It was initiated by the private sector and its different ingredients namely the planting stock production; raising plantations on farmland; harvesting trees; transporting wood; its marketing, trading, and processing; and the product manufacturing are in the private sector. Even the major R&D efforts to develop new productive clones (Dhiman 2024) and supportive standard practices for selected tree species are developed and contributed by the private sector (Dhiman *et al.* 2024b). This concurrent food and wood production system in agroforestry has evolved with active participation of 2 major contributors, namely the farmers and WBI, though some others, like state forest departments, research institutes, finance and insurance establishments, together created a favourable ecosystem for its success through dynamic policy initiatives, suitable regulations and some other initiatives. WBI opted for this approach because it could not hold land for growing industrial plantations. Farmers, on the other hand, adopted this integrated production system for additional economic gains from the sale of wood products to mills. WBI supported this venture through their direct and indirect investments, which also include spending on Corporate Social Responsibility (CSR) and Corporate Environmental Responsibility (CER) funds in developing such plantations. The lesson learning from Indian success story for its replication in other countries need to follow the entire value chain right from R&D to manufacturing wood products. Regular wood demand is critical and a pre-requisite for its success & sustenance and mere promotion of plantations without its front-end integration with the wood-based industry will not work.

CACs are located within narrow geographical coordinates, have much similarity in climatic conditions, and their natural resources including forests, and wood yielding trees. Wood value chains in CACs are based on costly imports. There are some exports of wood products from them, which are primarily manufactured using imported timber. This mechanism of costly wood imports for manufacturing products and thereafter their export provides a little economical leverage to the local product manufacturers and as such do not have long-term sustainable trade benefits. To make it internationally competitive both economically and physically, native quality wood production for manufacturing products for export and domestic consumption needs priority in all the CACs.

CACs are low-income countries and have limited financial resources (Dhiman *et al.* 2025b). The public expenditure on forestry sector is dismally low in all of them and they face limitations in allocating adequate budgets for forestry activities as the returns on such expenditure is generally not recoverable even after a long period. For example, only 2,405 Th.USD were earmarked for forestry sector in Kyrgyzstan and 7,318 Th.USD in Uzbekistan during 2010 (FAO 2015). Every CAC wishes to create new forested land, improve and maintain the older ones, as such; there is a need for huge expenditure. The proposed forestry programmes in CACs (UNECE 2019) as discussed under Para 2 need huge investments in forestry sector even for such small programmes. While there may be some push on the enlisted programmes with internal and external sources, an alternate ecosystem of sustainable wood production and its utilization base similar to India needs to be created. Once it starts happening, may be initially with government support, its transformational value is huge (Dhiman 2012b). Farmers start getting consolidated money from the sale of wood, which finds local market in manufacturing wood products. The practice thereafter expands among other farmers with corresponding expansion in WBI.

The Indian success story started with the poplar culture in the Indo Gangetic plains, commonly referred to as the food bowl of the country. This region having the bulk of Poplar based agroforestry is known for highly intensive agriculture based on high input-high output production system, which provides higher and better economical returns to farmers compared to those received from sole crops in most other parts of the country. There are certainly some regions and zones of similar agricultural practices in many CACs. For example, a high-intensive irrigated agriculture is reportedly happening over 0.42 million km^2 in Uzbekistan and 0.21 million km^2 in Kazakhstan (Kienzler *et al.* 2012) and in some other CACs. Poplar trees are visible around some such locations in CACs. Their effective and systematic integration with agriculture crop production system to the extent it has happened in India is not visible. The Indian story provides direct lesson learning for adopting high input-high output agroforestry based growing of Poplar and some other suitable tree species to resolve many of the social, economic, forestry, agriculture and other challenges faced by many countries. Even in other locations with low input agriculture, other tree species have been effectively integrated on many farmlands for improving and sustaining the farm productivity, enhancing farmer income, improving wood production, and other benefits. Poplars, Willows, and some native farm-grown trees could be grown in a similar integrated system in CACs as well.

There is already some sensitization of the local policy formulators and planners that agroforestry in CACs can provide valuable goods and ecosystem services. The key barriers to its adoption are referred to as small field sizes and potential conflicts with neighbouring landowners due to the negative effects of trees on the yields of adjacent crops. India also faced similar challenges when the country started promoting commercial agroforestry. Connecting tree components with economic activity is the major motivating factor to adopt new crops, including long gestation trees. Once the tree growers start getting consolidated returns from tree sales, many get self-motivated to venture into this activity.

A couple of land and tree resources are apparently similar between CACs and India. Among them, the Poplar and Willow trees and the Indian Himalayan parts, especially Jammu and Kashmir (J&K), including the Ladakh region, have many similarities. CACs have a wide diversity of these tree species, which may have higher potential in wood production. The species and clones/varieties of these trees, climatic conditions, planting and management techniques, marketing and trading conditions, and wood processing infrastructure may currently not be at par with Indian ecosystem; there is no reason to believe that some of the Indian system of integrated value chain if emulated in the matching regions in CAC, it could give a quick and much needed boost to their wood based economics. We therefore identified some successful case studies based on Poplar and Willow based wood value chains from India for their possible replication in some of the CACs. A small section is also added on exploiting the biological potential of fast grown Eucalyptus in CACs as a few cold hardy species of this tree are now grown in many cold climate countries having similar climate to some of the CACs.

J&K's Union Territory (UT) is very similar to the CACs in term of geographical locations and climatic conditions. Ladakh Region, known for its cold aridity, was part of the Jammu and Kashmir state till recently. The entire region of J&K and Ladakh has many features like those of CACs which include cold arid conditions, cold winters, mountains and valleys, and some common species resources like Poplars and Willows. Poplar and Willow value chains are well developed and are very important in the Kashmir valley of J&K UT, which involves wood production, harvesting, processing and manufacturing many industrially and domestically essential products. Kashmir valley is located between 33°-35° North latitudes and 73°-76° East Longitudes. Its geographical area is 15,948 km^2 and the population is 7.5 million

people. The forest area of the valley region is 8,128 km^2, which is 10.21% of the total GA (FSI 2011). With a changed conservative perspective in the forestry sector, the wood supply chain has now shifted from government forests to agroforestry grown trees. During 1980, 80% of the wood supply was from government forests which reduced to just 3.49% during 2022. Wood demand estimate for J&K during 2022 was 3.496 million cubic feet (cft), out of which 3.249 million cft was from agroforestry grown wood, 0.092 million cft from forest and 0.099 million cft from imports.

A detailed inventory of TOFs in the J&K region was estimated by FSI (FSI 2011), which reported a total of 86.48 million trees, out of which 73.44 million were in rural and 3.04 million in urban areas. Total growing stock (GS) was 16.01 million $m^{3,}$ out of which 15.15 million m^3 was in rural areas and 0.83 million m^3 in urban areas. The report further mentioned Poplars and Willows as the top 2 TOFs in the state with 15.22 million number and 5.29 million m^3 of GS of Poplars and 10.44 million trees and 3.79 million m^3 of GS of Willows in J&K. In Kashmir valley, the TOF number was reported as 42.30 million and growing stock (GS) as 15.18 million m^3 in rural areas and 2.08 M TOF and 0.83 million m^3 GS in urban areas. These were also the 2 main trees in rural Kashmir with 14.09 million Poplar and 9.69 million Willow trees. Regarding GS, it was 4.91 million m^3 for Poplars and 3.18 million m^3 for Willows in rural Kashmir. These data sets are though old for the year 2010-11, it is believed that their number has increased over the years, as both these trees are largely grown by farmers for their sale to the constantly expanding wood base industry.

There are at least six impactful Poplar and Willow wood based activities in J&K, which are significantly contributing to the local economy, employment and trade. These are:

- J&K share is 60% of the cricket bat industry of the country and is largely dependent on valley grown Willow plantations.
- Over 90% of the Willow wicker work of the country is in the Kashmir valley and is totally dependent on the trees grown there.
- A major share of the pencil industry (80%) of the country is based on Poplar wood grown in the valley.
- Poplar wood is the main wood source in building construction in cold arid regions and its share is now significantly increasing in making house roof trusses in the valley.
- J&K is known as the fruit bowl of the country with the top 1st position in fruit production, which is largely dependent for packing cases on locally grown Poplars and Willow wood for their transport to other parts of the country
- Poplar is the main wood used by the panel industry located within the state, and a significant share of core veneer made here is also sent to the panel based industry in Punjab and Haryana.

Poplar and Willow based wood value chains in CACs and India, including those in the Kashmir valley are briefly discussed below.

8. POPLAR RESOURCES AND WOOD VALUE CHAIN

8.1. CENTRAL ASIAN COUNTRIES

Poplars have widespread distribution in Central Asia & Europe. A large number of native and introduced species are significant contributors to the Poplar resources and its diversity in CACs. Dhiman (2025b) reviewed the list of *Populus* species found in CACs which include atleast *P. deltoides, P. pyramidalis, P. bolleana*, *P. thevestina, P. densa, P. bachofenii*, *P. alba*, *P. balsamifera*, *P. laurifolia, P. vernirubens, and P. simonii,P. nigra, P. tremula* and *P. euphratica* in Kazakhstan; *P. nigra* and *P. divesrifolia* in Kyrgyzstan; *P. pruninosa, P. euphratica, P. alba, P. tadshikistanica, P. catracti, P. usbekistanica, P. talassica, P. pamirica, P. densa and P.* diversifolia in Tajikistan; *P. efrati, P. pruinosa* and *P. euphratica*in Turkmenistan; and *P. caspica* and *P. euphratica* in Uzbekistan (https://efloraofindia.com/efi/populus/). Some of the Poplar species are native in the area and many of them from erstwhile USSR were reportedly in CACs. The major forest area including that under Poplars in USSR was in the northern region whereas the current CACs are in its southern region. *P. alba* is the most common Poplar which has been reported form all the five CACs (https://efloraofindia.com/efi/populus/).

Growing introduced and native Poplars has a long tradition in some of the CACs. The tree fits well in their policy and plantation programs to produce much needed wood, generate additional income for the growers, reduce water consumption in agriculture, and build resilience against heat waves due to climate change. Besides having some native poplar species in their forests, most of its past plantations were raised using clones introduced from the Soviet Union. Currently, *P. nigra* var. *pyramidalis is* the most widely planted Poplar in agroforestry and forest land in CACs (Sarsekova 2015). It was introduced from Sotchi in 1952 (Usmanov 1971). Properties and uses of Poplars are well documented around CACs, especially in Russia and European Union (Trasev 2018). Many poplar species grown in CACs, especially aspens (*P.*

tremuloides and *P. tremula*), have better wood density and durability than *P. deltoides* grown in India. This fast grown tree offers endless opportunities in designing and manufacturing much needed new engineered products. Dedicated Poplar plantation programmes in CACs could mitigate wood shortage and expand local product manufacturing. Some poplar species have been identified for planting on specific sites. For example, *P. nigra* with narrow and pyramidal crown is recommended and being planted as avenue tree and *P. euphratica* for high saline soil sites (Nemtsova 1959).

There are reports of Poplars being planted in CACs for landscape, recreational, wood production, protective purposes, as compact plantations, windbreaks and for additional income. The tree is planted around the houses, irrigation ditches, canals, roads, along rivers, reservoirs, mine dumps etc. A small area of 22 ha is reported under poplar based natural forests and 7,854 ha under plantations on government land in Kazakhstan (Ruppert *et al.* 2020); 27,500 ha under Poplars in forest area and 6,000 ha in plantations in Tajikistan (FRA 2005); 44.5 Th. ha area with 0.27 M^3 GS in Turkmenistan (FRA 2005); and 25,300 ha forests with Poplar as the main species, 28,000 ha under intensive Poplar plantations including 4,800 ha in government (state) forests, and 10,000 ha under poplar based agroforestry in Uzbekistan (Bolman and Tolipov 2009). Not much is reported on planted poplar resources from Kyrgyzstan. Reported use of Poplars in CACs is in construction, poles, firewood, charcoal making and a few others.

8.2. INDIA

In India, poplar is one of the ideal trees for growing with agricultural crops during the retention of trees on agricultural fields. Poplar based agroforestry is currently a highly remunerative production system generating up to INR 0.2 million/acre/year net returns to growers. Around 35 million poplar saplings are currently planted annually in a small GA of northern India. Poplar wood trade has been estimated worth of INR 15,225 million in addition to many other direct and indirect benefits throughout its value chain (Dhiman *et al.* 2024a). Out of a total of 35 species under the genus *Populus*, there are 4 native species namely *P. ciliata, P. gambeli, P. jacquemontii* var. *glauca* and *P. rotundifolia*to in the Indian Himalayas. Over a dozen *Populus* species and their clones were introduced from temperate countries in the past and were tried in selected locations. In plantation forestry, *P. deltoides* is the major planted species, which has now become synonymous to Poplar culture in the country. Three other species namely, *P. nigra, P. balsemifera,* and *P. alba* have been grown in cold arid region for quite some time. *P. nigra* is grown in significant number for wood production in Ladakh region and its share in Kashmir valley is much less than *P. deltoides.*

Poplar in India is used for around 3 dozen utilities, of which the major ones include wood panels, firewood, paper pulp, sports goods, construction, ice-cream spoons and sticks, packing cases, safety matches, artificial limbs etc. At the country level, the current major use (almost 50%) of Poplar wood is in WPs, and the tree is a lifeline for manufacturing at least Plywood (PW), block board (BB), and flush doors (FD) products in the poplar growing region of north India. The wood panel (WP) industry in India, estimated at INR 300,000 to 500,000 million, largely depends on Poplar and Eucalyptus based agroforestry wood (Dhiman and Vaidya 2024). PW is the main product made from Poplar wood, which is largely used in building construction, with its share of 70% in wood panels.

Not much is reported for Poplar wood use in building construction from India, though its wood has traditionally been used in building construction in the cold arid region of the Inner Himalayas for centuries, and later has started finding increased use in the lower areas, including valleys. Poplar wood is used in round form as beams, rafters, purlins, poles, columns and billets; and sawn timber for frames and shutters of doors and windows, lintels and sills, molding and beading profiles for different shapes and designs, trusses and other items for roof structures. Recent anatomical studies of wood samples in old building structures in cold arid region have confirmed the use of Poplar wood in very old buildings (Mertz 2021, Sangita *et al.* 2020). Poplar wood was found in 67.5% of the studied samples compared to 17.1% in that of willows, 8.1% in junipers, and 7.3% in pine samples. The common belief of poor wood not being durable is negated in the cold arid region of the Himalayas where some of its elements used in buildings have been discovered to sound even after 1000 years of use. The cold and arid climate of the inner Himalayas significantly delays its wood degradation due to the absence of wood degrading agents like termites and other wood pests in that region. As a result, the shelf life of wood in use is very long, favouring extensive use of Poplar wood in building construction there. Some of its recorded wood uses in columns and carving products were not documented in the past. Even in lower areas in Kashmir valley, there is a surge in Poplar wood use in building construction for two reasons, low availability of traditional conifer species and their high costs. The current cost of Poplar wood is INR 400-500/cft compared to around INR 4000/cft for Deodar, which has been a traditional wood for

building construction in the valley (Dhiman 2025a). Growing Poplars is happening in all the CACs. Yet, it is not as extensive, organised, systematic and integrated with agroforestry and its value chain is not so well established and extensively developed as it is in India.

All the CACs are gradually expanding in their urban and semi-urban habitations. Kazakhstan had a maximum of 60.3% urbanization among the CACs, which was followed by 53.3% in Turkmenistan, 37.3% in Kyrgyzstan and Uzbekistan, and a minimum of 26.6% in Tajikistan during 2020. https://digitallibrary.un.org/record/639679?ln=en& v=pdf). The change in urbanization between 2000 and 2020 was recorded as a maximum of 8.5% in Turkmenistan, followed by 4.5% in Kazakhstan, 3.3% in Kyrgyzstan1. 4% in Uzbekistan and 0.4% in Tajikistan. The role of Poplars in landscape and roadside avenues has increased in many temperate countries. They serve a multifunctional role of production, conservation, landscaping, bioremediation, reclamation and rehabilitation in such highly populated areas. In the Indian Himalayas including Kashmir valley of J&K, *P. nigra* based avenue plantations have been raised since long. Of late, the avenue plantations have been clubbed with wood production in many locations, including some urban and semi-urban areas where commercially important *P. deltoides* is also now planted as an avenue tree. However, in such high-populated locations only male clones of *P. deltoides* are planted to avoid the spread of floss associated with female clones (Dhiman 2014).

9. WILLOW RESOURCES AND WOOD VALUE CHAIN

9.1. CENTRAL ASIAN COUNTRIES

The occurrence of some willow species is reported from some of the CACs. The occurrence of *Salix alba* is reported in Tugai forests of Kyrgyzstan (Asian Forest Forum 2022) and *S. schugnanica* in small-leaved forests at high elevations of around 3000 m amsl in Tajikistan (FAO 2008). Willows in many temperate countries are used for timber and chipwood production. Not much is reported about Willows utilities from CACs and it appears that the biological potential of these wonderful multipurpose trees and shrubs in CACs is not fully harnessed. The Indian story of Willow based value chain given below indicates its good potential for replication in some of the regions in CACs.

9.2. INDIA

There are over 300 *Salix* species worldwide (Argus 1999), out of which 24 are reported native to the Indian Himalayas (Troup 1921). Twenty-three species are reported from J&K,15 of which are from the alpine and sub-alpine zone (Dhar and Kachroo 1983). From Himachal Pradesh, 10 (Aswal and Mehrotra 1994) to 12 (Nautiyal 1991)species have been reported.The Kashmir valley of J&K is reported as the hub of Willow-based economic activity in India, where it is reported to have around 1400 km^2 area under its native and introduced species. Approximately 5 million Willow trees (16% of total broadleaf tree inventory) are reported from Kashmir valley (Masoodi *et al.* 2004).

Willow is used for a large number of utilities which include their use in willow-wicker work, sports goods especially cricket bats, construction, furniture, panel products, fuelwood, fodder, fiber, and for small-scale industries/products. The tree is also planted for soil conservation and phyto-remediation purposes. The main impactful activities around Willow include its use in manufacturing cricket bats, wicker-willow work, packing cases, and construction. There is an estimated number of 500 Willow industrial units in the Kashmir valley and 600 units in the Jammu region, which provide livelihood directly to around 0.3 million persons (https://www.dailyexcelsior.com/withering-willow-industry/).

Willow wood is a special choice for making cricket bats. *S. alba* var. *caerulea* is the most preferred species for making cricket bats, and this tree is largely grown in the Kashmir valley. There are around 195 functional units in Anantnag and Pulwama districts in Kashmir valley which make fully finished cricket bats and half-processed bats (locally called as clefts) which are supplied to 3 other cricket making clusters located in Jalandar in Punjab, Meerut in Uttar Pradesh and New Delhi (Bhat *et al.* 2017). The share of the cricket bat industry located in the valley is around 60%, with an estimated volume of INR 1000 million per annum. The export of cricket bats has been reported to be worth INR 740 million during 2014-15 and INR 620 million during 2018-19. There is a large socio-economic activity around this sector, which also generates revenue to the government in the form of 18% GST from the sale of cricket bats. The demand for cricket bats was projected as 4 million number per annum during 2020 (Masoodi *et al.* 2004)

Over 90% of the Willow-wicker work of the country is located in Kashmir valley. Willow artifacts made from it are traded throughout India and exported to some countries. Willow-wicker work is locally called as Kaeni Kaem and is undertaken in a very large geographical area in Central Kashmir Region for which its plantations are raised throughout the Kashmir valley (Except Kupwara). Maximum of its plantations are in eastern Srinagar and northern district Baramulla. The favoured willow species for

wicker Willow work are *S. triandra, S. dickymat, S. rubra, S. purpurea*, *S. viminalis*, and *S. daphnoides*. The activity involves harvesting shoots from pollarded willow trees, their segregation, bundling size-wise, boiling, peeling and drying in the sun before being used for making basketware, kitchenware and other items, including furniture. The average yield of wicker willow has been reported around 7 to 12 t/ha, depending upon species and site conditions. Willow-wicker work is reported to contribute about 35.34% to the farmer's income (Rather *et al.* 2010), including income of INR 59534.70 per year and an employment of 367 person days per year (Islam 2015).

Use of Willow in certain sections of building construction has been happening for centuries in the cold arid region of the inner Himalayas. Its use has been recorded as billets in roof structures, purlins, rafters, bracts and poles. Some of the wood samples analyzed from old buildings confirmed their use in building sections where high strength is needed. Willow has been confirmed to be used in old building structures with some of them being very old in Leh, Ladakh (Metz 2021) and Himachal Pradesh (Sangita *et al.* 2020). In the Ladakh region, out of 111 collected samples, Willow wood was used in 17.1% of the wood samples. In Spiti, Himachal Pradesh, Willow and Poplars have been recorded in some building sections of the 1000 year old Tabo Monastery. The fruit industry in J&K, including Kashmir valley, is worth INR 12500 M, employs 2.5 M people and extensively uses Willow and Poplar wood for packing cases to export fruits outside J&K (Bhat *et al.* 2017).

10. EXPLORING EUCALYPTUS TRIALS IN CACs

Eucalyptus is the top planted tree and wood producer in many countries. Ninety percent of the Eucalyptus planted forests around the world are dominated by its 9 species namely, *E. camaldulensis, E. grandis, E. tereticornis, E. globulus, E. nitens, E. urophylla, E. saligna, E. dunnii*, and *E. pellita*; and their hybrids (Stanturf *et al.* 2013). A complete Eucalyptus based wood value chain from India has been reported by Dhiman *et al.* (2023). Currently, there is around 20 M ha under Eucalyptus plantations with Brazil having over 5 M ha, China over 4 M ha and India around 4 M ha. The Eucalyptus tree is known for excellent survival, fast growth, high productivity and resilience and adaptability to different climatic conditions. Around 450 M plants are currently being planted annually in the country. The trade value of Eucalyptus produced wood has been estimated at INR 480,000 M, with direct employment of 760 M man-days in 2023 (Dhiman *et al.* 2023). Eucalyptus based AF is reported to provide net economic returns to the farmers up to INR 83,662 per acre per year, which is higher than returns from sole Eucalyptus (INR 68,085) and agriculture cropping (INR 24,740). Other direct benefits from Eucalyptus based agroforestry include improvement in soil fertility, which helps to maintain and sustain soil fertility and its production potential.

Eucalyptus species are adapted to many ecological niches and environmental conditions varying from tropical lowlands to high elevations in Pacific islands near the snow line, indicating a wide variation in cold hardiness within and among its species (Kellison *et al.* 2013). Many Eucalyptus tree species are reported to be adapted and grow in cold climates (Higa and Carvalho 1990, Swain and Gardner 2002, Arnold *et al.* 2015, Yu and Gallagher 2015). Some of them are reported to tolerate low temperatures up to a low of -23°C (https://www.angelfire.com/bc/eucalyptus/euccoldhard.html). Twenty-eight Eucalyptus species are enlisted for cold climates on a website (https://www.anbg.gov.au/gnp/cold-climate/eucalypts-cold-climates.html). Some of the successful *E. globulus* plantations were raised in the semi-arid cold region of Kinnaur District in Himachal Pradesh in the past. CACs can explore trials with suitable Eucalyptus species in some of their warm, low-lying plains and valley areas. These countries import a large quantity of some Eucalyptus based products, especially its oil, for meeting their domestic needs. Eucalyptus, if found suitable, could avert many of the forestry and land management challenges in CACs, similar to what it has helped a great deal in India and many other countries.

11. CONCLUSION

The sustainable use of land resources is essential for better economic growth, human well-being, social equality, and ecosystem services in CACs. Fast-growing trees, such as Poplars, Willows, and possibly Eucalyptus, and other species, provide numerous opportunities for wood production on both farmland and government lands. This could contribute to achieving self-reliance in meeting the country's domestic wood needs, and potentially even support export demands. The successful case studies presented here on Kashmir valley, and the wood value chain of Poplar and Willows have been transforming economic conditions of locals in India for decades and could also have a similar and immediate transformative effect in some regions in CACs. The potential scope of Eucalyptus success is based on a longer time horizon as it still involves base work on the identification of suitable species and their clones, conducting field trials at suitable sites, and connecting them with local utilities. Agroforestry based wood production will also help in the efficient use of water resources in CACs, which appears to be currently underutilized.

For example, Turkmenistan is reported to use almost three times more water than India to produce one GDP dollar (Varis 2014). While Poplar, Eucalyptus and Willow value chains in India are fully developed and widely reported, their replication in CACs may further need a better understanding of the social, economic, administrative, and vernacular ecosystem in those countries. Indian wood value chains based on Poplar and Willow trees have a high potential of being successful in CACs as these species are already reported and grown in many of them.

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