

INBAR Working Paper



National Assessment

Mobile App-Based Bamboo Resource Assessment in Punjab, Pakistan

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List of Abbreviations

C.F	Conservator of Forests
DD	Director of Division
DFO	District Forest Officer/Divisional Forest Officer
DG Khan	Dera Ghazi Khan
GT	Grand Trunk
IDRC	International Development Research Centre
INBAR	International Bamboo and Rattan Organization
MIS	Management Information System
PFI	Pakistan Forest Institute

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Preface

The International Bamboo and Rattan Organization (INBAR) and Pakistan Forest Institute (PFI) are pleased to present the on-farm mobile app-based bamboo resource assessment in Punjab, Pakistan, conducted from June 22 to October 2023. This pioneering initiative aimed at comprehensively evaluating bamboo resources in Pakistan, particularly in the Punjab province where substantial bamboo plantations are located, leveraging mobile app technology to gather accurate and real-time data. The survey was conducted in collaboration with local stakeholders and experts, with a focus on enhancing sustainable bamboo management and promoting its socio-economic benefits in the region.

The survey report provides a detailed analysis of bamboo resources in Pakistan, including distribution, species composition, physical characteristics (diameter, thickness, height, etc.), ownership status, and growth patterns. The utilization of mobile app technology yielded survey data that are not only comprehensive but also accessible in real time, providing an invaluable resource for policymakers, researchers, and industry professionals. Furthermore, the report outlines key findings and recommendations for optimizing bamboo resource management, ranging from conservation efforts to sustainable harvesting practices. However, the data were gathered in large part by individuals without expertise in bamboo or with limited knowledge of bamboo species and taxonomy. Therefore, the accuracy of the data related to bamboo species may not be accurate.

INBAR recognizes the significance of bamboo as a versatile, renewable, and economically viable natural resource. It is an ingenious solution to global challenges, such as plastic pollution, climate change, poverty, unemployment, and inequality. As such, the survey report serves as a vital tool in advocating for the sustainable development of bamboo in Pakistan, fostering environmentally friendly practices, and empowering local communities through the facilitation of bamboo-related businesses and enterprises.

The mobile app-based bamboo resource assessment survey report represents a pioneering endeavor that underscores the commitment of INBAR and its partners to promoting sustainable bamboo utilization and conservation in Pakistan. The insights and recommendations outlined in the report are poised to drive positive change, facilitate informed decision-making, and contribute to the socio-economic development of the region.

Authors

1 Introduction

Bamboo predominantly grows in tropical climates throughout the world. In Asia, bamboo holds significant ecological, social, and commercial importance (INBAR, 2021; Neto et al., 2021; Austin et al., 1983; IDRC, 1980). It is equally obvious that there exists a potential to significantly increase the production of bamboo and improve its productivity for current and alternative uses, as bamboo is seen as a relatively scarce resource (due to low productivity of natural stands) yet widely utilized in manufacturing, as a food source, and in making paper (McCormack, 1985).

There are around 1600 species of bamboo globally, and among these, three are native to Pakistan: *Arundinaria falcata*, *Bambusa bamboo*, and *Dendrocalamus strictus* (Banik, 2016; Vorontsova et al., 2016; Lobovikov et al., 2007). Of these, *A. falcata* has been recorded in the northwest Himalayas at 1200–2000 m, and *B. bamboo* has been cultivated in Punjab and Sindh, and has occasionally been found in the eastern side of the Ravi River (Ahmad, 1997; Suleman, 2005). *D. strictus* has been recorded in the Margalla Hills, Chattar, the eastern Salt Range, Shahpur, Mirpur, Ambela, Maskipur, and Bagra in Buner, up to an altitude of 800 m (Siddiqui, 1994).

A number of species were introduced to the country; some authors indicated that 13 new species were introduced from China, Bangladesh, Sri Lanka, and Thailand (Lobovikov et al., 2007), while others suggested that 25 species were brought (Siddiqui, 1994; Suleman, 2005). Although some species grew successfully, others did not adapt due to poor post-harvesting and processing procedures, leading to a fall in prices and plantations being uprooted (Rao and Ouedraogo, 1997). Some of the well-adapted species to the country's condition, especially in Punjab province, are *Dendrocalamus giganteus*, *Dendrocalamus strictus*, *Dendrocalamus hamiltonii*, *Dendrocalamus longispathus*, *Bambusa arundinacea*, *Bambusa tulda*, *Bambusa vulgaris*, and the ornamental species *Phyllostachys aurea*.

Punjab is the only province in Pakistan where substantial bamboo plantations are raised on farmland. The climatic and edaphic factors of the province in general, and the availability of substantial irrigation water in central Punjab districts favor bamboo growth and successful establishment (Tables 1–12). Instead of marginal lands, bamboo plantations have been raised on productive agricultural lands in many districts, including Kasur, Sargodha, Mandi Bahauddin, Dera Ghazi Khan (DG Khan), Chiniot, Muzaffargarh, Nankana Sahib, Gujranwala, Sheikhpura, Hafizabad, and Bahawalnagar of Punjab province. Most of these plantations range from 0.5–200 acres of land. In the Sargodha district, small farmers have also successfully established small bamboo groves of 4–10 acres area, duly supplemented by bamboo nurseries in the private sector. However, major chunks of larger areas are primarily located in Tehsil Chonia and Nizampura of the Kasur district only.

The extent of bamboo plantations is influenced by local and national market demands. *D. strictus*, *D. hamiltonii*, and *B. tulda* are the three major species grown on private farmlands (Lobovikov et al., 2005). These species are primarily used for construction purposes, with limited consumption in the paper and pulp industries. Scholars have emphasized that development based on bamboo is an effective way to improve the livelihoods of the rural poor in bamboo-growing areas. This is because they generally have adequate access to these crops, as bamboo can be grown and

harvested on forest margins or as part of an agroforestry system, requiring modest capital investment to generate farm income.

1.1 Background

Pakistan has limited natural bamboo forests. Since 1970, with active government support, bamboo plantations have steadily increased, reaching an estimated area of 9,000 ha by 1990, and about 20,000 ha by 2005 (FAO, 2010).

Since joining INBAR in 2021 as a member country, Pakistan has intensified its bamboo sectoral development to promote green economic development and to enhance ecosystem services. This includes efforts to mitigate climate change, prevent land degradation, floods, and landslides, and respond to earthquakes. Importantly, these initiatives aim to create livelihood opportunities and income for local people, particularly rural people, through bamboo product development.

1.1.1 Ecology

Bamboo is a type of grass known for its rapid growth and versatility. In Pakistan, bamboo species primarily belong to the *Bambusoideae* subfamily. They are adapted to various ecological niches, with different species thriving in different regions. Bamboo prefers tropical and subtropical climates, which are found in the central and southern parts of Pakistan.

1.1.2 Distribution and Range

Bamboo is distributed across various regions of Pakistan. Most bamboo resources in Pakistan are located in the Punjab province of the country. The specific species found in Punjab region may vary, but collectively, this region supports bamboo growth due to its suitable climate and topography.

1.1.3 Potential for Expansion

In Pakistan, bamboo has significant potential for expansion due to its versatile uses and benefits. In what follows, we discuss some factors that positively contribute to its potential for expansion.

1.1.3.1 Climatic Diversity

Pakistan has diverse climates, from tropical in the south to temperate and alpine in the north. This variety allows for the cultivation of different bamboo species across a range of conditions throughout the country.

1.1.3.2 Environmental Benefits

Bamboo plays a crucial role in controlling erosion, plugging of gullies, strengthening and reinforcing vulnerable banks of river/streams/torrential seasonal nallah, protecting watershed, and sequestrating carbon. As environmental concerns grow, the demand for bamboo in afforestation and land restoration projects may increase over time.

1.1.3.3 Soil Reclamation

Vast areas of the country have remained prone to extensive soil erosion since the devastating floods of 2010, 2013, and 2022, especially in parts of Punjab, Sindh, and Baluchistan provinces of Pakistan. Considering its rapid growth and extensive properties of colonization in a short period of time, bamboo could prove to be the most demanded perennial species for immediate reclamations of affected areas, having significant economic potentials.

1.1.3.4 Economic Opportunities

Bamboo has numerous economic uses, including construction, furniture, handicrafts, and paper production. Developing bamboo-based industries could create jobs and stimulate economic growth in rural areas of Pakistan, with relatively limited upfront investment.

1.1.3.5 Sustainability of the Resource

Bamboo is known for its rapid growth both vertically and horizontally, besides producing substantive biomass, making it a sustainable source of income for local farmers. It can be harvested without causing long-term harm to the environment, and the area can be quickly recuperated within a limited time duration from an existing rhizome network.

1.1.3.6 Export Potential

Pakistan could grow into the international market for bamboo products, given its proximity to major markets in Asia, Europe, and the Middle East.

1.1.4 Challenges

There are imminent challenges to bamboo expansion in Pakistan, including limited awareness, infrastructure constraints, and the need for proper management and regulatory frameworks. Addressing these challenges and promoting bamboo cultivation and utilization can unlock its full potential for ecological and economic benefits in the country.

1.2 Scope of the Task of the Pakistan Forest Institute, Peshawar

To promote bamboo sectoral development, understanding the status and extent of bamboo resources alongside their current bamboo value chains is crucial for achieving the sustainable management of bamboo forests and capitalizing on their proper potential. Moreover, each bamboo species has unique properties that make it suitable for different areas of the country, enabling the production of various products and the provision of untamed ecosystem services. The present intervention aims to assess existing bamboo resources for future development and analyze bamboo value chains to develop a national bamboo conservation strategy and an action plan for Pakistan.

1.3 Potential areas of Punjab Province with Bamboo Plantations

Punjab is indeed the largest province in Pakistan, accommodating at least 60% of the population. Among the 42 districts of Punjab, only 10–13 districts have extensive to scarce bamboo plantations (Figure 1) spread throughout the district, as listed below.

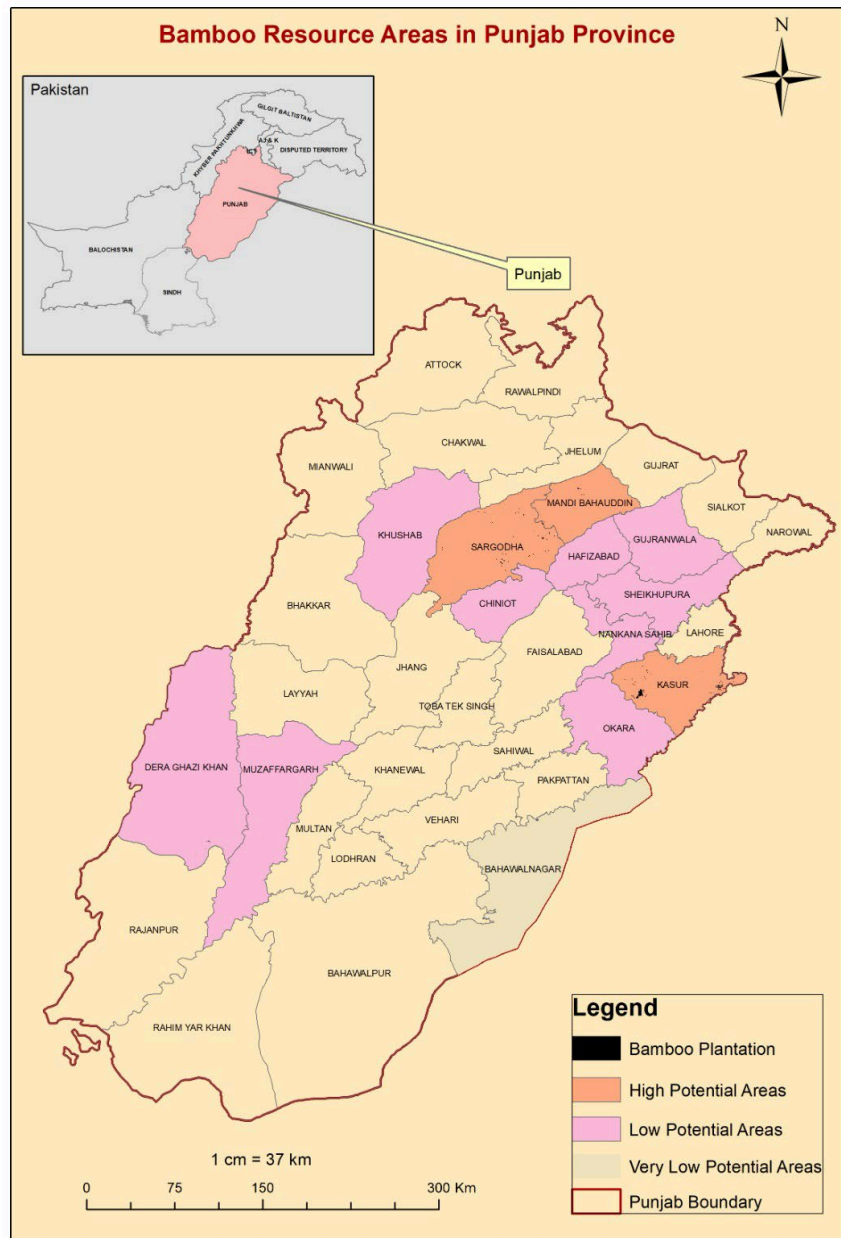


Figure 1. Status and potential distributions of bamboo plantations in the districts of Punjab province, Pakistan

1.3.1 Profile of Districts with Bamboo Plantations

Here, we provide a brief account of the relevant districts.

1.3.1.1 Kasur District

Located in the mixed cropping zone of Punjab, Kasur is surrounded by Lahore in the north, Okara in the south, and Nankana Sahib in the northwest, with an international border between Pakistan and India to the east and southeast. The climate of the district comprises hot summers and cold

winters. The main crops grown in this district include wheat, rice, maize, cotton, sugarcane, and vegetables.

1.3.1.2 Sargodha District

Located in northern Punjab, Sargodha mainly consists of flat and fertile plains lying between the river Jhelum on the west and north and the Chenab River to the east. The climate of the district comprises hot and dry summers and moderately cold winters. During summer, the maximum temperature can reach up to 50°C (122°F), while in winter, the minimum temperature can drop to the freezing point. Summers typically last from April to September, with intense heat becoming intolerable. Winter usually lasts from the end of October to the middle of March and is generally pleasant. The Sargodha region experiences annual rainfall of 250–759 mm. The highest precipitation months are July and August, when the monsoon reaches Punjab. September to December are relatively dry months, with low average rainfall. January to May are the driest months, with minimal precipitation. On average, Sargodha receives about 0.86 inches (21.87 millimeters) of precipitation yearly, with approximately 46.78 rainy days (12.82% of the time) annually (Urban, 2022). The district represents a mixed cropping zone in Punjab and is mainly famous for citrus exports. The main crops grown in Sargodha include wheat, rice, maize, and sugarcane.

1.3.1.3 Mandi Bahauddin District

The Mandi Bahauddin district is bordered on the northwest by the Jhelum River, on the southeast by the Chenab River, and on the southwest by the Sargodha district. The region experiences hot and dry weather during the summer and cold weather during the winter. Wheat, rice, sugarcane, vegetables, and fodder are the main crops of the area.

1.3.1.4 Dera Ghazi Khan District

Located in the foothills of the Suleman Mountain Range, the climate of the DG Khan district is hot and dry during the summer and moderately cold in the winter. Occasional heavy rain causes flooding in the region. Hill torrent irrigation is practiced in the western part of the district. It also includes a hill station called Fort Munro, located at a height of 1,972 meters above sea level.

1.3.1.5 Chiniot District

Chiniot is positioned between the heart of the Chenab River and the heads of small rocky hills. The climate of the district is characterized by hot summers and cold winters. The land is fertile and suitable for producing crops such as wheat, rice, sugarcane, vegetables, and fruits. Traditionally, wooden furniture from Chiniot is widely known and exported worldwide.

1.3.1.6 Sheikhpura District

Famous for its industrial and agricultural surroundings, the Sheikhpura district is known for producing the best export quality rice. The climate is hot and dry during summer and moderately cold during winter. The main crops in the district include rice, wheat, sugarcane, and a variety of vegetables.

1.3.1.7 Muzaffargarh District

The Mughal governor of Multan, Nawab Muzaffar Khan, founded the Muzaffargarh district in 1794. The district lies between the Indus River in the west and the Chenab River in the east. Hot and dry weather prevails in the summer and cold weather prevails in the winter. The main crops grown in the district are cotton, wheat, sugarcane, and fruit orchards (mainly mangoes and citrus fruits). The land close to the Chenab River is usually flooded during the monsoon season.

1.3.1.8 Nankana Sahib District

Formerly a tehsil of Sheikhpura district, Nankana Sahib was raised to the status of a district in May 2005. The climate of the district comprises hot summers and cold winters. The main crops grown in the area are wheat, rice, maize, sugarcane, and vegetables. Nankana Sahib is famous for being the birthplace of Baba Guru Nanak, the founder and first guru of Sikhism.

1.3.1.9 Hafizabad District

Hafizabad is situated in central Punjab and is renowned for its high-quality rice production. The district experiences hot and dry weather during the summer and moderately cold weather in the winter. Due to the proximity of the hills, there is more rainfall in the eastern parts of the district than in the western parts.

1.3.1.10 Gujranwala District

The Gujranwala district lies on the main Grand Trunk (GT) Road built by emperor Sher Shah Suri in the 16th Century. The climate of the district comprises hot summers and cold winters. The main crops include wheat, rice, sugarcane, vegetables, and fodder. The district has several industrial and commercial centers for the manufacturing of ceramics, metal tools, utensils, fans, leather, textiles, etc.

1.3.1.11 Bahawalnagar District

Situated in the southeast of Punjab, most of the land in Bahawalnagar is dedicated to agriculture, with some desert areas, such as Cholistan. The climate of the district is characterized as a hot desert, with hot summers and mild winters. The majority of the precipitation falls during the monsoon season from June to August, although some of the precipitation also occurs from February to April. The main crops in the area are wheat, rice, and cotton.

1.3.1.12 Okara District

The Okara district is renowned for its fertile land, livestock, and tranquil natural environment. It is bounded by the Ravi River in the northwest and the Sutlej River in the southeast. The climate is hot in the summer and moderately cold in the winter. The district represents Punjab's well-defined mixed cropping belt.

1.3.1.13 Khushab District

The Khushab district is bounded in the north by the Salt Range and in the east by the Jhelum River. The climate is extreme, with long hot summers and cold dry winters. The district has diverse landscape features that vary from mountains and deserts to lush, green lands. Soon Sakaesar Valley, one of the beautiful hill stations of Pakistan, lies in the Khushab district. The district is abundant in natural resources, such as salt and coal.

1.3.2 Optimal Soil Conditions for Bamboo Growth in Punjab Districts

To reveal the basic potentials of bamboo plantations. in the listed districts of Punjab, the soil parameters were analyzed based on the report “Soil Fertility Atlas of Pakistan: The Punjab Province” (FAO, 2017). Considering various soil attributes and cropping patterns, relevant details of each district with bamboo plantations are tabulated in Table 1 for easy reference.

Table 1. Soil profile of districts of Punjab province with bamboo plantations

S. No.	District	Total area (Hectares/000)			Major crops		Soil Attributes						
		Sown	Uncultivated	Irrigated	Rabi	Kharif	Parent material	Dominant soil series	pH	Electrical Conductivity (dS/m)	Organic matter (%)	Available phosphorus (PPM)	Extractable Potassium (PPM)
1.	Kasur	521	79	520	Wheat	Rice, Maize & Sugarcane	Mixed calcareous, alluvium	Bhalwal, Sultanpur	8.14	0.76	0.79	8.02	150
2.	Sargodha	706	119	706	Wheat	Maize, Rice, Sugarcane	Mixed calcareous/ Sand dunes	Yazman, Lyallpur	8.34	0.84	0.61	5.89	157
3.	Mandi Bahaudin	355	46	352	Wheat	Rice, sugarcane	Mixed calcareous, alluvium	Lyallpur, Shahdara	8.27	1.18	0.71	6.26	153
4.	Dera Ghazi Khan	356	225	324	Wheat	Cotton, Rice & Sugarcane	Mixed calcareous, alluvium	Shahdara, Kashmir	8.31	0.92	0.54	5.20	172
5.	Chiniot	306	64	306	Wheat	Rice, Maize, Sugarcane	Mainly loamy and clayey	Kasur, Shahpur	8.06	0.43	0.61	6.40	141
6.	Sheikhupura	517	53	517	Wheat	Rice, Sugarcane	Mixed calcareous alluvium	Lyallpur, Bhalwal	8.28	0.53	0.72	6.34	163
7.	Muzaffargarh	680	404	659	Wheat	Cotton, Sugarcane	Mixed calcareous, alluvium	Shahdara, Sultanpur	7.91	0.37	0.76	4.89	148
8.	Nankana Sahib	313	39	313	Wheat	Rice, Maize & Sugarcane	Mainly loamy and clayey	Pindorian, Wazirabad	8.32	0.43	0.57	6.07	148
9.	Hafizabad	348	46	347	Wheat	Rice & Sugarcane	Mainly loamy and clayey alluvium	Pindorian, Rasulpur	8.34	0.54	0.58	7.23	149

10.	Gujranwala	551	52	548	Wheat	Rice & Sugarcane	Mixed calcareous, alluvium	Lyallpur, Gujranwala	8.12	0.28	0.55	5.85	156
11.	Bahawalnagar	818	102	803	Wheat	Cotton, rice	Mixed calcareous, alluvium & Sand dunes	Lyallpur, Sultanpur	8.34	0.84	0.61	5.89	157
12.	Okara	633	91	633	Wheat	Maize, Potato, Sugarcane	Mixed calcareous, alluvium	Shahdara Lyallpur	8.15	0.42	0.92	5.33	137
13.	Khushab	430	186	144	Wheat	Coarse grain, Rice	Rolling Sandy Plain, Mixed alluvium of rivers	Bhakhar, Lyallpur	8.06	0.54	0.85	4.86	154

(Source: FAO, 2017)

2 Methodology

2.1 Approach and Method of Resource Assessment (App, Field Methods, Data Recording/Analysis, etc.)

A well-conducted bamboo resource assessment can yield valuable insights into the bamboo ecosystem, facilitating informed decision-making, sustainable resource management, and the advancement of bamboo-based industries and conservation efforts.

2.2 Approach and Identification of Survey Areas

2.2.1 Literature Review

We searched the existing literature to determine bamboo species, distribution, and ecological requirements, indicating bamboo's potential presence in central Punjab, particularly Sargodha, Kasur, and Mandi Bahauddin.

2.2.2 Trader Links

Based on the data collected from the local bamboo-based markets and information shared by officers of the Punjab Forest Department, potential districts with bamboo plantations were initially selected for bamboo resource assessment in Punjab. These areas mainly include the following districts: Kasur, Sargodha, Mandi Bahauddin, DG Khan, Chiniot, Muzaffargarh, Sheikhpura, Nankana Sahib, Hafizabad, Gujranwala, and Bahawalnagar. Local staff of the Forest Department or leads from plantation owners helped confirm specific areas with bamboo plantations.

2.2.3 Use of Remote Sensing and Geographic Information System

Following the initial data collection from areas with potential bamboo plantations, the survey teams utilized remote sensing and geographic information system technology to extract and map bamboo plantations in various districts. This helped the teams in objectively determining the actual position on the ground, while also providing useful guidance to reach potential areas using their Android phones.

2.2.4 Field Surveys

Once the bamboo status and distribution were confirmed, mobile app-based field surveys were carried out from June to October 2023 to gather primary data regarding the extent of plantations, species compositions, density and health, types of supporting soil, owners, primary bamboo uses, etc. These data were collected using the INBAR mobile app for direct uploading to the relevant database.

2.3 Bamboo Resource Inventory

During the comprehensive inventory of bamboo resources, data, including location, species, age, density, growth rates, etc., were collected in the field. Additional data on the following aspects were gathered for analysis and for future progressions in the field.

2.3.1 Climate and Soil Analysis

Further, climate data were gathered to assess the suitability of different regions for bamboo cultivation, including identifying areas with optimal temperature, rainfall, and soil conditions for bamboo growth.

2.3.2 Social and Economic Assessment

Apart from ecological data on bamboo, information on socio-economic aspects related to bamboo, including its utilization by local communities, potential markets, and economic opportunities, was also explored and recorded on-site.

2.3.3 Bamboo Growth Modeling

To help sustainable harvesting and resource management, bamboo biomass, potential yield, and growth models were also estimated.

2.3.4 Bamboo Utilization Potential

To assess the demand for bamboo products, the potential uses of bamboo in the region, such as construction, handicrafts, furniture, paper production, and more, were also evaluated.

2.4 Community Engagement

While conducting field surveys, local communities and stakeholders were duly involved in the assessment process to give them a sense of ownership of the process, gather insight regarding bamboo development, build awareness, and ensure sustainable management practices.

2.5 Capacity Building

The local communities and relevant authorities were trained in bamboo cultivation and management techniques to promote sustainable practices in the field.

2.6 Report and Recommendations

The collected data were compiled, analyzed, and findings deduced, paving the way for the preparation of a comprehensive report that may be used for sustainable bamboo resource management, conservation, and other utilizations.

2.7 Strategy and Work Plan for Coordinating Bamboo Resource Assessment in Punjab Province

The Pakistan Forest Institute (PFI) was initially tasked with coordinating and conducting bamboo resource inventory in Punjab province. Twelve experts from the Punjab Forest Department were intensively trained to conduct data collection, monitoring, and information recording using the mobile app installed on their Android mobile phones. However, a number of challenges arose in the data collection. For example, the motivation to plant bamboos on private farmland is primarily a market-driven entrepreneurship of progressive farmers having considerable land holdings in specific areas of the Punjab province. However, the Punjab Forest Department or the Agricultural Department do not play a significant role in managing, processing, or marketing bamboo plantations grown on private lands. Hence, there was a challenge involving the Punjab Forest Department in resource assessment due to conflicting priorities between conducting the bamboo inventory and its official duties, which, in most cases, was out of its mandate. We observed that the initial stage of the bamboo resource assessment alongside the training ran on a slow pace, covering only 177 hectares (Appendix I) in Sargodha district during June 23–26, 2023, and an additional 700 hectares assessed between July 2 and August 10, 2023, in Sargodha and other locations, despite data being collected by well-trained local staff of the Punjab Forest Department.





Figure 2. a–d. Initial strategy and work plan for coordinating bamboo resource assessment in Punjab province involved 12 experts from the Punjab Forest Department who received proper training during the Peshawar session.

2.8 Revised Strategy and Work Plan for Coordinating Bamboo Resource Assessment in Punjab Province

In response to the slow pace of resource assessment in Punjab and the need to complete the task within the stipulated time, a revised strategy emphasizing coordination, collaboration, facilitation, supervision, and monitoring was developed and implemented. The revised strategy and work plan for coordinating the bamboo resource assessment in Punjab province focused on accelerating the assessment with active engagement with stakeholders, and seeking support from relevant authorities. Efforts were made to secure the support of the Ministry of Climate Change & Environmental Coordination, enlist the support of district administration, capitalize on personal links, and increasingly involve the PFI staff. Support was also sought from the project director of the Ten Billion Tree Tsunami Afforestation Project, who utilized his official connections to collect relevant data from the bamboo assessment from various concerned parties. Despite facing challenges and limited results due to local persuasion, the strategy worked effectively in expanding the assessment to additional areas in the province, with considerable progress achieved. The coordination, training, and deployment of PFI team members, along with collaboration with the Punjab Forest Department and other authorities, significantly contributed to the successful uploading of additional areas with bamboo plantations for assessment purposes. Throughout the process, a detailed schedule was established to guide the survey teams in their area-specific assessments, with continual exploration of potential bamboo plantation areas in the province.

The adopted strategy worked very well during the first phase and helped in uploading data on at least 2,500 hectares of additional areas with bamboo plantations in selected districts, such as Kasur, Chiniot, Gujrat, Mandi Bahaudin, etc. During the second, third, and fourth phases, data on at least 5,000 hectares (Annex II) of additional areas with bamboo plantations in the selected districts, such as D.G. Khan, Bahawalnagar, Muzaffargarh, Nankana Sahib, Sheikhpura,

Hafizabad, Gujranwala, etc., were uploaded to the INBAR database. Further efforts were made to explore and expand the survey team to survey as many areas of bamboo plantations as possible in the potential areas of the Punjab province of Pakistan to cover more areas in the shortest possible time span.



Figure 3. a–f. Revised strategy and work plan for coordinating bamboo resource assessment in the province.

3 Results

3.1 Distribution of Bamboo by Province and District in Pakistan

Contrary to the literature previously published on the subject and the limited reports available, the actual field survey has established that the Punjab province of Pakistan is the main hub of bamboo plantations, mainly located in its 10–13 districts of the central and southern Punjab, as highlighted in Table 2.

Table 2. Estimated and actual bamboo resources in the districts of Punjab, Pakistan

S. No.	Province	District	Total area			Remarks
			District (in km ²)	Estimated plantations (in ha)	Actually surveyed (in ha)	
1.	Punjab	Kasur	3,995	4,218	3,796	Farm plantation
		Sargodha	5,856	2,361	2,125	Farm plantation
		Mandi Bahauddin	2,673	327	294	Farm plantation
		DG Khan	11,922	202	182	Farm plantation
		Nankana Sahib	2,960	56	50	Farm plantation
		Chiniot	2,643	50	45	Farm plantation
		Gujranwala	3,622	33	30	Farm plantation
		Muzaffargarh	8,249	29	26	Farm plantation
		Sheikhupura	5,960	28	25	Farm plantation
		Hafizabad	2,367	24	22	Farm plantation
		Bahawalnagar	8,878	2	2	Farm plantation
		Faisalabad	5,857	0	0.17	Punjab Forestry Research Institute, research plots
2.	Khyber Pakhtunkhwa	Peshawar	1,257	0	0.61	PFI, research plots
3.	Sindh	Hyderabad	5,519	0	1.55	Limited resources in patches.
4.	Balochistan	Nasirabad	3,387	0	2.01	

5.	Gilgit Baltistan	Diامر	10,936	0	0	Not reported
6.	Azad Jammu & Kashmir	Mirpur	1,010	0	0	Not reported
		Bhimber	1,516	0	0	
		Kotli	1,862	0	0	

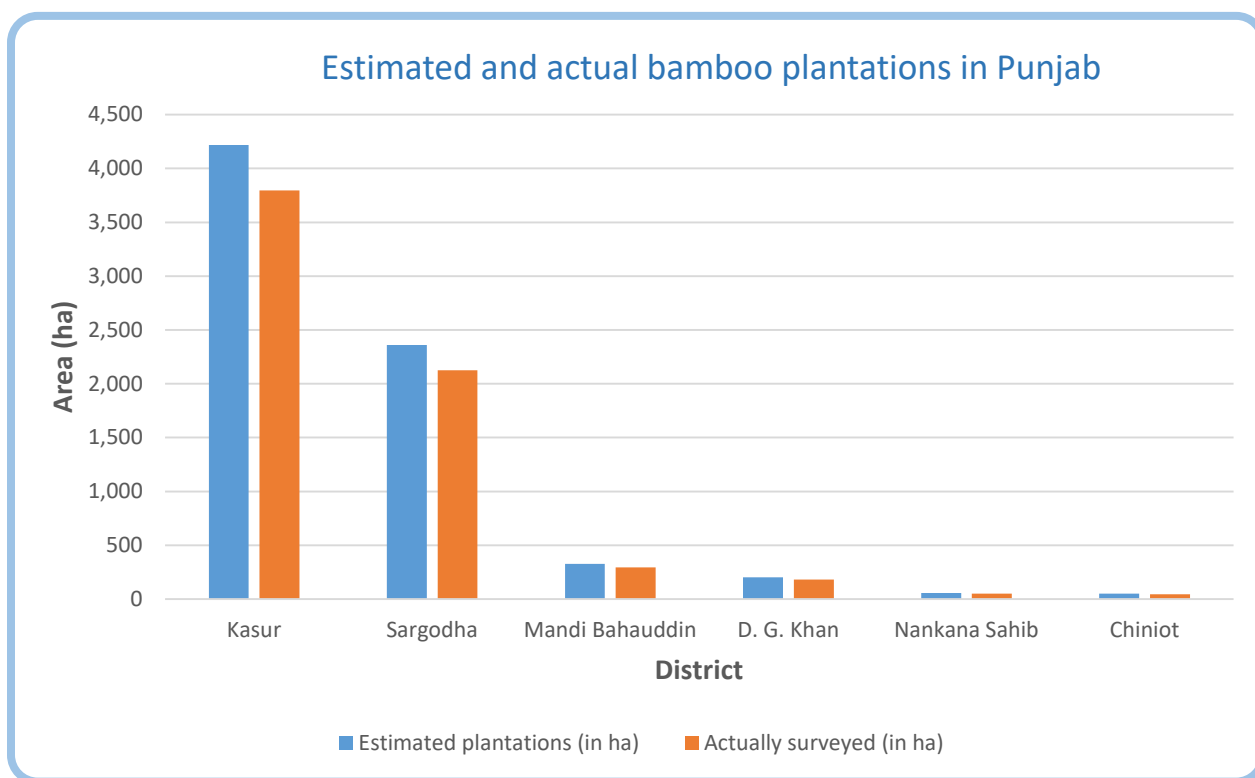


Figure 4. Estimated and actual bamboo plantations in Punjab

3.2 Observed Discrepancies in the App's MIS and Factual Field on the ground

The bamboo survey app's management information system (MIS) lacks updates reflecting newly created districts, such as Mandibahauddin, Hafizabad, and Nankana carved out from larger districts of Gujrat, Gujranwala, and Sheikhpura, respectively. The new districts are missing from the MIS, causing a gap in the data.

Table 3 provides a comparative overview of the previous and current districts in Punjab, Pakistan. This reference aids in preventing confusion in future activities and facilitates updating the MIS of INBAR's bamboo survey app.

Table 3. Areas falling in previous and current districts of Punjab, Pakistan

S. No.	District	Commune (includes)	Area in ha
1.	Sargodha	Sargodha	2,176
2.	Lahore	Kasur, Sheikhpura, Okara, Lahore	3,797
3.	Gujranwala	Gujranwala, Hafizabad (Mandibahauddin is missing in the app)	337
4.	DG Khan	DG Khan and Muzaffargarh	207
5.	Faisalabad	Faisalabad (No Chiniot)	44
6.	Bahawalnagar	Bahawalnagar	2
Total			6,563

During a 72-day field survey in 13 potential districts of Punjab, PFI staff and Punjab Forest Department personnel visited 827 bamboo plantation sites for collection of relevant data. The survey resulted in the documentation and upload of 6,600 hectares of bamboo plantations in the form of 720 polygons, 1,700 hectares as 52 polylines, and 300 hectares as 55 points. Detailed information is provided in Tables 1–3, Figure 1, and Appendix II.

In the Kasur district, bamboo plantations are predominantly situated in the southeastern and northwestern parts of the district, as indicated in Figure 5. It is noteworthy that the INBAR mobile app currently does not recognize Kasur as a separate district, as it was previously part of the Lahore district. This discrepancy may require an update of the mobile application to reflect current ground realities.

Similarly, in the Sargodha district, most bamboo plantations are located in the southern, eastern, northern, and central parts of the district, as depicted in Figure 6.

In the Mandi Bahauddin district (Gujrat), bamboo plantations are primarily situated in the northern-central and northern-western parts of the district, as shown in Figure 7. Again, the INBAR mobile app does not currently recognize Mandi Bahauddin as an independent district, as it was previously part of the Gujrat district. This discrepancy may require updating the app to reflect actual ground realities.

In the case of DG Khan, bamboo plantations are limited to a particular area in the southern part of the district, which is predominantly owned by a single family and local property owners. This distribution is illustrated in Figure 8.

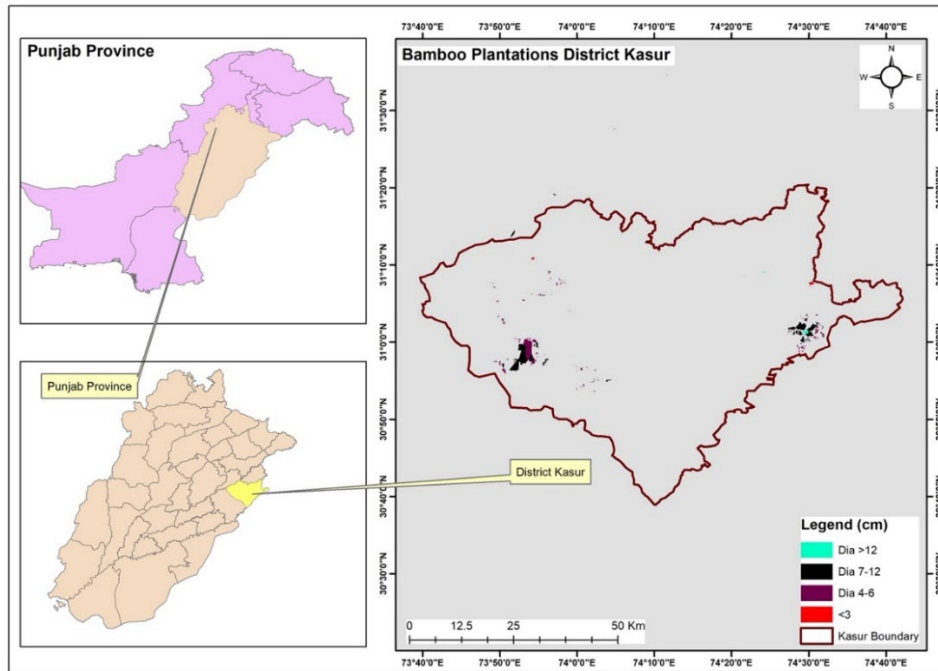


Figure 5. Status and distribution of bamboo plantations in Kasur district, Punjab, Pakistan

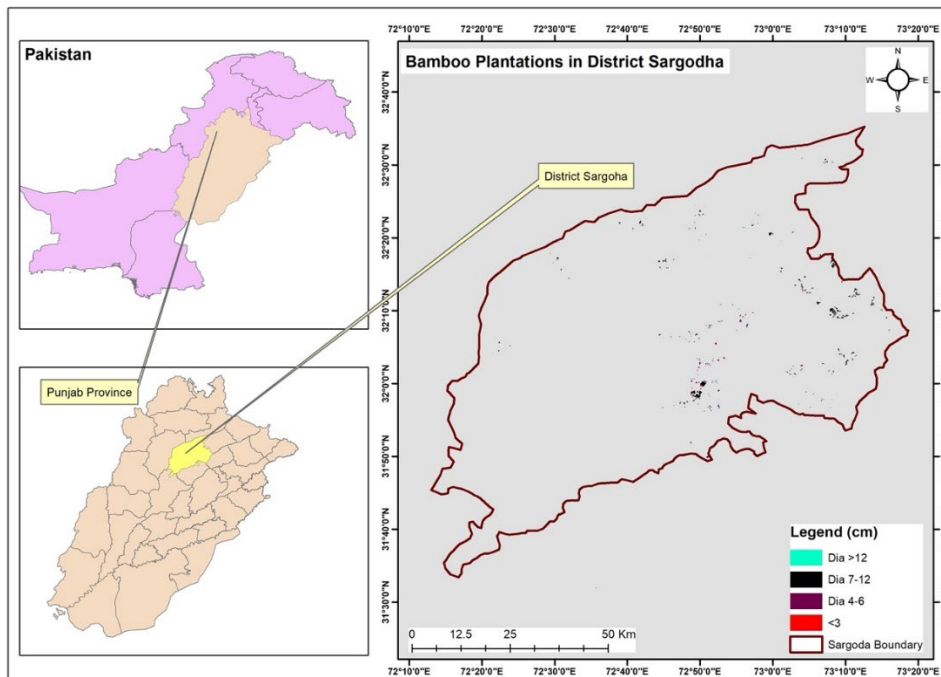


Figure 6. Status and distribution of bamboo plantations in the Sargodha district, Punjab, Pakistan

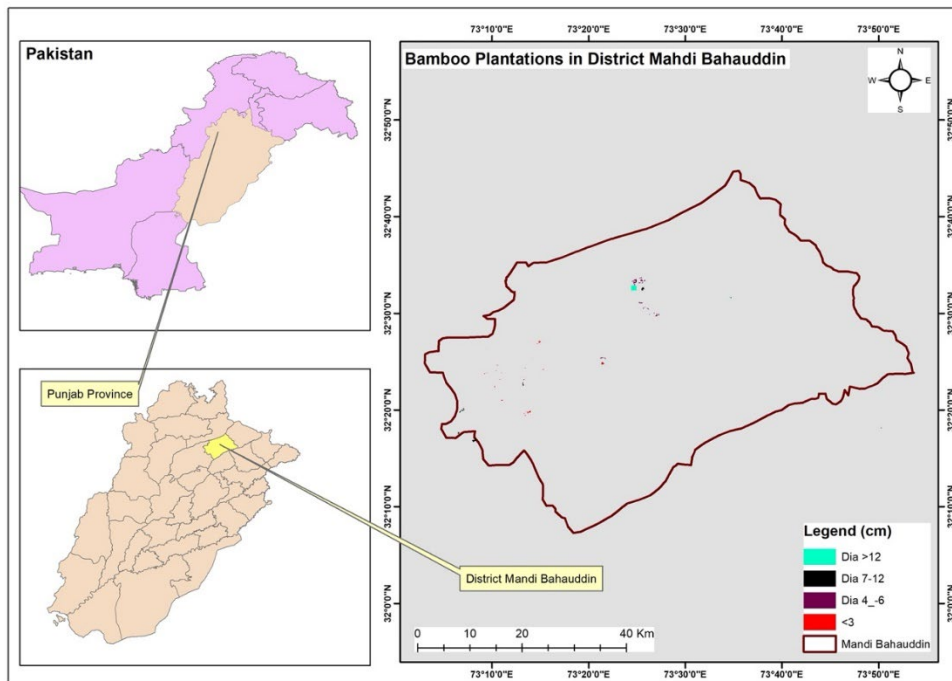


Figure 7. Status and distribution of bamboo plantations in the Mandi Bahauddin district, Punjab, Pakistan

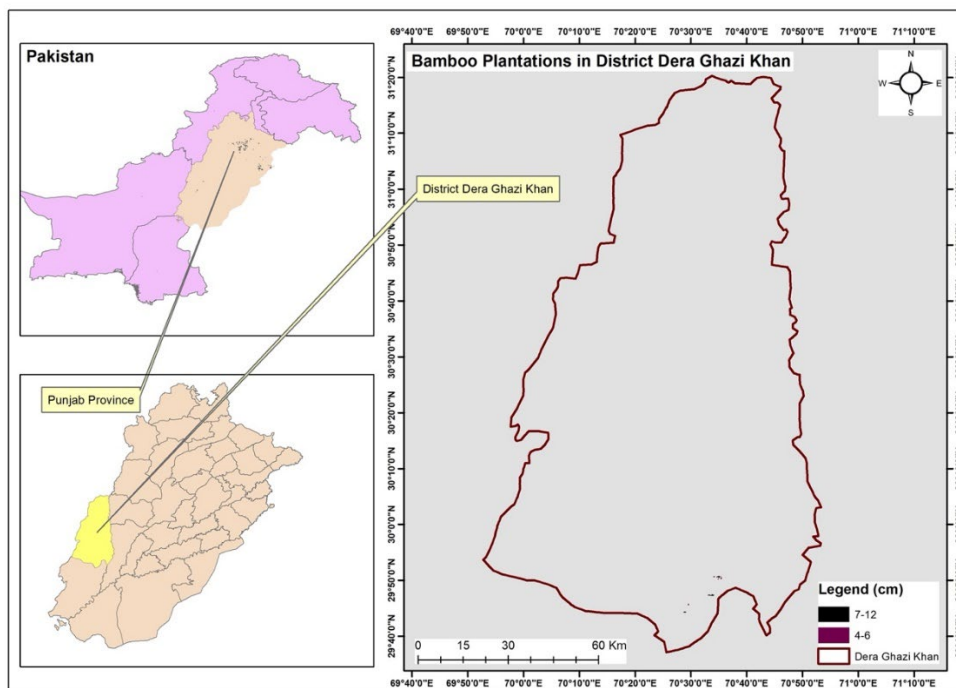


Figure 8. Status and distribution of bamboo plantations in the Dera Ghazi Khan district, Punjab, Pakistan

3.3 Distribution of Bamboo Plantations Based on Diameter and Height

1. The data collected from the field on at least 720 polygons were plotted against diameter classes, as shown in Figure 9.
 - i. The figure shows that the bamboo plantations in the area more or less present the traits of a normal curve rather skewed towards one side, which is a good sign of sustainability in terms of their production and usage.
 - ii. The figure also shows that generally, more than 400 polygons fall within the diameter class of 7–9 cm, which is in accordance with the average pole diameter observed and recorded in the field, representing premature or nearly mature crops.
 - iii. Around 60–70 polygons fall within the diameter class of ≤ 3 cm, signifying either new plantations or fresh regeneration of the plantations exploited in the near past. Further, more than 180 polygons fall within a diameter class of 4–6 cm, representing plantations of more than one year and less than two years.
 - iv. Around 50–60 polygons fall within the diameter class of 10–12 cm, representing nearly mature crops or freshly planted areas approaching 3–4 years.
 - v. A smaller number of polygons fall within the diameter class of 13–15 cm, and 16 cm or more are areas either ready for harvesting or most of the plantations have already been harvested, as physically observed during the field survey.

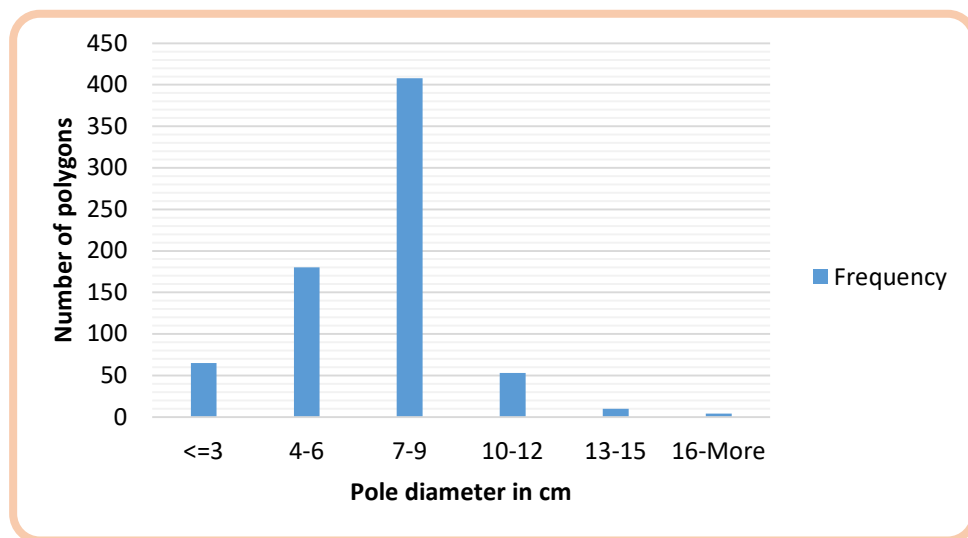


Figure 9. Frequency distribution of polygons based on diameter classes in Punjab, Pakistan

2. The data collected during the field survey in the potential districts of Punjab, Pakistan, were plotted against height classes. The frequency distribution of the polygons based on height classes is shown in Figure 10.
 - i. As illustrated in Figure 10, the bamboo plantations in the area more or less present the traits of a normal curve rather skewed towards one side, which is a good sign of sustainability in terms of their production and usage.
 - ii. The figure demonstrates the following height class distribution shows that generally, more than 460 polygons fall within the height class of 12–17 m, which

is consistent with the average pole height observed in the field, representing premature or nearly mature crops.

- iii. Approximately 50–60 polygons fall within the height class of ≤ 5 m, indicating new plantations or fresh regeneration of the plantations exploited in the recent past. Besides, more than 130 polygons fall within the height class of 6–11 m, representing plantations of more than one year and less than two years.
- iv. Around 40–50 polygons fall within the height class of 18–20 m, depicting nearly mature crops or fresh plantations reaching 3–4 years.
- v. A smaller number of polygons fall within the height class of ≥ 21 m, indicating areas either ready for harvesting or where most of the plantations have already been harvested, as was physically observed during the field survey.

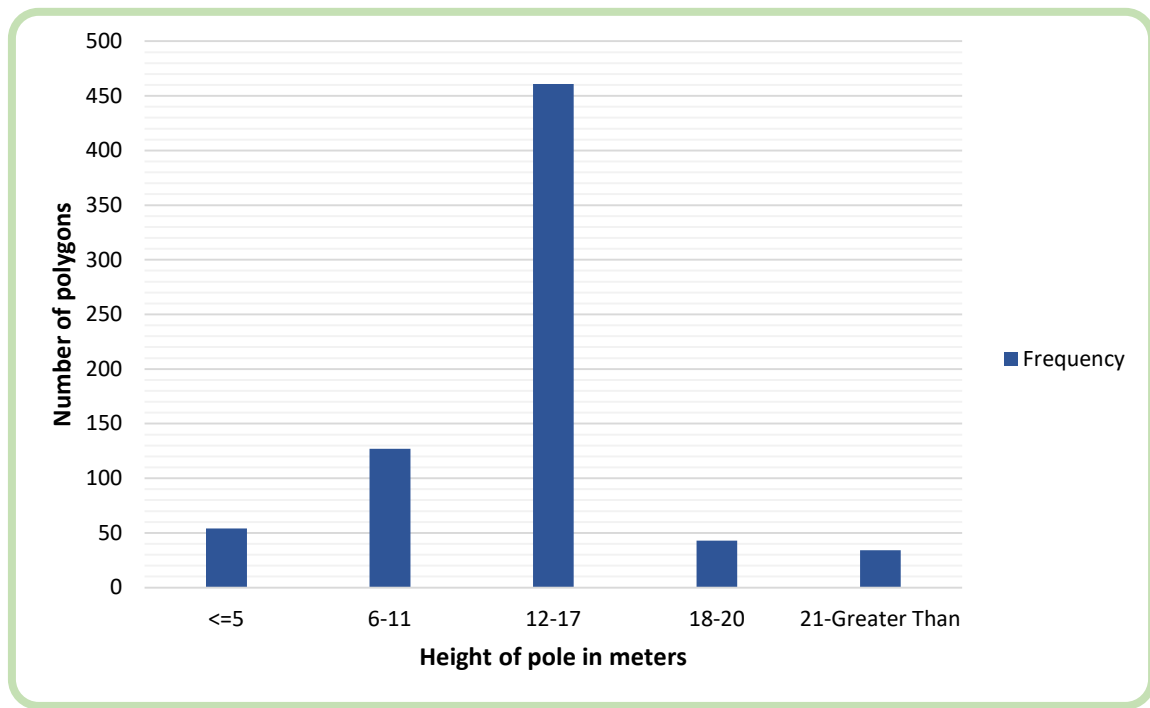


Figure 10. Frequency distribution of bamboo polygons based on height in Punjab, Pakistan

Based on Figures 9 and 10, the available data were merged into a single entity for better comprehension and presented as Figure 11.

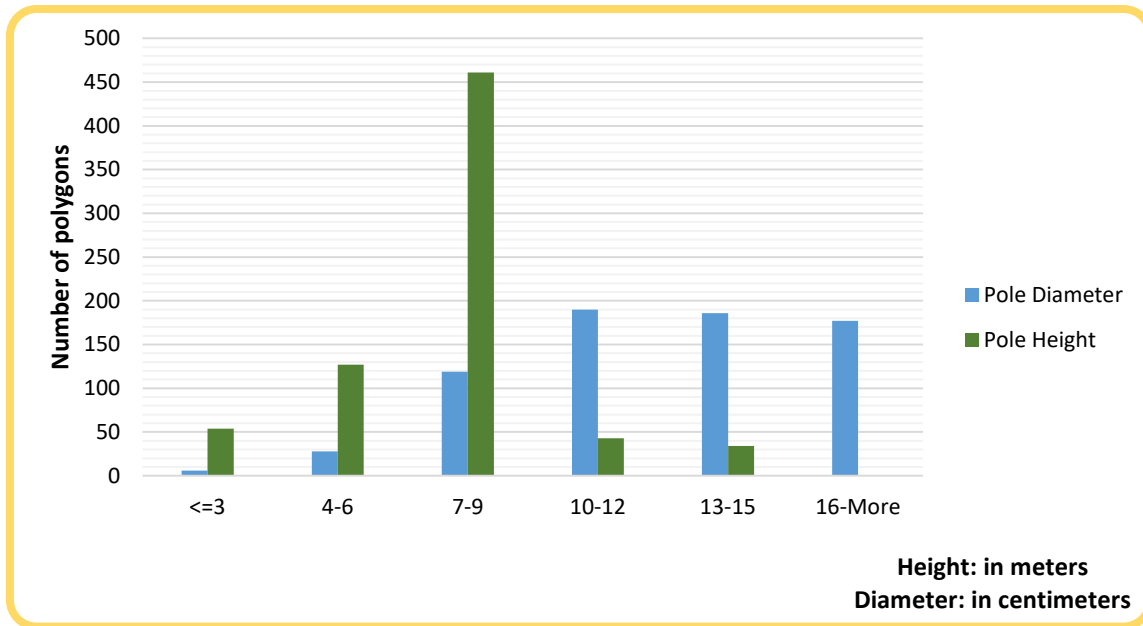


Figure 11. Frequency distribution of bamboo plantations in Punjab based on diameter and height

In Punjab, bamboo plantations are available in at least 12 districts, but substantial plantations are only available in the Kasur, Sargodha, Mandi Bahauddin, and DG Khan districts. Figure 12 is a graphical representation of these plantations in terms of polygons and their corresponding diameter classes. Obviously, the Kasur district is leading in the number of plantations, followed by Sargodha, Mandi Bahauddin, and DG Khan districts.

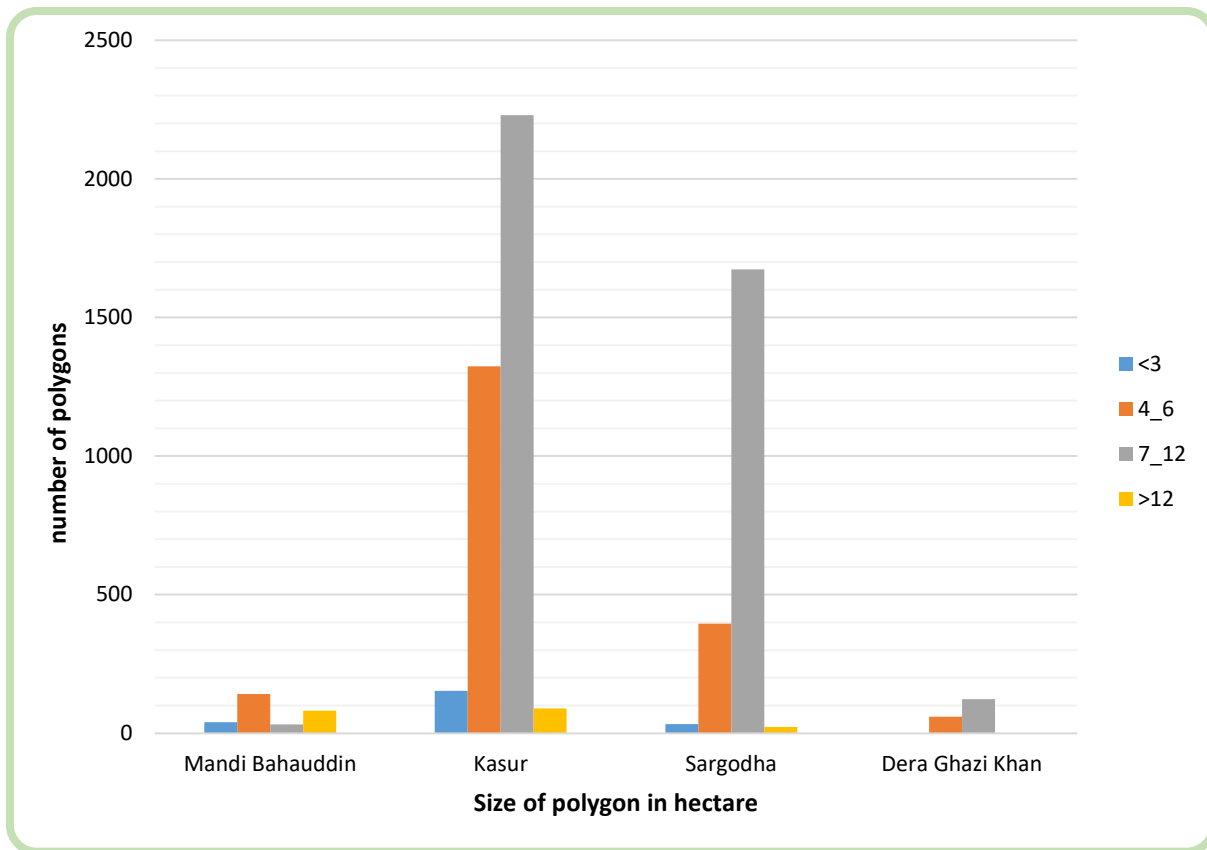


Figure 12. Frequency distribution of polygons based on diameter class in potential districts of Punjab, Pakistan

3.4 Species Composition and Area Coverage by Various Bamboo Species in Pakistan

The districts of Punjab province where bamboo is established in agricultural lands are Sargodha, Jhang, Kasur, Lahore, Khushab, Ganda Singh, Bhalwal, Mandi Bahauddin, and DG Khan (Karim Alm-Ns, 2016; Lobovikov et al., 2007; Suleman, 2005), and the major species cultivated on private farmland are *D. strictus*, *B. tulda*, and *D. hamiltonii* (Lobovikov et al., 2007; Suleman, 2005).

Whatever species were introduced earlier, at the time of the survey, at least 13 species were observed and recorded in various potential districts of Punjab. However, out of them, only 5 species have substantial representation in the prevailing plantations of Kasur district, Sargodha, Mandi Bahauddin, and DG Khan. Nevertheless, the area coverage of *D. strictus* is more than 33%, *D. giganteus* is around 30%, *D. hamiltonii* is around 25%, *B. arundinacea* is around 9%, *B. vulgaris* is 3%, and the rest of the species are to the tune of less than 1% in Punjab province of Pakistan (Table 4 and Figure 13).

Table 4. Cover percentage of various bamboo species in Pakistan

S. No.	Species	Area in hectare	Coverage %
1.	<i>Dendrocalamus strictus</i>	2,147	33.018
2.	<i>Dendrocalamus giganteus</i>	1,943	29.875
3.	<i>Dendrocalamus hamiltonii</i>	1,612	24.787
4.	<i>Bambusa arundinacea</i>	582	8.945
5.	<i>Bambusa vulgaris</i>	168	2.580
6.	<i>Dendrocalamus longispathus</i>	25	0.385
7.	<i>Dendrocalamus latiflorus</i>	11	0.169
8.	<i>Dendrocalamus membranaceus</i>	10	0.154
9.	<i>Bambusa brandisii</i>	3	0.050
10.	<i>Dendrocalamus barbatus</i>	1	0.016
11.	<i>Bambusa polymorpha</i>	1	0.014
12.	<i>Bambusa balcooa</i>	0	0.005
13.	<i>Bambusa bamboos</i>	0	0.003
14.	<i>Other species</i>	0	0.005
Total		6,503	100.000

Note: The data were gathered by a large number of individuals without expertise in bamboo or with limited knowledge of bamboo species and taxonomy. Therefore, the accuracy of the data related to bamboo species might have been compromised.

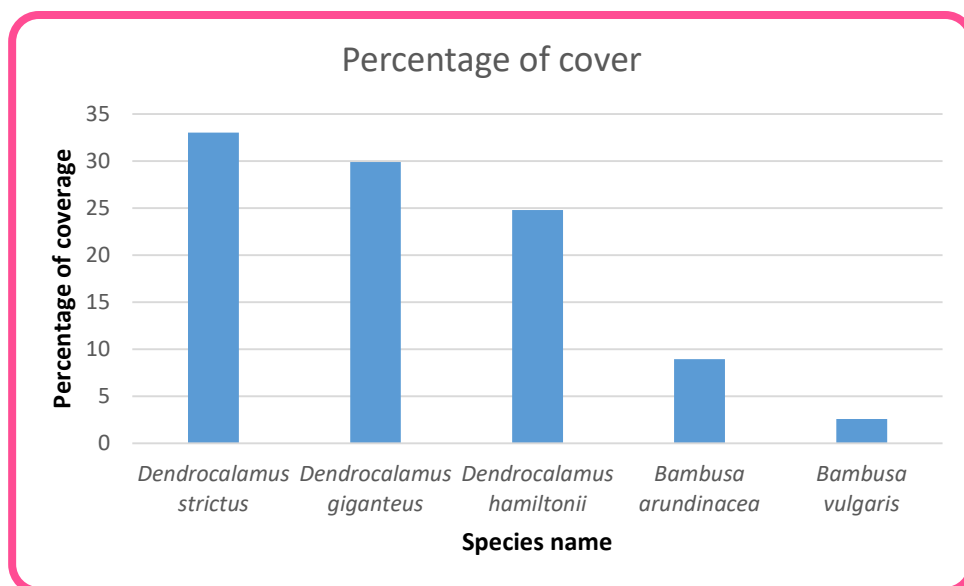


Figure 13. Cover percentage of various bamboo species in Pakistan

3.5 Total Number of Culms and Volume by Species Composition in Punjab, Pakistan

Based on the data presented in Table 4 and Figure 13, along with data collected in the field, the total number of culms produced by various bamboo species in Pakistan has been calculated to be approximately 86.523 million. The corresponding volume of this production is approximately 38.743 million m³, as detailed in Table 5.

Table 5. Total number of culms and volume by Species composition in Punjab, Pakistan

S. No.	Species	Number of culms	Volume in m ³
1.	<i>Dendrocalamus strictus</i>	52,978,033	25,109,098
2.	<i>Dendrocalamus giganteus</i>	13,602,873	5,355,618
3.	<i>Dendrocalamus hamiltonii</i>	16,653,185	5,761,174
4.	<i>Bambusa arundinacea</i>	1,125,183	2,063,167
5.	<i>Gigantochloa spp.</i>	515,814	214,748
6.	<i>Bambusa vulgaris</i>	560,504	147,066
7.	<i>Phylostacys aurea</i>	315,192	60,031
8.	<i>Bambusa polymorpha</i>	113,400	10,321
9.	<i>Dendrocalamus longispathus</i>	27,104	7,628

10.	<i>Guadua weberbaueri</i>	19,992	4,951
11.	<i>Guadua aculeata</i>	27,349	3,598
12.	<i>Dendrocalamus membranaceus</i>	62,000	1,626
13.	<i>Bambusa brandisii</i>	46,197	1,343
14.	<i>Bambusa balcooa</i>	6,600	1,269
15.	<i>Dendrocalamus latiflorus</i>	26,850	1,181
16.	<i>Dendrocalamus barbatus</i>	440,000	277
17.	<i>Bambusa bamboos</i>	600	60
18.	<i>Other spp</i>	2,400	35
Grand Total		86,523,276	38,743,191

3.6 Diameter, Wall Thickness, and Height of Bamboo Species in Punjab, Pakistan

Besides the number of culms and volume by species, data pertaining to diameter, wall thickness, and height of various bamboo species planted in Punjab were calculated and presented for easy reference (Table 6 and Figure 14).

Table 6. Diameter, wall thickness, and height of bamboo species in Punjab, Pakistan

Species	Minimum			Maximum			Average		
	Dia in cm	Thickness in cm	Height in m	Dia in cm	Thickness in cm	Height in m	Dia in cm	Thickness in cm	Height in m
<i>Dendrocalamus strictus</i>	0.32	0.08	0.8	40.16	2.7	30	20.2	13.54	15.4
<i>Dendrocalamus giganteus</i>	0.64	1.1	5.5	20	6	30	10.3	3.55	17.75
<i>Dendrocalamus hamiltonii</i>	0.32	0.5	2	8.92	5	30	4.62	2.75	16
<i>Bambusa arundinacea</i>	0.2	0.7	3	16	9	29	8.1	4.85	16
<i>Bambusa vulgaris</i>	2.5	1	5	9.24	3.1	35	5.87	2.05	20

<i>Dendrocalamus longispathus</i>	2	1	10	7.5	2.5	20	4.75	1.75	15
<i>Dendrocalamus latiflorus</i>	2	1	5	3	2.5	15	2.5	1.75	10
<i>Dendrocalamus membranaceus</i>	1.27	1	4	6.9	1.5	12.5	4.09	1.25	8.25
<i>Bambusa brandisii</i>	5.1	6.5	12	5.1	6.5	12	5.1	6.5	12
<i>Dendrocalamus barbatus</i>	0.41	3.5	15	0.41	3.5	15	0.41	3.5	15
<i>Bambusa polymorpha</i>	7.01	6.5	5.5	7.01	6.5	5.5	7.01	6.5	5.5
<i>Bambusa balcooa</i>	5.8	2	16	5.8	2	16	5.8	2	16
<i>Bambusa bambosa</i>	2.95	1	10	2.95	1	10	2.95	1	10
<i>Gigantochloa spp.</i>	9	4	14	12	5	18	10.5	4.125	16
<i>Guadua aculeata</i>	6.25	2.5	3	6.25	2.5	3	6.25	2.5	3
<i>Guadua weberbaueri</i>	5.73	1.9	12	5.73	1.9	12	5.73	1.9	12
<i>Other spp</i>	2.5	1.25	25	5	5	30	3.75	3.125	27.5

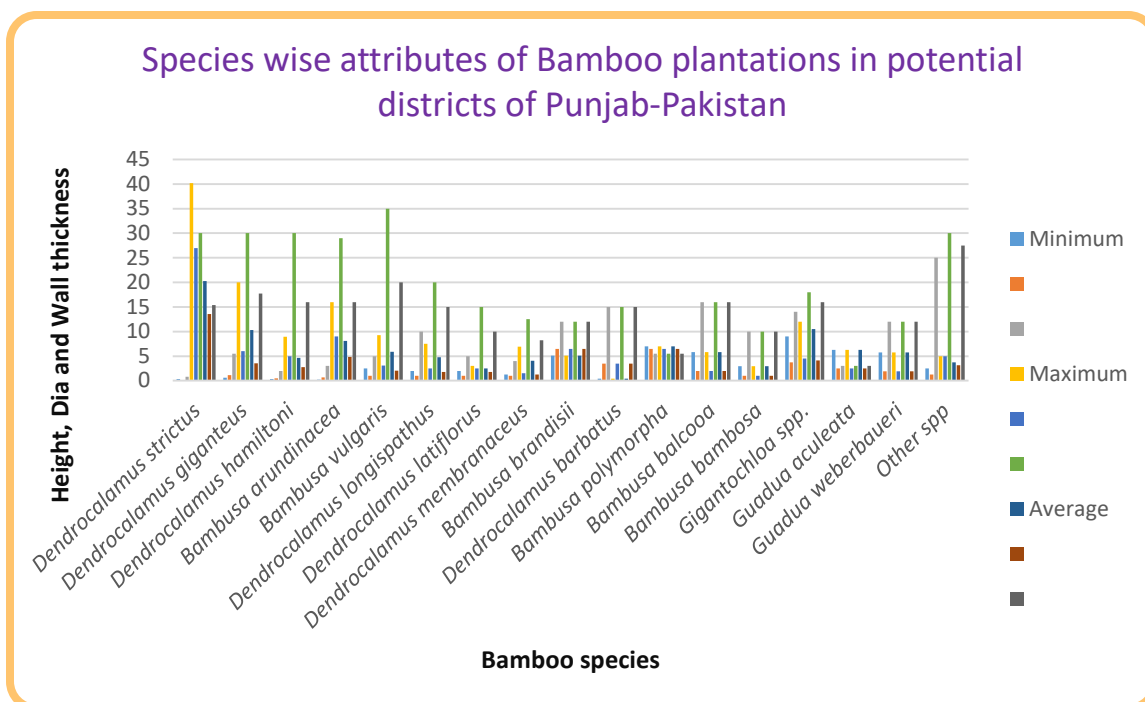


Figure 14. Species attributes of bamboo plantations in districts of Punjab, Pakistan

Despite the fact presented in Table 4 and Figure 13, species composition and area coverage varied from area to area in the potential districts of Punjab. However, in the Sargodha district, 62% bamboo plantations are of *D. strictus*, more than 17% of *D. hamiltonii*, at least 16% of *B. arundinacea*, more than 2% of *B. vulgaris*, and the rest of the species cover merely 2% of the planted area (Table 7 and Figure 15).

Table 7. Cover percentage of various bamboo species in the Sargodha district, Punjab, Pakistan

S. No.	Species	Area (in ha)	% age	Volume in m ³
1	<i>Dendrocalamus strictus</i>	1,342	61.54	21,452,812
2	<i>Dendrocalamus hamiltonii</i>	367	16.83	547,772
3	<i>Bambusa arundinacea</i>	343	15.75	5,898
4	<i>Bambusa vulgaris</i>	48	2.18	44,841
5	<i>Phyllostachys aurea/Phyllostachys spp.</i>	33	1.51	60,031
6	<i>Dendrocalamus giganteus</i>	16	0.72	20,485
7	<i>Gigantochloa spp.</i>	14	0.64	214,748
8	<i>Guadua aculeata</i>	9	0.43	5,397
9	<i>Dendrocalamus membranaceus</i>	9	0.42	1,592
Total in m³		2,180	100.02	22,353,576

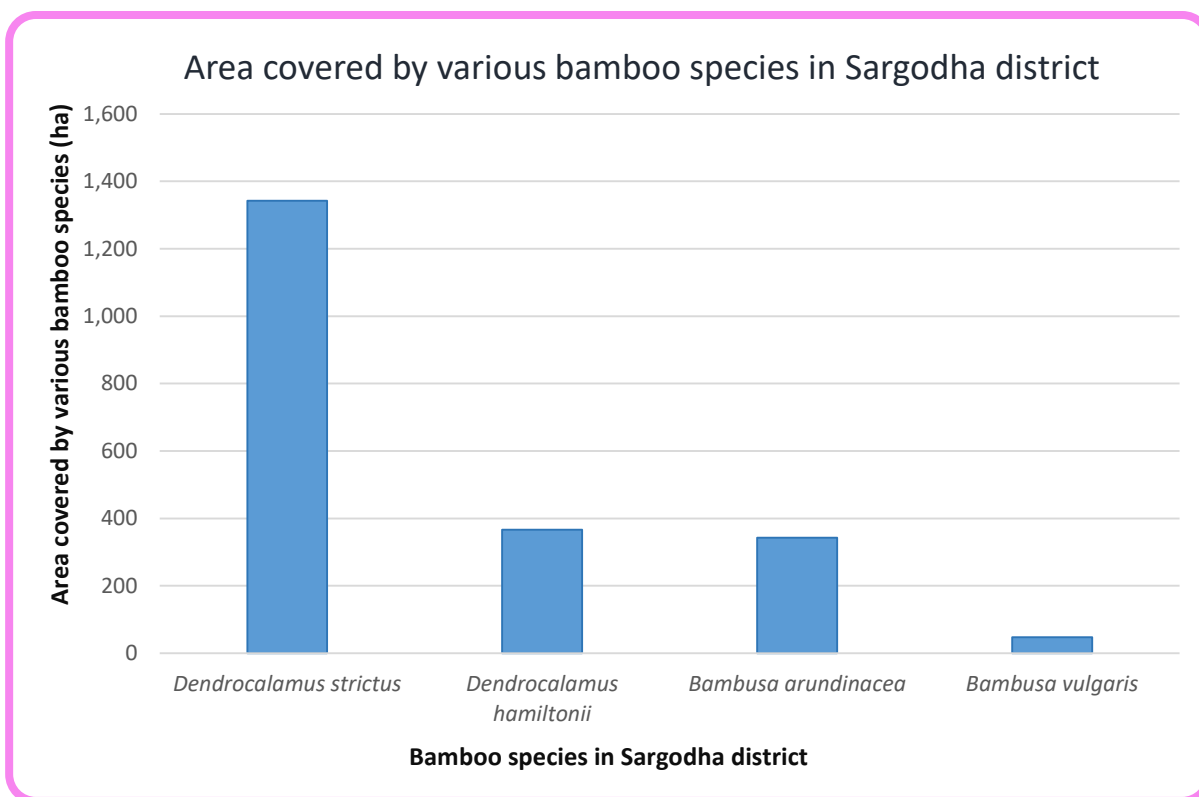


Figure 15. Cover percentage of various bamboo species in Sargodha district, Punjab, Pakistan

Contrary to the Sargodha district, more than 45% of bamboo plantations in Kasur district are of *D. giganteus*, 28% of *D. hamiltonii*, 13% of *D. strictus*, 6% of *Bambusa arundinacea*, more than 2% of *B. vulgaris*, and the rest of the species cover merely 1% of the planted area (Table 8 and Figure 16).

Table 8. Cover percentage of various bamboo species in the Kasur district, Punjab, Pakistan

S. No.	Species	Area (in ha)	Cover % age	Volume (in m ³)
1	<i>Dendrocalamus giganteus</i>	1,832	45.02	5,330,748
2	<i>Dendrocalamus hamiltonii</i>	1,120	27.53	4,839,125
3	<i>Dendrocalamus strictus</i>	529	12.99	2,257,975
4	<i>Bambusa arundinacea</i>	238	5.84	2,039,070
5	<i>Bambusa vulgaris</i>	238	5.85	491,456
6	<i>Bambusa vulgaris</i>	112	2.75	93,004
7	<i>Bambusa balcooa</i>	0.3	0.01	1,269
8	<i>Dendrocalamus barbatus</i>	1	0.03	277
Total in m³		4,070	100.01	15,052,923

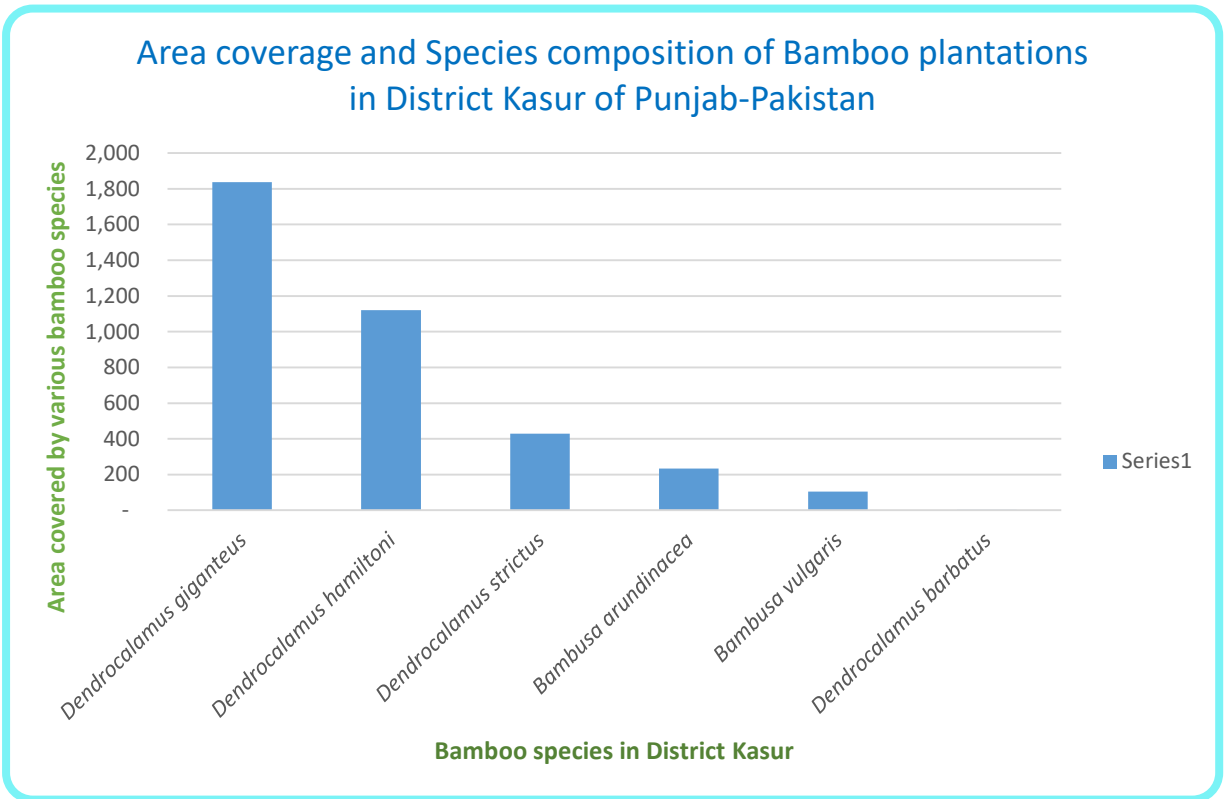


Figure 16. Cover percentage of various bamboo species in Kasur district, Punjab, Pakistan

In the Gujrat (Mandi Bahuddin) district, the distribution of bamboo species is as follows: 43% of *D. giganteus*, 16% each of *D. strictus* and *B. arundinacea*, 12% of *Dendrocalamus longispatus*, 7% of *B. vulgaris*, and 5% of *D. latiflorus* (Table 9 and Figure 17).

Table 9. Cover percentage of various bamboo species in the Gujrat (Mandi Baha Uddin) district, Punjab, Pakistan

S. No.	Species	Area (in ha)	Cover % age	Volume in m ³
1	<i>Dendrocalamus giganteus</i>	89	43	4,285
2	<i>Dendrocalamus strictus</i>	33	16	13,923
3	<i>Bambusa arundinacea</i>	32	16	326
4	<i>Dendrocalamus longispatus</i>	25	12	7,628
5	<i>Bambusa vulgaris</i>	15	7	7,917
6	<i>Dendrocalamus latiflorus</i>	11	5	1,180
Total in m³		205	100	35,259

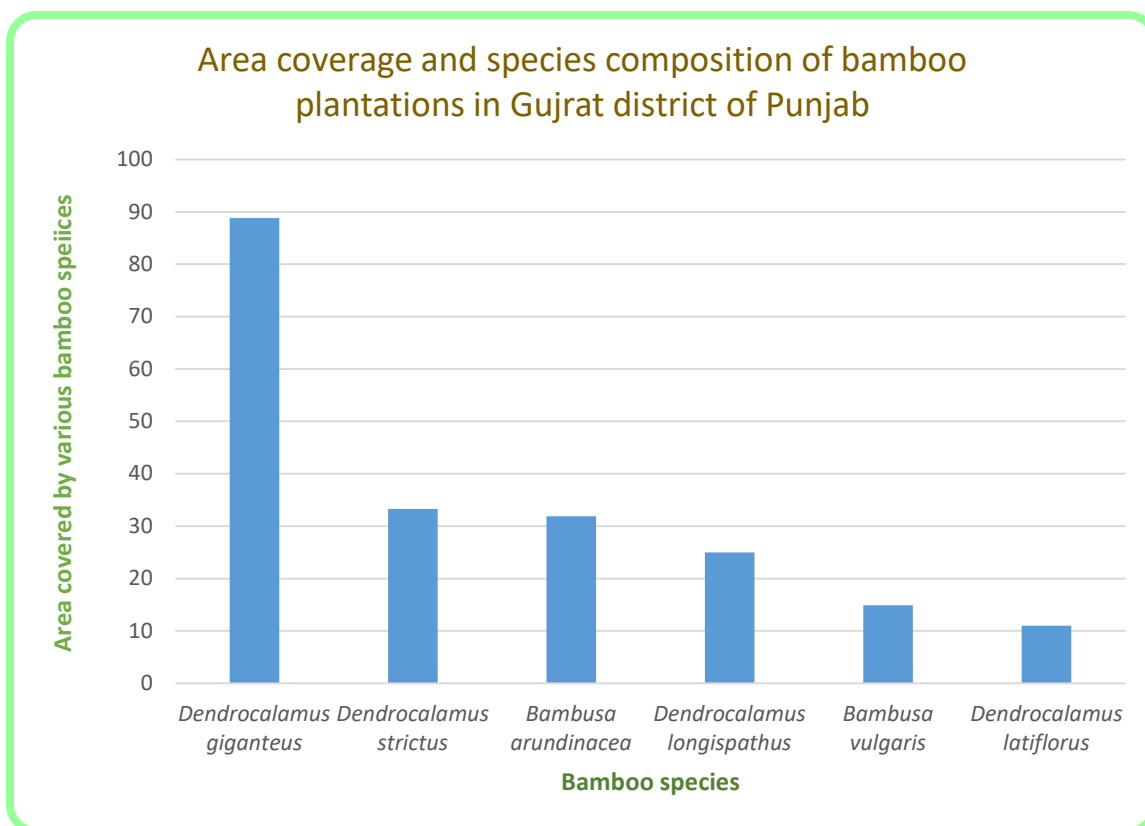


Figure 17. Cover percentage of various bamboo species in the Gujrat (Mandi Baha Uddin) district, Punjab, Pakistan

Similar to the Sargodha district, species composition in the Gujranwala district is dominated by *D. hamiltonii* at 93%. Additionally, there are 3% each for *B. arundinacea* and *B. brandisii*, *B. vulgaris*, and the rest of the species cover merely 1% of the planted area (Table 10, Figure 18).

Table 10. Cover percentage of various bamboo species in the Gujranwala district, Punjab, Pakistan

S. No.	Species	Area (in ha)	Cover % age	Volume in m ³
1	<i>Dendrocalamus hamiltonii</i>	101	93	295,471
2	<i>Bambusa arundinacea</i>	4	3	245
3	<i>Bambusa brandisii</i>	3	3	1,342
4	<i>Dendrocalamus membranaceus</i>	1	1	34
5	<i>Bambusa polymorpha</i>	1	1	10,320
Total in m³		109	100	307,412

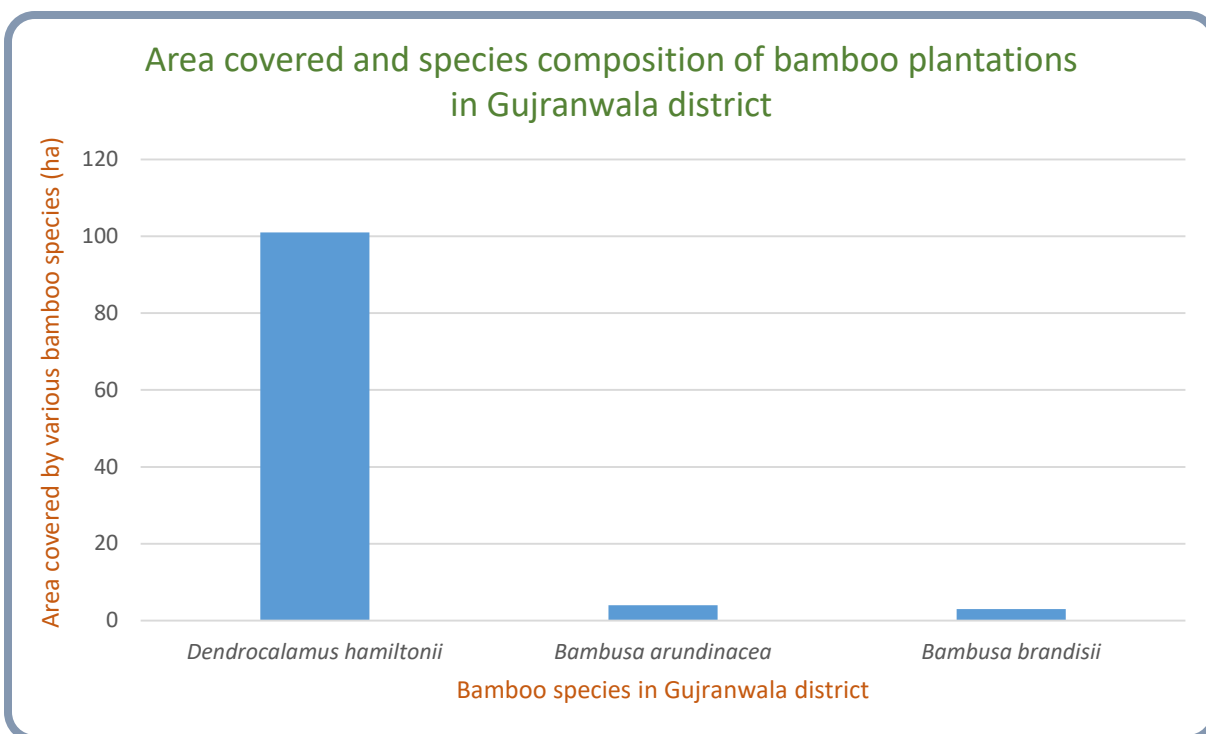


Figure 18. Cover percentage of various bamboo species in Gujranwala district, Punjab, Pakistan

By contrast, in the Dera Ghazi Khan district, only *D. strictus* is the preferred choice of farmers for plantations in their areas, constituting 100% of the distribution (Table 11 and Figure 19).

Table 11. Cover percentage of various bamboo species in the Dera Ghazi Khan district, Punjab, Pakistan

S. No.	Species	Area (in ha)	Cover % age	Volume in m ³
1.	<i>Dendrocalamus strictus</i>	207	100.00	1,194,670
Total in m³		207		1,194,670

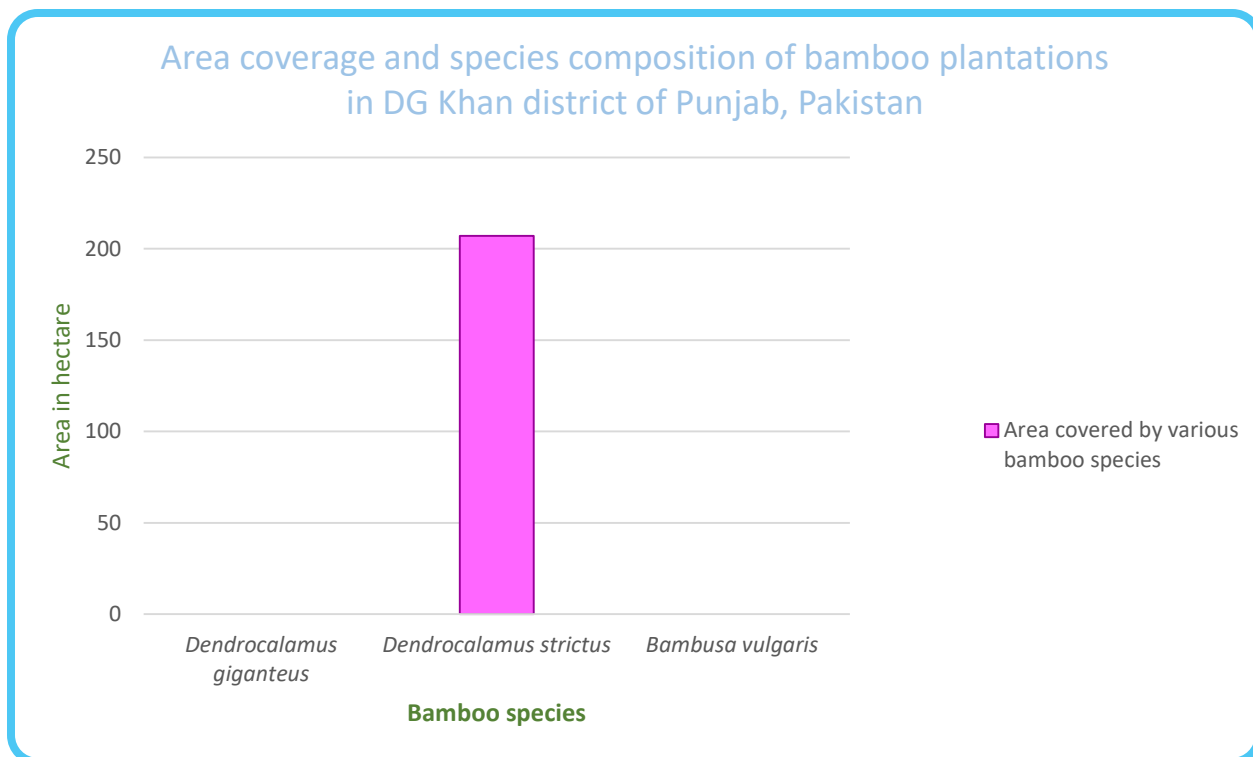


Figure 19. Cover percentage of various bamboo species in the Dera Ghazi Khan district, Punjab, Pakistan

Based on the coverage and species composition, the total coverage area (A) is calculated by using the formula:

$$A = \pi r^2 \times \text{number of clumps} \times \text{average number of culms in each polygon}$$

The volume of various bamboo plantations based on the species has been calculated and presented for reference in Table 12 and Figure 20.

In summary, at least 6,679 hectares of bamboo plantations with different species were surveyed across various areas using the INBAR mobile app, resulting in a total estimated volume of at least 38.74 million m³ in Punjab, Pakistan. Based on the field data, the dominant species with the maximum volume includes *D. strictus* 25.12 million m³ (65%), *D. hamiltonii* 5.7 million m³ (15%), *D. giganteus* 5.4 million m³ (14%), and *B. arundinacea* 2.1 million m³ (5%). The remaining species collectively contribute to a volume of 2.63 million cubic meters.

Table 12. Cover percentage of various bamboo species and accrued volume in Punjab, Pakistan

S. No.	Species	Area (in ha)	Volume in m ³	% age
1	<i>Bambusa arundinacea</i>	619.57	2,063,167	5.3252
2	<i>Bambusa balcooa</i>	0.34	1,269	0.0033
3	<i>Bambusa bamboos</i>	0.21	60	0.0002
4	<i>Bambusa brandisii</i>	3.22	1,343	0.0035
5	<i>Bambusa nutans</i>	0.00	0.00	0.0000
6	<i>Bambusa polymorpha</i>	0.66	10,321	0.0266
7	<i>Bambusa tulda</i>	0.28	0.00	0.0000
8	<i>Bambusa vulgaris</i>	176.05	147,066	0.3796
9	<i>Dendrocalamus barbatus</i>	1.05	277	0.0007
10	<i>Dendrocalamus giganteus</i>	1,973.14	5,355,618	13.8234
11	<i>Dendrocalamus hamiltonii</i>	1,643.70	5,761,173	14.8702
12	<i>Dendrocalamus latiflorus</i>	10.97	1,181	0.0030
13	<i>Dendrocalamus longispathus</i>	24.96	7,628	0.0197
14	<i>Dendrocalamus membranaceus</i>	10.14	1,626	0.0042
15	<i>Dendrocalamus strictus</i>	2,155.40	25,109,098	64.8091
16	<i>Gigantochloa spp.</i>	13.59	214,748	0.5543
17	<i>Guadua aculeata</i>	9.34	3,598	0.0093
18	<i>Guadua weberbaueri</i>	2.76	4,951	0.0128
19	<i>Phyllostachys aurea</i>	32.90	60,031	0.1549
20	<i>Other species</i>	0.87	35	0.0001
Total		6,679.15	38,743,190	100.000

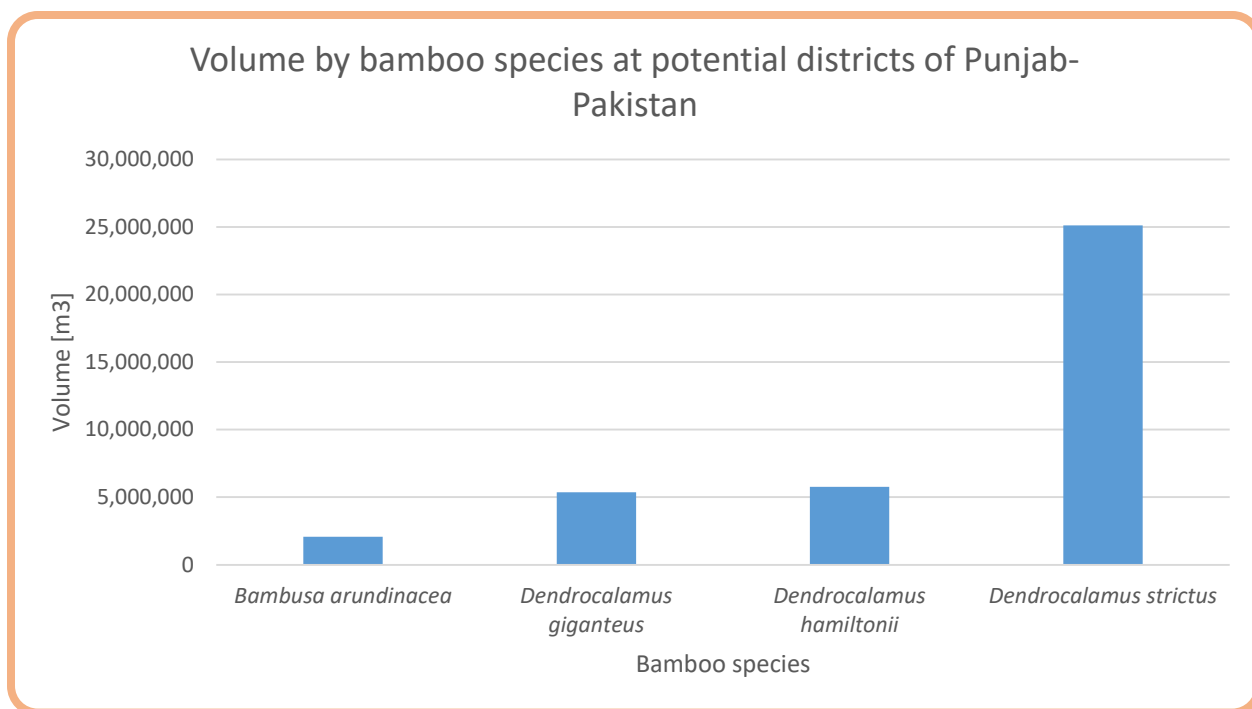


Figure 20. Cover percentage of various bamboo species and accrued volume in Punjab, Pakistan

3.7 Ownership Status

Except for a couple of bamboo research plots owned and managed by the Pakistan Forest Institute, Peshawar and the Punjab Forestry Research Institute, Gutwala Faisalabad in Punjab, and Sindh and Balochistan Forest Departments of Pakistan, all the bamboo resources in the form of plantations raised on private farmlands are primarily owned by local farmers or their absentee landlords.

4 Bamboo Resource Development and Management

4.1 Propagation

Bamboo shoots and culms grow from a dense rhizome root system. There are two main categories of rhizomes: monopodial and sympodial. Monopodial rhizomes grow horizontally, often at a surprising rate, and are often referred to as 'runners'. The rhizome buds develop either upward, generating a culm, or horizontally, resulting in a new tract of the rhizome. By contrast, sympodial rhizomes are short and thick, and the culms above the ground are closely grouped together in a compact clump, which expands evenly around its circumference. Their natural habitats are tropical regions, and they are not invasive.

Cultivation through seed is uncommon, as the plant is monocarpic and seed production may take 3-4 decades. Other methods of propagation include rhizome planting, whole culm cutting, layering, and branch cutting. In Pakistan, the most common method used by bamboo farmers is branch cutting. The branches from the main culm are cut in such a manner that the rhizome of the branch also becomes part of it. These branches are then nurtured in nurseries for 2 to 3 months before being introduced to farmlands with an optimal spacing of 20' × 20' (6 m × 6 m) or approximately 100 plants per acre (0.4 ha).





Figure 21. a–d. Bamboo farmers in Pakistan usually use branch cutting to take branches with rhizomes from the main culm (a–b), nurturing them in nurseries (c–d) before planting them in farmlands.

4.2 Management

The bamboo research plots maintained by public sector organizations, such as the PFI, Punjab Forestry Research Institute, Punjab, and Sindh Forest Departments, are primarily managed for the collection of data on their research trials. Upon harvesting, the sale proceeds either go to their provincial exchequer as revenue of their organizations or to the Institute Endowment Fund intended for further research and management.

By contrast, the private plantations established in various districts of Punjab are primarily managed as entrepreneurial ventures driven by market forces driven by demand and supply. As a result, in certain areas, they are expanding, while in others, they are being eradicated from the fields. In regions where the owners have extensive land holdings and cultivate a diverse range of crops, such as cereals, vegetables, sugarcane, cotton, and fruit orchards, the bamboo area is steadily expanding. Farmers are of the opinion that they could maximize their profits by cultivating various crops on their farmlands, as bamboo requires less intensive labor, inputs, and pesticides. Bamboo requires limited input in the form of fertilizers (urea) during planting, regeneration, and regular watering until harvest.

However, farmers with limited land holdings do not find it economical due to its long rotation period of at least five years initially, followed by a regular cycle of three years, with the land being fully occupied and having no other productive uses. By comparison, short-duration cereal crops, such as wheat, rice, cotton, maize, millets, and sesame, offer substantial economic returns in a shorter period of time and provide farmers with more flexible sowing choices compared to bamboo plantations.

4.3 Protection and Care

As a hardy species, bamboo does not require rigorous physical protection in the field once established. According to farmers, bamboo crops can thrive with a plentiful water supply, while

others recommend the application of fertilizers for rapid growth and biomass production. However, great care and attention are necessary during the transplantation of planting stock, as there is a likelihood that the plants will shrink when their roots are exposed to sunlight. Additionally, wild boars and porcupines are known to nibble on fresh bamboo shoots and dig out the rhizomes for feeding.



Figure 22. Bamboo thrives without the need for intensive care or physical protection in the field (a). Nevertheless, ample water and fertilizers can boost its growth and biomass yield, even when grown alongside other agricultural crops (b).

4.4 Harvest Cycle

Once successfully established, the first harvest is carried out after five years, followed by economic rotation of three years on a regular basis. Once harvested, the crop rejuvenates through root suckers and rhizome networks in the fields.





Figure 23. Following a five-year growth period, the first bamboo harvest is performed with subsequent economic rotations every three years (b and c). Bamboo can be harvested manually (a) or with the use of mechanical machinery for various tasks (d).

4.5 Technical recommendation on resource management, harvest, governance/administration

Given the resilience and adaptability of bamboo species and the limited availability of farmland with multifaceted uses and fertility for various crops, bamboo plantations may be established on marginal lands with limited potential for productive agriculture. Research institutes, such as the PFI in Peshawar, the Punjab Forest Research Institute in Faisalabad, universities, and others, should investigate cultivating bamboo in saline and marshy areas to help land reclamation and ensure the productive utilization of bamboo products.

4.6 Constraints and Bottlenecks Encountered in this Study

1. Financial closure at the end of June posed challenges in balancing official obligations with field survey commitments.
2. The Eid ul Azha is an important festival, leaving little time for bamboo resource assessment that coincides with festival celebrations.
3. High temperatures, humidity, and the presence of venomous snakes slowed data collection during the hottest summer months.
4. Monsoon rains in June–August caused mudslides, water stagnation, and flooding in areas with bamboo plantations, hampering data collection.
5. The forestry department's routine planting campaign in Punjab province hindered the provision of full teams of field staff to help with bamboo resource assessment.
6. The accessibility, size, and contiguity of bamboo plantations affected the pace and cost of resource assessment, especially in remote and inaccessible areas. Furthermore, the absence of owners and tenants of bamboo plantations impeded interviews and the collection of correct information, exacerbated by unknown owners and absentee property owners.

4.7 Key Lessons Learned

Consulting stakeholders at all levels before planning any activity is crucial to avoid future inconveniences or challenges and to ensure smoother execution. Conducting a prefeasibility study can help in understanding the quantum and scope of work accurately, preventing discrepancies between planned and actual requirements in the field. Stakeholder analysis is

essential for proper planning and implementation of interventions, identifying relevant parties, and ensuring realistic funding to prevent cost and time overruns. Proper budget estimates aligned with defined stakeholders and activities are necessary to effectively fund and execute fieldwork, avoiding deviations and increased costs. Flexibility in activities and expenditure during fieldwork planning allows for adaptation to changing conditions, ensuring smoother operations and efficient adjustments. Using a vibrant process approach rather than a rigid blueprint method in fieldwork planning can lead to more successful achievement of targets amid varying field conditions. The availability of suitable transport and field gear is crucial for quality fieldwork, ensuring the safety and efficiency of fieldworkers in challenging environments. Establishing and utilizing strong linkages and social contacts is beneficial for facilitating cooperation and collaboration in fieldwork, particularly when facing challenges with official engagements or busy schedules.



Figure 24. a–d. At times, surveyors face challenges in directly accessing bamboo plantations due to extensive and deep-flowing irrigation canals, dense sugarcane, or muddy paddy fields. These conditions can make it difficult for them to completely capture polygons using the INBAR mobile app.

5 Conclusion and Recommendation

5.1 Conclusion

The detailed field survey conducted across various districts of Punjab in Pakistan has shed light on the distribution, quantity, and characteristics of bamboo plantations, highlighting key insights and discrepancies encountered during the data collection process. Punjab province emerged as the primary hub of bamboo plantations, particularly in districts like Kasur, Sargodha, Mandi Bahauddin, and DG Khan. The survey results documented a total of 6,600 hectares of bamboo plantations, providing detailed information on the size, location, and composition of the plantations.

Analysis of bamboo distribution based on diameter and height classes indicated sustainable plantation practices, with varying stages of maturity observed across different sites.

Ownership status analysis highlighted local farmers and absentee property owners as the primary owners of bamboo resources on private farmlands, showcasing a blend of entrepreneurial management and research-driven practices. Propagation methods, such as branch cutting, are commonly employed by farmers, emphasizing sustainability and efficient growth practices.

The constraints and bottlenecks encountered during the survey, including financial closures, religious festivals, climatic challenges, and accessibility limitations, highlighted the need for strategic planning and stakeholder consultations to overcome obstacles and ensure successful data collection.

The data were gathered by a large number of individuals without expertise in bamboo or with limited knowledge of bamboo species and taxonomy. Therefore, the accuracy of the data related to bamboo species might have been compromised. The key lessons learned underscored the importance of stakeholder engagement, prefeasibility studies, budget estimations, flexibility in planning, and collaborative partnerships for efficient fieldwork execution and successful outcomes. These findings will guide future interventions and resource management strategies to enhance the sustainability and productivity of bamboo plantations in the region.

5.2 Recommendations

Establish large-scale bamboo plantations on marginal lands or as shelterbelts along agricultural field boundaries to mitigate potential negative impacts on productive agricultural land designated for short-duration cash crops.

Bamboo's relative advantages over trees, including its light weight, resilience to environmental consequences, and efficiency in coping with calamities, make it a suitable choice for plantations in various environments.

Utilize bamboo plantations to support the growth of medicinal fungal species and manage nurseries in or adjacent to human habitations.

Promote extensive awareness campaigns to highlight the ecological and commercial significance of bamboo among local communities, farmers, and landowners.

Encourage bamboo plantations on degraded land, such as waterlogged, saline, eroded, and riverbed areas, for productivity enhancement and land reclamation.

Replace decades-old bamboo planting stock with more efficient cultivars suitable for Pakistan's altitudinal variations and soil types.

Encourage local research on various aspects of bamboo in Pakistan and the establishment of a network of bamboo growers to easily convey extension services, better harvest techniques, effective utilization of leftover materials, and marketing of bamboo products at the grassroots level.

The Ministry of Climate Change and Environmental Coordination should take appropriate steps to incorporate bamboo into the regulatory frameworks and Forest Departments should keep bamboo plantations related data and samples to facilitate monitoring and recovery in case of adversity.

The observed inconsistencies between the app's MIS and the current administrative subdivision led to gaps in data collection due to administrative reshuffling and district reorganization. An update to the app's MIS is highly recommended to ensure accurate data representation.

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Prominent Glimpses of Active Field Interactions in Punjab



Figure 25. a & b. Enlisting support for field formations at Changa Manga (Kasur Forest Division)



Figure 26. Training field staff at Changa Manga



Figure 27. Meeting with CF Lahore (to the right of INBAR, PFI coordinator), DFO Kasur (to the left of INBAR, PFI coordinator), and his field staff at Changa Manga Irrigated Plantations



Figure 28. a & b. Enlisting the support of the field staff at Jhang Forest Division at Jhang



Figure 29. Training field staff at Dapher (Gujrat Forest Division)



Figure 30. Meeting with the divisional forest officer Gujranwala, Punjab



Figure 31. Bamboo plantation in Hafizabad



Figure 32. Meeting with conservator of forests, Sargodha, Punjab

Appendices

Appendix I

Schedule of resource assessment and area surveyed by officers of the Pakistan Forest Institute, Peshawar in various districts in Punjab

S. No.	Date	District	Total area (ha)
1.	June 22–26, 2023	Sargodha	177
2.	August 2–10, 2023	Kasur, Mandi Bahauddin, Faisalabad, Chiniot	2,184
3.	August 24–31, 2023	D.G. Khan, Muzaffargarh, Bahawalnagar, Kasur, Sheikhpura, Nankana sahib	653
4.	September 1–4, 2023	Sheikhpura, Kasur, etc.	190
5.	October 9–22, 2023	Kasur, Lahore, Hafizabad, Gujranwala, Sargodha	1,684
Bamboo area exclusively covered by PFI team			4,888

Appendix II

Results of bamboo resource assessment in Punjab, Sindh, Khyber Pakhtunkhwa and Baluchistan

S. No.	Province	Districts surveyed	Bamboo assessment conducted (in ha)		
			Polygon	Polyline	Point
1.	Punjab	Kasur	3,796	0.38	0.044
ii.		Sargodha	2,125	0.5	0.002
iii.		Mandi Bahauddin	294	0.07	0.002
iv.		D.G Khan	182	0.25	0
v.		Nankana Sahib	50	0	0
vi.		Chiniot	45	0	0
vii.		Gujranwala	30	0.2	0.016
viii.		Muzaffargarh	26	0.06	0.10
ix.		Sheikhupura	25	0.02	0.004
x.		Okara	25	0	0
xi.		Hafizabad	22	0.09	0
xii.		Faisalabad/ Punjab Forestry Research Institute	20	0.1	0.010
xiii.		Khushab	11	0	0
xiv.		Bahawalnagar	2	0	0
xv.		Lahore	0	0.01	0
2.	Baluchistan	Naseer Abad	2	0	0
3.	Sindh	Hyderabad	2	0	0
4.	Khyber Pakhtunkhwa	Peshawar PFI	0.61	0	0.02
Total (in ha)			6,657.61	1.68	0.198

Appendix III

Details of officers and officials of Punjab Forest Department trained during INBAR Mobile app-based bamboo resource assessment in Punjab

SI #	Forest Division	Name	Designation	Login-ID	Place of duty	Assessment (In ha)
1.	Pakistan Forest Institute, Peshawar	Muhammad Farooq	Forest Ecologist	Afridifarooq30	PFI, Peshawar	1,172
		Salman Ahmed	RO	Slamansk7218		
2. i.	Kasur	Mr. Naveed Ali	Forest Guard	-	Chunia	
ii.		Mr. Zafar Iqbal		Naveedali423		
iii.		Mr. Khalid Shehzad		Zafariqbal9747		
iv.		Mr. Khalid	RO Chunia	-		
v.		Mr. Kashif Bukhari	SDFO Kasur	-	Kasur	
vi.		Mr. Abdullah	Forest Guard	Shabirkashifbukhari		
vii.		Mr. Ishfaq Ahmed		Nj6363635		
viii.		Mr. Naveed Ali	Forest Guard	-	Chunia	
ix.		Mr. Zafar Iqbal		Naveedali423		
x.		Mr. Khalid Shehzad		Zafariqbal9747		
xi.		Mr. Khalid	RO Chunia	-		
xii.		Mr. Kashif Bukhari	SDFO Kasur	-	Kasur	
xiii.		Mr. Abdullah	Forest Guard	Shabirkashifbukhari		

xiv.		Mr. Ishfaq Ahmed		Nj6363635		
3.	Gujrat	Mr. Mukhtar		Khalidshehzad51	Mandibahauddin	
i.						
ii.		Mr. Irfan		Imran.forest784		
iii.		Mr. Rana Iftekhhar				
iv.		Mr. Amaar	Block Officer			
4.	Jhang	Mr. Jamshaid	Range Chiniot	Abidmahmood10101	Chiniot	
i.						
ii.		Mr. Amjad Nisar	Block officer	Amaarasif5262		
5.	D.G. Khan	Ansar Khan		Ansarkhan	DG Khan Forest Division	
6.		Sanauallah	Forest Guard	DFODGK		

Appendix IV

Ownership of bamboo resources, assessed during a field survey in Punjab province on 2–10 August 2023

S. No.	Name of owner	Location	Date of survey	Total area (In ha)	Bamboo species
1	Choudhry Safdar	Chak No 90SB	23/6/23	13.00	<i>Dendrocalamus strictus</i>
2	Amir Shehzad			2.09	
3	Sajjad Ullah		24/6/23	21.00	
4	Tasneem			26.00	
5	Khurshaid	Shahpur/jhavarian	24/6/23	2.63	
6	Sarfraz Gondal	Lal mor, Kot Momin		6.54	
7	Sarfraz Gondal			1.88	
8	Irfan Gondal			10.16	
9	Nasar Waraich	Chak No 90SB	25/6/23	11.00	
10	Muhammad Zahid			04.00	
11	Muhammad Amin Nat			02.00	
12	Muhammad Zahid			1.34	
13	Ch. Akaml	Moazam abad		2.81	
14	Zafar			0.18	
15	Babar Wali	Bucha kalan	25/6/23	3.07	
16		Basraa		1.67	
17				3.12	
18				0.20	
19				12.00	
20				5.26	
21				0.46	
22		1.11			
23	Islamullah Sial	Chak No 84SB	26/6/23	5.70	
24	Amanullah			2.42	
25	Afzal Sial			1.32	
26	Ahmad			0.80	
27	Afzal Sial			1.70	
28	Islam			3.12	
29	Gul Muhammad	Basra		3.98	
30	Hafiz Abu bakar			1.31	
31	Mian Muhammad Azam		4.45		
32	Muhammad yar		0.38		
33	Elahi Dad	Chak 8 ML	26/6/23	1.34	
34	Elahi Dad			4.68	
Total area covered (in hectare)				162.72	



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