

Poplar Farming in Punjab

Expanding Crops, Increasing Income

Helena Cardenas, Chetali Chauhan, Zhixian Luo, Chandan Singha, Priya Shyamsundar





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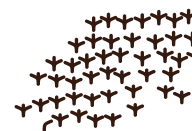
01. Executive Summary

Agroforestry—the integration of trees and shrubs into agricultural landscapes—offers the possibility of diversifying Punjab’s farming landscape. It offers an alternative to the traditional rice–wheat system, with the potential to improve soil health and broaden farm income sources. Poplar plantations, in particular, are favored for short rotation cycles, wood quality and compatibility with winter crops like wheat.

This study evaluates the economic viability of poplar-based agroforestry in Punjab. It analyzes economic returns from poplar cultivation while considering land opportunity costs. It also investigates farmers’ preferences for agroforestry incentives, such as government subsidies, to help guide future policy and practices. Study methods include cost–benefit analyses to estimate net returns to farmers who grow poplar in block plantations or as boundary plantations and farmers who grow annual crops; and choice analyses to understand how adoption of agroforestry may increase if farmers are offered financial incentives, including tree-growing cost-sharing subsidies and insurance.

Results are drawn from a survey of 457 randomly selected farm households across 30 villages in Punjab, conducted in April and May of 2025. The sample covered three districts where TNC saw opportunities for agroforestry expansion (Gurdaspur, Amritsar and Ludhiana), capturing both adopters and non-adopters of agroforestry. Data collection included structured interviews focusing on farm characteristics, cropping patterns, agroforestry practices, investment costs and farmer perceptions regarding incentives and barriers.

Farmers grow trees in block plantations or as boundary plantations along field boundaries. Trees in block plantations are often intercropped with wheat (or sugarcane) during the first few years, while boundary trees thrive alongside annual rice–wheat crops, i.e., boundary plantation farmers continue to receive an annual income from rice–wheat crops. Most often, intermediaries purchase tree stands, and harvest and transport wood to markets. Poplar block plantation farms in our sample have an average tree-growing area of 2.42 acres. Block plantations average 837 trees per farm (360 per acre), while boundary plantations have an average of 146 trees per farm (66 per acre).



There are notable differences among farmers who plant poplar trees in block plantations, those who grow trees on plot boundaries and farmers who don't grow trees. Block plantation farmers typically have larger farms (9.75 acres, on average) and a wider network of tree-growing farmers. Boundary plantation farmers are often smallholders (5.64 acres on average) who depend on formal credit and are prominent in Gurdaspur. Non-tree growers, i.e., farmers who grow annual crops, have less experience and fewer tree-related connections relative to farmers who plant trees. These distinctions highlight unique opportunities and challenges for each group in adopting agroforestry.

Both block and boundary plantations offer higher returns relative to conventional rice-wheat farming. Cost-benefit analyses show that block plantations, with trees harvested after five years, yield a Net Present Value (NPV) of income of ~INR 4.3 lakh per acre on average; boundary plantations (along with annual rice-wheat crop income) offer an average NPV of ~INR 4.1 lakh per acre; and annual crop production (rice-wheat) offers an average NPV of ~INR 3 lakh per acre (based on 2025 prices). The benefit-cost ratio for an acre of land in block plantations (not accounting for the opportunity costs from losing annual rice-wheat income) is 5.28 relative to 3.75 for boundary plantations that are grown alongside rice-wheat and 2.68 for annual rice wheat crops (without tree crops).

Farmers switching from rice-wheat farming to block plantations will forgo annual crop income, but block plantations remain profitable. The NPV of income for block plantations, after accounting for foregone rice-wheat income, is approximately INR 1.28 lakh per acre. Thus, for farmers who switch from rice-crop to block plantations of poplar, this is the income gain they can expect over a five-year period in present value terms. Monte Carlo simulations also indicate downside risks to block plantations from variation in timber prices: The probability of a negative NPV ranges from 19% under high-price scenarios to 26% under low-price scenarios.

Boundary plantations may be most appealing to farmers as they offer an annual food crop return as well as a medium-term tree-crop return. If a rice-wheat farmer added a boundary poplar plantation to their field, they would increase the NPV of their income by INR 1.25 lakh from the tree crop over a five-year period. The income gain occurs despite losing some food crop income in later years from competition.



A cost-sharing subsidy covering 30% of planting and care costs (~INR4,500/acre/year), alongside technical support, has the potential to increase block plantation adoption rates to 5% for new farmers and 18% for existing block plantation farmers. With technical support, this would expand poplar tree plantations by about 26,000 acres in the study area. A five-year subsidy is projected to cost around INR 520 million (USD 6 million), excluding technical assistance or management costs. Preliminary analysis shows that carbon project financing may also boost agroforestry adoption, depending on farmers' experience and payment timing.

Younger farmers and those willing to use credit are especially receptive to agroforestry interventions, insurance, and carbon financing options. Social networks are also a critical channel for disseminating information and sustaining adoption momentum, especially in the early stages.

In general, poplar agroforestry presents a viable and profitable alternative to conventional cropping in key districts in Punjab, especially when supported by technical support, targeted subsidies and other financial options such as insurance. Adoption is strongly influenced by economic incentives, perceived risks and farmer demographics. These results are most applicable to the three districts from which we surveyed farmers. Extrapolating to all of Punjab would require additional analyses.

Water concerns must be addressed before large-scale expansion in Punjab's groundwater-stressed regions. Water savings from poplar depend mainly on replacing kharif rice—the main cause of groundwater depletion—rather than simply adding poplar to existing rice-wheat fields, which could increase water extraction. The landscape-scale water impacts of block versus boundary expansion are unstudied, and no multi-year comparative data exist on water balance for poplar agroforestry versus rice-wheat systems in Punjab. Future research should prioritize filling these knowledge gaps.

The study offers a policy roadmap for scaling poplar-based agroforestry in Punjab. In the near term, restoring nursery support and seedling supply—disrupted since 2023—would be an important enabling condition. A cost-sharing subsidy of around 30%, paired with technical assistance and insurance coverage, could increase adoption likelihood, particularly among farmers already experienced with tree planting. Technical assistance on spacing, pruning and intercropping management is essential as agroforestry is a relatively unknown farming practice. Over the medium term, timber market reforms—including price transparency mechanisms—could improve the reliability of returns. Carbon markets represent an additional financing opportunity, depending on program design, transaction costs and the timing of payments to farmers. Finally, program design and outreach would benefit from reflecting farmer heterogeneity (e.g., block versus boundary versus non-tree growers, and differences in farm size, credit access and social networks) and focusing on biophysically and market-suitable locations. Persistent adoption barriers can be addressed by providing clear information on crop impacts, integration methods and transparent revenue versus cost projections to dispel misconceptions and manage expectations. Additionally, given groundwater stress in Punjab, further research on the water implications of block versus boundary expansion is warranted. These considerations require deliberation among state government, farming communities and market stakeholders before a formal program is designed.

02. Introduction



Agroforestry, the practice of integrating trees and shrubs into farms, can influence farm productivity, profitability, local biodiversity and longer-term sustainability (Government of India 2014; Chavan et al. 2015). India has 25.31 million hectares (8.2% of land) under agroforestry, sequestering 34 MtCO₂e annually (TERI 2021). with several states implementing initiatives to boost farm incomes through the National Agroforestry Policy (Chavan et al. 2015). However, there are challenges to agroforestry expansion. These include investment costs, yield uncertainty, management complexity and competition from imported products (Metzel & Montagnini 2014; Paul et al. 2017; Reed et al. 2017; Anand et al. 2025). Still, Indian farmers have grown trees for a long time and policy support can further contribute to this effort.

Poplar trees have emerged as a preferred choice for agroforestry, particularly in the northwestern states of Haryana, Punjab and Uttar Pradesh, because of its short rotation cycle, quality wood and profitability (Chauhan & Mangat 2006). As of 2019, approximately 270,000 hectares in India were planted with poplar (Sukhpal Singh 2024). This wood is utilized as industrial roundwood in applications such as pulp and paper, matchsticks, pencils and plywood. With a typical rotation period of 5–8 years, poplar trees are planted both in blocks and along boundaries. As a deciduous tree, farmers are able intercrop other rabi (winter) crops such as wheat, sugarcane, potato, mustard, maize, pulses, vegetables, fodder and medicinal plants, alongside poplar during its initial years of growth.

In Punjab, agroforestry offers a practical alternative to traditional rice–wheat farming, with the potential to conserve soil carbon (Singh & Singh 2018) and increase soil water-holding capacity (depending on various implementation factors, such as management, density and crop substitutions) (Dhaliwal et al. 2020). Farmers cultivate poplar (*Populus deltoides*), eucalyptus (*Eucalyptus tereticornis*), and melia (*Melia composita*) in the state, with poplar making up about 21% of trees outside forests (Pandey 2008).¹ Poplar agroforestry can largely be found in Ludhiana (1.02% of land areas), Rupnagar (4.09%) and Hoshiarpur (3.19%) and SBS Nagar (0.43%) (Rizvi et al. 2020). Available evidence suggests that poplar offers higher financial returns relative to most other crops (Jain & Singh 2000; Bhangu & Kaur 2018; Chavan et al. 2022a).

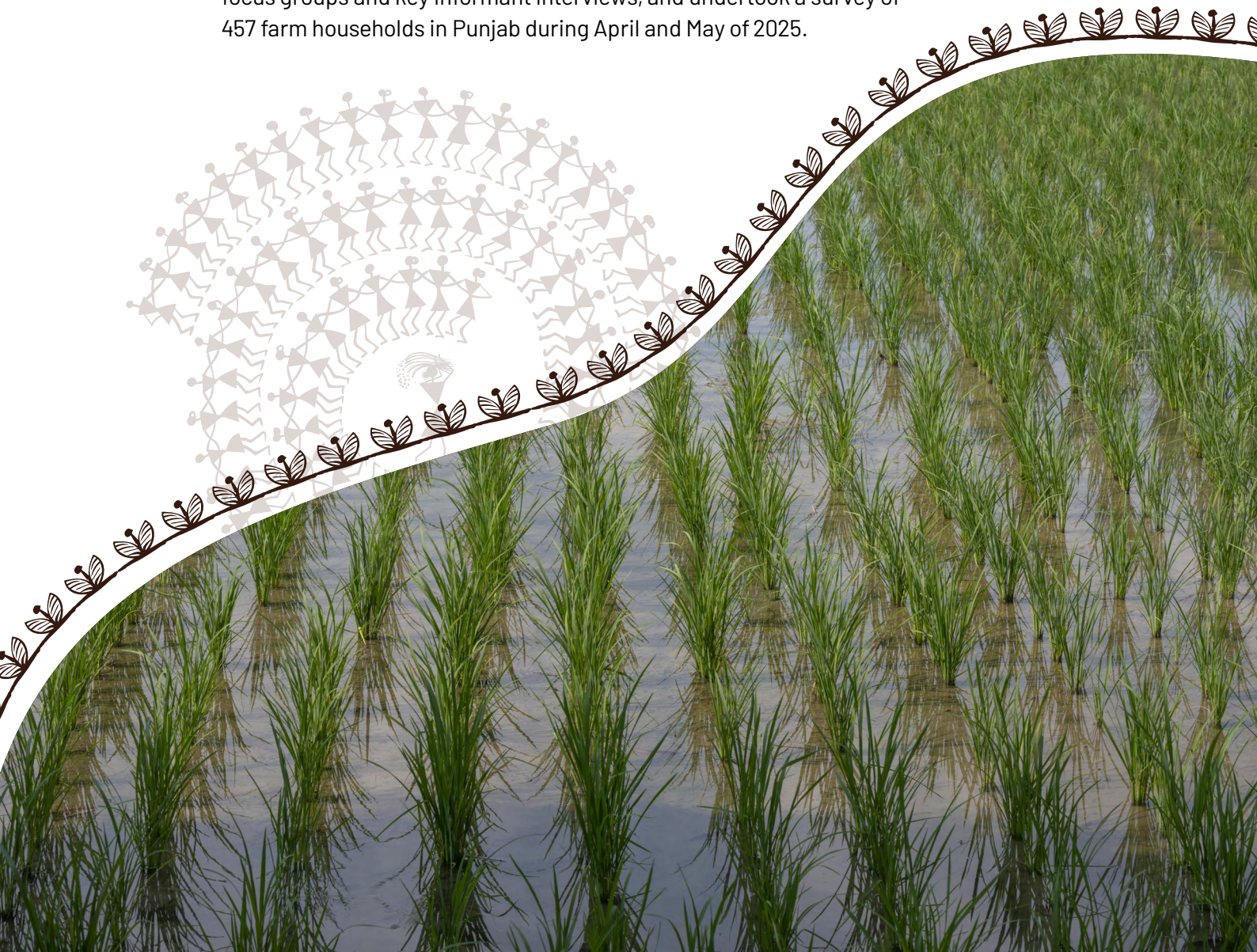
¹The corporation WIMCO brought poplar to Punjab in the 1980s by starting nurseries, supplying better plant varieties to farmers and using contract farming with buy-back deals. Later, ex-employees launched independent nurseries across Punjab (FRI 2020).



Since 2020, TNC's PRANA project has worked in 18 districts in Punjab to promote regenerative agriculture. In its next phase, PRANA seeks to encourage farm diversification into crops such as pear, poplar and cotton. This study provides background information to support PRANA's strategy for moving beyond the predominant rice-wheat system. Agroforestry, especially poplar cultivation due to strong market demand, is highlighted as a way to boost farm income, decrease residue burning, and improve soil health (Singh 2024).

This study aims to:

- Understand development of poplar agroforestry in Punjab and socio-economic differences between farmers who grow trees (adopters of agroforestry) and those who don't (non-adopters);
 - Assess the returns to investing in poplar cultivation for Punjabi farmers, factoring in land opportunity costs;
 - Examine farmer preferences for agroforestry incentives, including subsidies.
- To address these questions, we reviewed available literature, implemented focus groups and key informant interviews, and undertook a survey of 457 farm households in Punjab during April and May of 2025.



03. The Agroforestry System

In Punjab, farmers grow trees in block plantations or along field boundaries. Block plantation refers to the allocation of a minimum of 25 decimals of compact land area for tree planting (FAO 2003). In the boundary plantation system, poplar trees are planted along the edges of farm plots, allowing farmers to continue cultivating paddy and wheat within the main field. The trees that are generally grown in the state include poplar, eucalyptus and a variety of other trees as identified in Table A1.

Trees are often intercropped with wheat (or sugarcane) during the first few years. Farmers grow wheat during the first two winter seasons, while paddy cultivation is not feasible during the rainy season due to the high irrigation requirements and shade effects (Chavan & Dhillon 2019). Accumulation of woody biomass after the second year makes wheat cultivation in block plantations unviable beyond this period. Where farmers grow trees on boundaries (usually one side), they continue to grow rice and wheat. Poplar trees are generally harvested between five and six years after planting (Bhangu et al. 2024).

Tree crops can be sold in local markets (*mandis*) or transported to larger regional markets (for instance, in Yamunanagar, Haryana). However, most often, intermediaries purchase stands of trees and undertake the tasks of harvesting and transporting wood to markets. The intermediaries generally charge about 14% commission on the sale value of the trees from farmers for providing these services. When farmers bring their trees to local mandis, commission agents purchase wood at the market rate, subtracting a commission fee of 4% and a market fee of 2% from sale values, as indicated by interviews.

Agroforestry practices and access to institutional support varies across districts in Punjab. The Government of India's Sub-Mission on Agroforestry (SMAF) and the Crop Diversification through Agroforestry (CDAF) schemes have offered phased subsidies and technical guidance for agroforestry, but the ending of nursery support in 2023 may have lowered farmers' interest in and access to planting material. An institutional innovation is an E-Timber App that seeks to connect growers and buyers. Key informants suggested that while agroforestry promises good long-term returns, its adoption in Punjab is limited by delayed profits, wood price fluctuations, and weak institutional involvement.



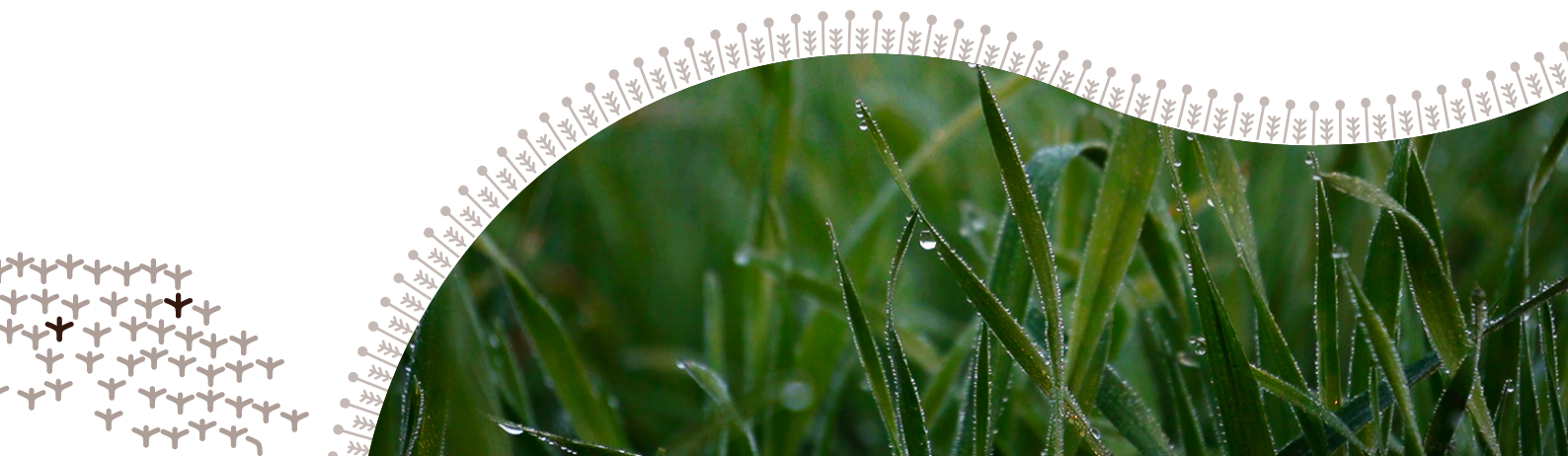
04. Data

The study was conducted in three districts of Punjab—Ludhiana, Gurdaspur and Amritsar. The selected districts encompass diverse agricultural landscapes, ranging from the intensively cultivated central plains of Ludhiana to the mixed irrigated–rainfed systems of Gurdaspur and the semi-arid conditions of Amritsar.

As a precursor to the household survey, we first undertook field visits in Patiala (November 2024) and Ludhiana (December 2024) to assess the operations, economics and institutional support for poplar and eucalyptus agroforestry systems in Punjab. We organized two focus group discussions with 11 and 12 farmers respectively. Additionally, we conducted six key informant interviews with two forest officials and four timber market stakeholders to understand how the agroforestry system worked in Punjab.

Our study utilizes primary data from a randomly selected sample of 457 households in 30 villages across the three districts (Ludhiana, Gurdaspur and Amritsar) collected in April and May 2025. District selection was conducted in consultation with TNC and based on local knowledge of farmers' tree-growing practices to identify districts with higher levels of agroforestry adoption as these were areas with farmers with more experience and interest in agroforestry. In addition, for ease of data collection within villages, our sampling focused on mid-sized villages within the selected districts, defined as those with 700 to 2,200 households (Census 2011).

We employed a two-stage stratified random sampling approach to select households for the survey within the identified districts. In the first stage, we categorized villages into those with a higher probability of poplar agroforestry adoption (stratum 1) and those with a lower probability of adoption (stratum 2), using information from the forest department and the PRANA field operations offices. Once the lists of villages for both strata were compiled, we randomly selected 20 villages from stratum 1 and 10 villages from stratum 2.



In the second stage, we stratified farmers in each of the 30 villages into two groups: those who grew commercial trees and those who did not. This stage used census information collected by the survey team upon arrival in each village. The team conducted this census to gather information on each farming household and to identify which households had tree plantations of poplar, eucalyptus and sheesham ([see Table A5](#) for the census questionnaire). Using these lists, we then randomized the selection of farmers to interview 15 households per village, identifying 39% of farmers who had planted trees and 61% who had not planted trees.

The household survey elicited information on demographic and farm characteristics; costs and revenues from crop and tree cultivation; preferences regarding hypothetical agroforestry programs; and exposure to government-supported agroforestry programs and commercial tree-growing activities. In addition to the household survey, a community informant was interviewed in each sampled village. These interviews enabled us to compile village-level information on socio-economic, infrastructure and market-related characteristics.



05. Descriptive Characteristics

Many factors affect the adoption of agroforestry, including farm and household traits, location, market access and government support (Arvola et al. 2020; Shyamsundar et al. 2022; Tacconi et al. 2022). Descriptive statistics provide an initial understanding of how farmers who undertake agroforestry may differ from those who don't.

[Table 1](#) and [Figure 1](#) and [Figure 2](#) summarize descriptive statistics for three farmer groups: farmers who plant poplar trees in block plantations, farmers who grow trees on plot boundaries, and non-tree growers. Notable differences are observed among the three groups in terms of key attributes.



Block plantation farmers have the largest average operational holdings (9.75 acres), followed by rice + wheat farmers (7.34 acres), then boundary plantation farmers (5.64 acres).



The average farmer age ranges from 48 (block) to 52 (boundary) years; formal education levels were similar across groups (~ nine years). Block farmers have a higher percentage of reserved caste households.



Block and boundary plantation farmers have similar tree-growing experience (12–13 years). A higher percentage of block plantation farmers have tree growers within their networks (70%) compared to boundary (43%) and rice + wheat (25%) farmers.



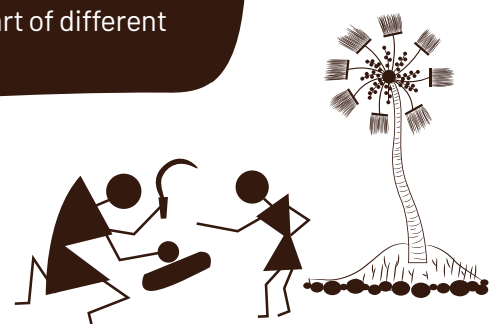
Formal sources of lending are lower among block farmers relative to other categories.



Some 52–55% of farmers expressed awareness of climate change.



Most farmers who had not participated in some form of agroforestry programs were largely unaware of the existence of such programs. A small number of farmers had received assistance to plant trees (3% of block plantation farmers; 0% in other groups) as a part of different agroforestry programs in the state.



[Figure 1](#) illustrates the distribution of boundary and block plantation systems among farmers with different landholding sizes in Punjab, India. Landholdings are categorized as small farms (≤ 5 acres), medium farms (between 5 and 8.5 acres), and large farms (> 8.5 acres). The figure shows that the share of large farmers adopting boundary plantation is substantially higher compared to medium and small farmers. At the same time, small farmers constitute a larger proportion of boundary plantation adopters within their own group, compared to medium and large farmers. This finding reinforces the conventional assumption that larger landholders are more likely to adopt long-rotation tree crops, as they can allocate land to trees without compromising household food security (Piñeiro et al. 2020; Messier et al. 2022). One possible explanation for the relatively higher adoption rate of boundary plantation among smallholders is that they may view agroforestry as a risk-hedging strategy, enabling them to diversify income sources and reduce their dependence on uncertain seasonal crop yields.

[Figure 2](#) illustrates the proportion of farmers who have other tree growers within their social networks, comparing boundary planters, block planters and non-adopters. The chart demonstrates that both types of adopters—farmers practicing boundary and block plantations—are much more likely to have tree-growing peers in their network than those who have not adopted agroforestry. This pattern highlights the significance of social influence: when tree-growing is visible within a farmer's immediate community, it encourages others to consider and adopt similar practices. The higher presence of adopters in social networks facilitates the spread of practical knowledge, demonstrates viability, allows for information exchanges, reduces uncertainties around agroforestry systems and helps lower the perceived risks and transaction costs linked with moving from conventional cropping to tree-based systems (Lapple & Kelley 2015).

In summary, block plantation farmers typically have larger farms and a wider network of tree-growing farmers. Boundary plantation farmers are often smallholders who depend on formal credit and are prominent in Gurdaspur. Non-tree growers have less experience and fewer tree-related connections but better access to government services and markets. These distinctions highlight unique opportunities and challenges for each group in adopting agroforestry.



06. Returns to Farmers from Growing Poplar trees

In this study we seek to understand the Returns on Investment (RoI) to poplar agroforestry in Punjab. Cost-Benefit Analysis (CBA) is a tool that quantifies the potential returns on varied investments, enabling decision-makers to assess the viability of various projects. We use this systematic approach to evaluate the economic advantages and disadvantages of different farm-level actions by comparing their expected financial costs and anticipated benefits to farmers.

CBA can help illustrate the financial implications of tree-related investments. Through careful assumptions about factors like tree growth rates, time to maturity and market demand for tree products, we can evaluate how farmers may be able to make informed choices about whether to allocate resources toward poplar as a tree crop. Understanding these returns aligns farm-level economic goals with environmental benefits. In this report, our analyses focus on the private financial benefits from tree-crop production — we do not estimate social and environmental benefits. We discuss below how we estimate the financial returns to farmers from poplar-based agroforestry. All comparisons are provided for the year of the survey, i.e., at 2025 prices.

[Table 2](#) compares key attributes of three farming systems in Punjab: poplar-based block (with wheat) plantations, boundary (with rice-wheat) plantations, and the conventional rice-wheat system. As the table shows, the majority of observations in our sample are associated with rice and wheat farmers (282), followed by poplar and wheat block plantation farmers (131), and poplar boundary plantation farmers (44). Block plantation farms have an average tree-growing area of 2.42 acres, representing 43% of their operational area (boundary plantations and rice-wheat farms do not report tree growing areas). Block plantations average 837 trees per farm (360 per acre), while boundary plantations have 146 trees (66 per acre). Tree crops of the farmers in our sample were at the early stages — block plantations report an average growing duration of 1.5 years, slightly longer than boundary plantations (1.3 years).

[Table 3](#) and [Table 4](#) present the streams of costs and returns associated with poplar-based agroforestry under intercropping and boundary plantation systems, respectively. The analysis assumes a five-year rotation cycle for poplar, consistent with insights from

focus group discussions and prevailing practices in the area. Other key assumptions underlying the analyses include a) 80% tree survival rate after five years; b) average poplar roundwood price INR 1,000/quintal; c) 10% discount rate; d) availability of timber markets when harvests are completed; e) with block plantations, a wheat crop is planted during the first two years; and f) boundary plantations are grown alongside annual rice-wheat crops. Further details are presented in the note under 'Supplementary Information'.

Table 3 outlines the stream of costs and returns for poplar-based agroforestry using block plantations over five years, expressed in Indian rupees (INR):



The first year incurs the highest operational cost (INR 19,197), while years 2–4 maintain a lower, steady cost (INR 8,379 each). Year 5 sees a significant increase (INR 1.09 lakhs) with tree harvesting costs.



Crop-related costs (INR 4,963) are only present in years 1 and 2, then drop to zero from year 3 onward.



Total costs are highest in year 1 (INR 24,920), decrease in year 2 (INR 13,342), remain low in years 3 and 4 (INR 8,379 each), and rise sharply in year 5 (INR 1.09 lakhs).



Substantial wheat intercropping revenue (INR 56,273) is realized in years 1 and 2; no revenue is generated in subsequent years.



There is no tree harvest revenue until year 5, when a significant income (INR 7.19 lakhs) is recorded.

Overall, the initial years feature moderate costs and wheat revenue, while the fifth year of block plantations is characterized by high costs and a substantial return from tree harvest.

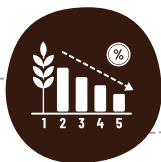
Table 4 provides a breakdown of cash flows, costs and revenues for poplar boundary plantations + Rice–wheat over a five-year period:



Average annual tree operational costs range from INR 2,846 to INR 26,626, with crop harvest costs consistently at INR 32,525 each year. The total annual costs (operational plus harvest) increase significantly in year 5, reflecting higher expenses associated with the final tree harvest.



Each year, the average revenue from wheat intercropping is INR 1.30 lakhs, indicating consistent income from this activity throughout the five years.



Wheat crop revenues are assumed to moderately decline in years 4 (3%) and 5 (4%) as the trees grow bigger and there is competition for light and water, following Bhangu et al. (2024).



No revenue from tree harvest is realized in the first four years, but in year 5, a substantial income of INR 1.3 lakhs is generated, corresponding to poplar harvest.

These results highlight the profitability of integrating wheat and poplar cultivation, with regular annual returns from wheat and a significant lump sum from poplar harvest at the end of the cycle.

[Table 5](#) presents the estimated Net Present Value (NPV), Annualized Rate of Return (ARR) and Benefit–Cost Ratio (BCR) for block and boundary plantations over a five-year cycle. The table outlines the financial performance of three agricultural strategies, emphasizing the Net Present Value (NPV) metrics. Notably, block plantations demonstrate a strong average NPV of INR 4.3 lakh. Boundary plantations also show a high average NPV of INR 4.1 lakh per acre, as these farmers earn returns from both annual (rice–wheat) crops (average NPV of INR 2.85 lakh) and boundary trees (average NPV of INR 1.25 lakh). Crop production (rice–wheat without any trees) reflects an average NPV of INR 3 lakh per acre on average.

The average returns (NPV) to block plantations, considering opportunity costs, is ~INR 1.28 lakh per acre. This is what farmers would gain if they shifted from rice–wheat farming to poplar block plantations. Thus, block plantations remain economically beneficial even though farmers will lose their regular annual rice–wheat revenue if they make the shift. Farmers will, however, earn some annual crop income during the initial years before trees grow to the extent that



this is not possible. The benefit–cost ratio for block plantations, taking opportunity costs into account, suggests that if a farmer puts in INR 1 investment in block plantations, they will earn INR 1.29 back.



However, if a farmer shifted from rice–wheat to poplar boundary plantations, they could continue to grow rice and wheat, obtaining an annual income from annual crop production during all five years. If a rice–wheat farmer added a boundary poplar plantation to their field, they would increase the NPV of their income by INR 1.25 lakh from the tree crop, even though they would lose some food crop income in later years from competition between the tree and food crops. Still, growing trees on boundaries alongside rice and wheat is more profitable than just growing rice and wheat, making boundary plantations more attractive to farmers who want to manage tree and annual crops on their plots.

Other metrics (see Table 5) can be used to evaluate profits to farmers, including the annualized return on investment, which converts the NPV over a five-year period to an annual value, making it easier to compare tree crops to annual crops. The Associated Annualized Returns (ARR1) are ~INR 1.14 lakh for block, ~INR 1.08 lakh for boundary + rice–wheat and ~INR 80,000 for annual rice–wheat crops. As we can see ARR1 is higher for tree crops relative to annual crops, making tree crops more profitable. The benefit–cost ratio for an acre of land in block plantations (not accounting for opportunity costs) is 5.28 relative to 3.75 for boundary plantations (with rice–wheat) and 2.68 for annual rice–wheat crops (without tree crops).

[Figure 3](#) is similar to Table 5 and compares net present value (NPV), benefit–cost ratio (BCR), and annual rate of return (ARR) from block plantation and boundary plantation, both under a wheat and poplar system, against the business–as–usual farming i.e., the wheat and paddy system. Overall, the poplar–based agroforestry block plantation demonstrates high initial returns, but profitability decreases when accounting for income forgone from traditional cropping systems. For smallholders who may need to better balance risk and return, boundary plantations are advantageous.

We note that the estimated cost of intercropping in our study is lower than that reported by Bhangu & Kaur (2018) and Chavan et al. (2022a), possibly due to the relatively younger





age of poplar trees among the sampled households and/or higher tree density, which may substantially reduce crop cultivation costs. Furthermore, while (Chavan et al. 2022b) examined boundary plantations integrating poplar with wheat and sorghum, farmers in our study predominantly combined poplar with wheat and paddy, which may account for some observed differences. Additionally, the estimated returns from the wheat-paddy system are slightly higher than those reported by Esar et al. (2023) and Sonker & Kallummal (2025). This divergence may reflect the use of a more comprehensive cost of cultivation dataset, differences between basmati and non-basmati paddy, and inter-annual variations in the Minimum Support Price (MSP) and market prices of wheat and paddy. Our adjusted estimates that include opportunity costs align more closely with those reported by Bhangu & Kaur (2018) and Chavan & Dhillon (2019).

So far, our discussion has focused primarily on the private returns from poplar-based agroforestry. Although a poplar + wheat system may generate substantially higher returns than the conventional wheat + paddy system, concerns remain regarding its implications for groundwater resources. This issue is particularly relevant in Punjab, where the groundwater table has declined by an average of 69.8 cm per year over the last two decades (Singla et al. 2022). After the initial rotation years, mature poplar trees may access groundwater directly through deeper root systems. At present, however, there is no conclusive evidence establishing aquifer depletion specifically attributable to poplar cultivation in Punjab. Existing evidence from other regions suggests that hydrological effects are highly context-specific and depend on local climate, soil and baseline land use. For example, in the Mediterranean basin of Spain, poplar plantations were estimated to consume approximately 20% of aquifer recharge and 46% of summer stream flow (Folch & Ferrer 2015). In contrast, evidence from Belgium shows that commercial-scale poplar plantations reduced overall water use by 18% relative to grassland systems (Bloemen et al. 2017).

A direct comparison of aquifer depletion under the predominant wheat + paddy system versus poplar-based agroforestry is beyond the scope of the present study. However, an important extension of this research would be to examine whether farmers adopting poplar-based agroforestry are concentrated in areas with relatively shallow groundwater tables, where such systems may be more feasible.

Examining price uncertainty in block plantations

To evaluate the sensitivity of profitability to timber price variation alone, we conduct a Monte Carlo simulation of NPVs for poplar block plantations. The deterministic baseline assumes a roundwood price of INR 1,000 per quintal. However, available market evidence suggests that poplar prices in the Yamunanagar timber mandi—a key benchmark market for Punjab growers—varied between INR 800 and INR 1,500 per quintal during 2022–2025 (Ply Reporter 2024; TreeKisan 2024). Using these observed price bounds, we estimate three summary statistics from the Monte Carlo simulation: mean NPV, standard deviation of NPV, and the probability of negative NPV (loss). Three price scenarios are considered:

The Monte Carlo procedure generates a distribution of NPV2, which incorporates opportunity costs. Figure 4 presents the simulated density curves and summary statistics for the three scenarios. Across all cases, the estimated distributions suggest that poplar block plantations remain economically viable, although the variability of returns and downside risk differ substantially across price levels.

Under Scenario 1, the expected NPV is INR 1.28 lakhs, with a 23% probability of loss. Under the low-price Scenario 2, the expected NPV declines to INR 1.02 lakhs, while the probability of loss rises to 26%. In contrast, under the high-price Scenario 3, the expected NPV increases to INR 1.91 lakhs, accompanied by a decline in the probability of loss to 19%. It is important to note that the estimated NPV in the baseline scenario is negative in 23% cases potentially due to higher operational costs arising from labor and non-labor inputs, as well as suboptimal seedling planting practices, which are likely to reduce timber yield. These results indicate that while poplar block plantations remain profitable on average, timber prices play a crucial role in shaping both expected returns and investment risk.



Scenario 1 (Benchmark)

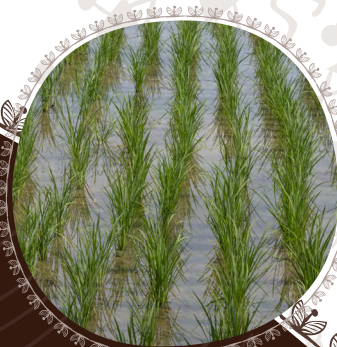
- Poplar price = INR 1,000 per quintal

Three price scenarios are considered:



Scenario 2 (Low price)

- Poplar price = INR 800 per quintal



Scenario 3 (High price)

- Poplar price = INR 1,500 per quintal

07. Incorporating Farmer Preferences into Agroforestry Support Design

Our second objective is to understand how farmers could be further motivated to undertake agroforestry. To design an agroforestry program that could incentivize farmers in Punjab to grow poplar trees, we conducted a choice experiment to elicit farmer preferences regarding agroforestry. A Choice Experiment (CE) is a survey-based method that elicits individuals' preferences by asking them to make choices among hypothetical alternatives, after providing them with clear information on the potential benefits, costs and characteristics of each option.

The Government of Punjab intends to promote agroforestry potentially through subsidies.² There is also varied interest among different stakeholders in using voluntary carbon markets for financing agroforestry (TERI 2020).³ Taking these considerations into account, we conducted a choice experiment within the farm household survey to assess farmers' interests and guide agroforestry program design in Punjab.

The choice experiment was developed in accordance with established best-practice guidelines (Johnston et al. 2017). Preliminary consultations with farmers and key informants highlighted essential components for an effective agroforestry support program, while pilot activities helped to identify the support levels worth evaluating to analyze adoption. Subsequently, data were collected on farmer preferences for different elements of an incentivized agroforestry scheme. Prior to gathering this feedback, farmers received comprehensive information regarding the benefits and costs associated with tree planting, program specifics and the importance of their input for policy development.

²<https://indianexpress.com/article/cities/chandigarh/punjab-scheme-is-helping-farmers-earn-diversify-conserve-9531747/>

³<https://www.global-agriculture.com/india-region/teri-verra-dialogue-paves-the-way-for-inclusive-carbon-markets-in-india/>



Drawing upon local insights from key informant interviews and focus group discussions, five components of a potential agroforestry program were identified for inclusion in the survey:



Technical assistance:

Recognizing that tree cultivation is unfamiliar to many farmers, technical assistance was designated as an indispensable element of any program variant offered.



Financial support:

Given the initial expenses involved in tree planting, financial incentives are critical, the experiment incorporated subsidy options at varying levels to reflect possible support mechanisms.



Insurance:

Due to expressed uncertainties surrounding tree planting, an insurance mechanism was included to mitigate potential financial losses resulting from unforeseen events.



Participation in a carbon project:

While most farmers lacked experience with carbon funding, detailed information about carbon project financing and its relevance was provided and verified for applicability.



Payment periods:

As carbon project disbursements may occur over extended timelines, different payment periods were examined to account for variations in return on investment.

Before soliciting farmer preferences over different aspects of the agroforestry support, we provided farmers with thorough explanations of these components along with a visual aid (Figure 5). Following this orientation, each farmer was presented with four randomly selected choice cards, each accompanied by its own visual card—which offered two program alternatives and a third option: no participation in the poplar program. Surveyed farmers indicated their preferred option for each card. Figure 6 illustrates an example choice card. We analyzed farmer responses to identify preferences for different aspects of an agroforestry program.

To interpret adoption preferences accurately, it is crucial to understand the farmers' baseline conditions, also referred to as 'status quo' conditions, as these influence their assessment of program options. Three key points about our sample's circumstances are:

- adoption of poplar plantations is very low, representing only about 1.2% of cultivated area in Punjab;
- at the time of the survey, very few farmers had heard of (1.3%) or participated in (0.8%) government-supported agroforestry programs; and
- only 3% of sampled farmers had heard of carbon projects. These figures demonstrate both low awareness of agroforestry programs and carbon projects in Punjab and that most respondents were not considering other support mechanisms when completing the survey.



Factors influencing program adoption

The results from the CE show that, on average, increased availability of subsidies, insurance and opportunities to participate in carbon projects all positively influence the likelihood of adoption. The five program components are highly relevant (statistically significant at $p < 0.001$) to farmers' participation decisions (see [Table A3](#) in SI)

Several farmer characteristics, risk perceptions, prior experience with tree planting, age, and education influence their agroforestry adoption. Using logistic functions, we evaluate the impact of these variables on preferences for different program components. [Table A4](#) in the SI section summarizes the models in which we find statistical significance.⁴

The analyses also indicate that younger farmers tend to show greater interest in insurance options, carbon projects and subsidies. Interest in insurance is also more prevalent among farmers exposed to pest risks, those requiring access to credit and those with prior tree-planting experience. Participation in carbon projects is of greater interest to farmers who need credit and those with previous tree-planting experience. Interest in subsidies is common overall but appears more pronounced among farmers with prior experience, established social networks of other tree planters and credit needs.

Agroforestry adoption with financial and insurance support

Changes in program design can shift the likelihood of farmers adopting these programs. Thus, we examine scenarios with distinct program designs to estimate adoption probabilities, projected areas of tree planting and associated costs. Results are reported separately for two groups: farmers with existing poplar block plantations and those who have not grown poplars before.⁵

⁴The models included in the table are limited to those with statistically significant demographic and contextual variables.

⁵This distinction is made for two reasons: a) Our survey intentionally included more poplar-growing farmers, as we aimed to assess the costs and benefits of poplar plantations. To ensure accurate analysis and projections, we correct for this oversampling and compare our sample to the broader population. b) The results reveal that adoption rates vary dramatically between these two groups. Therefore, recognizing these differences is important when developing agroforestry initiatives.



We start by exploring how financial incentives like subsidies and insurance can motivate farmers in Punjab to take up agroforestry. During our conversations about cost subsidies, we informed farmers that establishing poplar plantations typically requires an investment of INR 15,000 to 20,000 in the first year, with ongoing annual costs ranging from INR 10,000 to 15,000 thereafter. We then outlined subsidy options from the agroforestry program, which offered different levels of financial assistance based on the total anticipated costs.

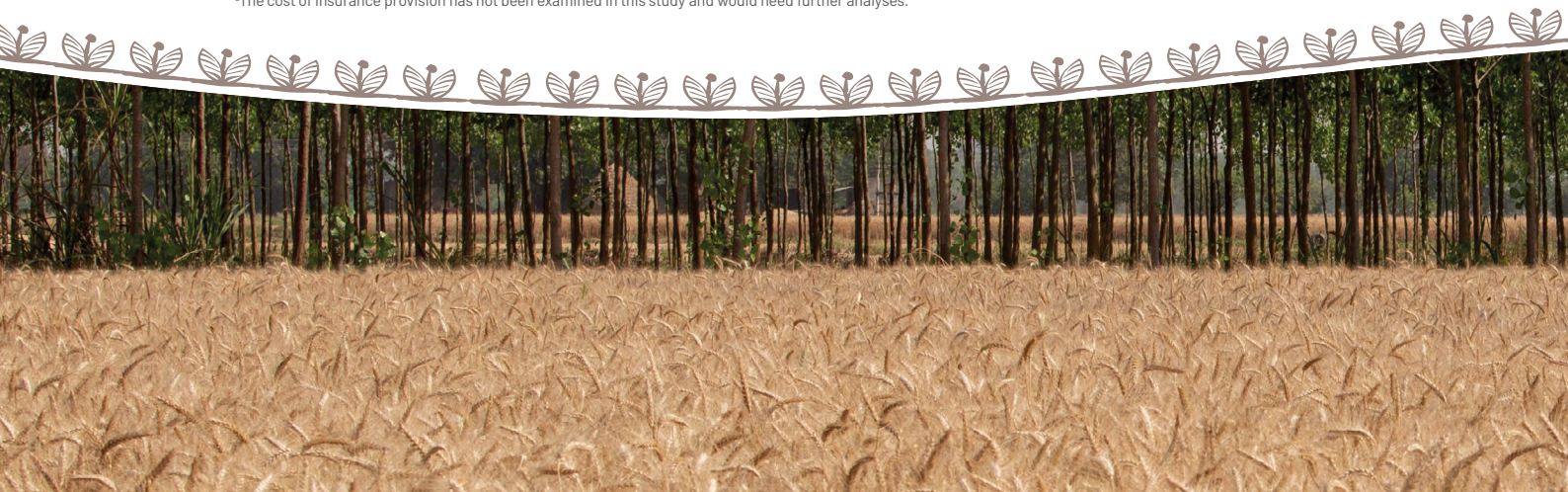
[Figure 7](#) presents the estimated adoption levels under the scenario of providing financial support through a subsidy. For farmers without block plantations, adoption could range from 3.5% to 8% as the subsidy increases from 10% to 75%, respectively. For farmers with block plantations, adoption could range from 14% to 30% as the subsidy increases from 10% to 75%, respectively. The probability of adoption at a 0% subsidy reflects farmers' interest in receiving support through an agroforestry program offering technical assistance (regardless of the subsidy level they might receive).

In a second scenario, we assess how farmer adoption of agroforestry may change if they were additionally provided with insurance to reduce risks. [Table 6](#) shows several risks that worry farmers in Punjab when incorporating trees in their farmlands. To address these perceived risks, we included insurance as a program component. Thus, we informed farmers if they were willing to pay a premium price for insurance of INR 1,500 per acre per year, insurance would cover 50% of the costs of losses resulting from matters outside the control of the farmer. [Figure 8](#) shows the estimated probabilities of program adoption for farmers without any previous experience and [Figure 9](#) shows those with previous experience. Both figures indicate that there is a significant increase in adoption when insurance is offered in addition to technical assistance and cost subsidies.

Evaluating a potential 30% subsidy program

The government in Punjab is potentially interested in subsidizing agroforestry. If the government offers a 30% cost-sharing subsidy, it will subsidize the costs farmers have to incur in planting and caring for trees up to their harvest. Our analysis suggests that a 30% subsidy (~INR 4,500/acre/year) on costs would increase the probability of adoption to 5% for farmers who do not have yet block plantations trees ([Figure 10](#)) and to 18% by farmers who already have block-plantation trees ([Figure 11](#)). Our analysis further shows that if, in addition to a 30% subsidy analyses, farmers were given access to insurance⁶, the probability of adoption would increase further from 5% to 7.5% for farmers without tree plantations, and from 18% to 27% for farmers with tree plantations. Overall, both costs and risks are important issues when farmers consider tree planting on their own lands.

⁶The cost of insurance provision has not been examined in this study and would need further analyses.





These estimated adoption probabilities can be used to assess possible areas of agroforestry expansion (taking farmers' preferences into account) and program costs. We used available Census data (2011), along with the estimated population growth rate in Punjab (9%), to calculate the number of farmers in the state. We also estimated the number of farmers with block plantations, based on the current estimate that 1.4% of cultivated area in Punjab is under poplar plantation. [Table 7](#) presents these estimates, as well as our calculations of expected increases in poplar agroforestry area under a 30% subsidy scenario. For this calculation, we used information collected during our survey regarding the area farmers would be willing to plant in poplar. As shown in [Figure 10](#) and [Figure 11](#), these areas differ significantly between farmers with and without existing tree plantations.

With a 30% cost-sharing subsidy and technical assistance for poplar tree plantations, the expected increase in poplar tree block plantation area is approximately 26,000 acres. The cost of this five-year cost-sharing subsidy program would be approximately INR 5,200 lakhs (USD 6 million), not taking into account any costs associated with technical assistance.

Additional considerations

We also evaluated whether carbon projects, through financial compensation, could incentivize farmers to adopt agroforestry practices. Initial results point to significant differences in adoption probabilities among farmers who already grow trees in block plantations and those who do not. Other important factors that affect adoption include the timing of compensation payments i.e., the years during which payments are made.

During the survey, we asked respondents about their most important motives for either participating or not participating in an agroforestry program. In the context of the suggested programs, of the 206 farmers who indicated in any of the four cards that they would not participate, the main reasons for non-participation included: (i) they do not have extra land; (ii) the long waiting time for income generation; and (iii) concern that tree planting might affect other crops. In contrast, farmers also reported motives for participation. Among the 300 farmers who indicated in at least one program card that they would participate, the most important reasons were to increase their farm revenues and household income. To a lesser extent, they also reported interest in contributing to environmental protection. These are important considerations to take into account in program design.



08. Conclusions and Recommendations

Poplar-based agroforestry presents a compelling opportunity for enhancing the economic sustainability and diversification of farming systems in Punjab. The comparative analysis of block and boundary plantations reveals distinct advantages and challenges for each approach. Block plantations, while requiring higher initial investments, offer substantial financial returns at the time of timber harvest and have net returns far higher than crop-wheat systems. In contrast, boundary plantations allow farmers to maintain their traditional rice-wheat cultivation, generating steady annual income and consistent positive net returns throughout the rotation cycle.

Economic outcomes across agroforestry systems are sensitive to several factors, including crop combinations, tree density, rotation length and market dynamics. Additionally, current agroforestry adoption patterns highlight the importance of system suitability and farmer characteristics. Boundary plantations are more readily adopted by small and medium farmers due to minimal impacts on wheat-rice yields and lower costs. Block plantations, with their higher financial returns, may require additional support to mitigate risk and upfront costs of investment.

The success of agroforestry adoption in Punjab is also influenced by non-economic factors. Persistent barriers—such as limited available land, concerns over delayed income and perceived negative impacts on other crops—underscore the need for clearer, more transparent communication.

Financial incentives—including cost subsidies and insurance—are effective in encouraging agroforestry, particularly among farmers already engaged in tree planting. However, since the majority of Punjab's farmers have yet to adopt these practices, targeted strategies for first-time adopters are essential. Even modest increases in adoption among this group could drive substantial expansion of agroforestry in the state.

Heterogeneity analysis indicates that younger farmers and those seeking credit are especially receptive to agroforestry innovations, insurance and carbon project options. Social networks are also a critical channel for disseminating information and sustaining adoption momentum, especially in the early stages.

While our analysis demonstrates strong economic returns to poplar-based agroforestry under both block and boundary configurations, several water-resource concerns (Singla et al 2022) warrant attention before recommending large-scale expansion in Punjab's groundwater-stressed context. First, if poplar were to expand, there is a water savings



case to be made that rests primarily on poplar replacing kharif rice—the dominant driver of Punjab's groundwater deficit. If poplar is instead added to existing rice–wheat fields as boundary plantations without reducing the rice area, the net effect on groundwater may be neutral or even negative, since mature poplar trees can increase localized water extraction (Folch & Ferrer 2015; Bloemen et al. 2017). Second, the water-use implications of block versus boundary expansion at landscape scale remain unstudied in the Punjab context. Additionally, no direct, multi-year comparative measurement of annual water balance (irrigation + evapotranspiration + groundwater uptake) for poplar agroforestry versus rice–wheat exists for Punjab. Filling this gap should be a research priority before scaling policy incentives.



Key recommendations emerging from these analyses include:



Integrate poplar-based agroforestry into Punjab's crop diversification strategies to reduce overdependence on rice and enhance farm resilience.



Provide technical support, especially regarding optimal spacing, pruning and survival techniques for both boundary and block plantations.



Offer financial incentives and insurance packages to lower initial investment barriers and mitigate risk, with special emphasis on farmers who have already shown interest in or have experience with tree planting



Address persistent adoption barriers by providing clear information on crop impacts, integration methods and transparent revenue versus cost projections, to dispel misconceptions and manage expectations.



Distinguish between large and small landowners as boundary plantations may be of more interest to small farmers with block plantations appealing to large farmers.



High uncertainty results in high income risk and lower probability of profitability. Therefore, insurance or price stability mechanisms can enhance the reliability of poplar intercropping returns.



Develop targeted outreach and communication strategies for younger farmers and credit-seeking individuals, highlighting the benefits and flexibility of program components.



Leverage social networks and farmer organizations to accelerate early adoption and sustain long-term program momentum.



Examine the water use implications of poplar agroforestry versus rice–wheat farming in Punjab.

References

Anand, S., Shyamsundar, P., Cardenas, H., Saigal, S. & Saigal, C.M. (2025). Agroforestry: Unlocking the Potential of Trees in India. Cool Green Science.

Arvola, A., Brockhaus, M., Kallio, M., Pham, T.T., Chi, D.T.L., Long, H.T., Nawir, A.A., Phimmavong, S., Mwamakimbullah, R. & Jacovelli, P. (2020). What Drives Smallholder Tree Growing? Enabling Conditions in a Changing Policy Environment. Forest Policy and Economics, 116, 102173.

Bhangu, P.K.S., Gohain, N. & Kaur, M. (2024). Enhancing Farm Profitability through Boundary Plantation of Poplar and Eucalyptus in Punjab. JADP, 34, 117-122.

Bhangu, P.K.S. & Kaur, M. (2018). Economic Evaluation of Poplar Based Agro-forestry System in Punjab. EA, 63.

Bloemen, J., Fichot, R., Horemans, J.A., Broeckx, L.S., Verlinden, M.S., Zenone, T. & Ceulemans, R. (2017). Water Use of a Multigenotype Poplar Short-Rotation Coppice from Tree to Stand Scale. GCB Bioenergy, 9, 370-384.

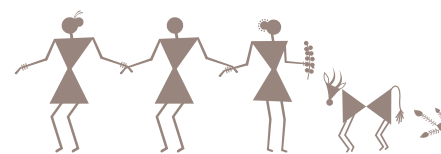
Chavan, S.B. & Dhillon, R.S. (2019). Doubling Farmers' Income through Populus deltoides-Based Agroforestry Systems in Northwestern India: An Economic Analysis. Current Science, 117, 219.

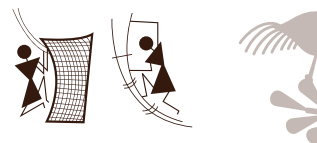
Chavan, S.B., Dhillon, R.S., Ajit, Rizvi, R.H., Sirohi, C., Handa, A.K., Bharadwaj, K.K., Johar, V., Kumar, T., Singh, P., Daneva, V. & Kumari, S. (2022a). Estimating Biomass Production and Carbon Sequestration of Poplar-Based Agroforestry Systems in India. Environ Dev Sustain, 24, 13493-13521.

Chavan, S.B., Dhillon, R.S., Sirohi, C., Keerthika, A., Kumari, S., Bharadwaj, K.K., Jinger, D., Kakade, V., Chichaghare, A.R., Zin El-Abedin, T.K., Mahmoud, E.A., Casini, R., Sharma, H., Elansary, H.O. & Yessoufou, K. (2022b). Enhancing Farm Income through Boundary Plantation of Poplar (Populus deltoides): An Economic Analysis. Sustainability, 14, 8663.

Chavan, S.B., Keerthika, A., Dhyani, S.K., Handa, A.K., Newaj, R. & Rajarajan, K. (2015). National Agroforestry Policy in India: A Low Hanging Fruit. Current Science, 1826-1834.

Dhaliwal, S.S., Naresh, R.K., Walia, M.K., Gupta, R.K., Mandal, A. & Singh, R. (2020). Long-Term Effects of Intensive Rice-Wheat and Agroforestry Based Cropping Systems on Build-Up of Nutrients and Budgets in Alluvial Soils of Punjab, India. Archives of Agronomy and Soil Science, 66, 330-342.





Esar, B.A., Sachdeva, J. & Mouzam, S.M. (2023). Cost of Cultivation and Production of Various Crops in Punjab. JADP, 33, 253–259.

FAO. (2003). Training Manual on Inventory of Trees Outside Forests (TOF). Food and Agriculture Organization.

Folch, A. & Ferrer, N. (2015). The Impact of Poplar Tree Plantations for Biomass Production on the Aquifer Water Budget and Base Flow in a Mediterranean Basin. Science of The Total Environment, 524–525, 213–224.

Government of India. (2014). National Agroforestry Policy 2014.

Jain, S.K. & Singh, P. (2000). Economic Analysis of Industrial Agroforestry: Poplar (*Populus deltoides*) in Uttar Pradesh (India). Agroforestry Systems, 49, 255–273.

Johnston, R.J., Boyle, K.J., Adamowicz, W. (Vic), Bennett, J., Brouwer, R., Cameron, T.A., Hanemann, W.M., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R. & Vossler, C.A. (2017). Contemporary Guidance for Stated Preference Studies. Journal of the Association of Environmental and Resource Economists, 4, 319–405.

Lapple, D. & Kelley, H. (2015). Spatial Dependence in the Adoption of Organic Drystock Farming in Ireland. European Review of Agricultural Economics, 42, 315–337.

Messier, C., Bauhus, J., Sousa-Silva, R., Auge, H., Baeten, L., Barsoum, N., Bruelheide, H., Caldwell, B., Cavender-Bares, J., Dhiedt, E., Eisenhauer, N., Ganade, G., Gravel, D., Guillemot, J., Hall, J.S., Hector, A., Hérault, B., Jactel, H., Koricheva, J., Kreft, H., Mereu, S., Muys, B., Nock, C.A., Paquette, A., Parker, J.D., Perring, M.P., Ponette, Q., Potvin, C., Reich, P.B., Scherer-Lorenzen, M., Schnabel, F., Verheyen, K., Weih, M., Wollni, M. & Zemp, D.C. (2022). For the Sake of Resilience and Multifunctionality, Let's Diversify Planted Forests! Conservation Letters, 15, e12829.

Metzel, R. & Montagnini, F. (2014). From Farm to Forest: Factors Associated with Protecting and Planting Trees in a Panamanian Agricultural Landscape. Bois for. trop., 322, 3–15.

Pandey, D. (2008). Trees Outside the Forest (TOF) Resources in India. int. forest. rev., 10, 125–133.

Paul, C., Weber, M. & Knoke, T. (2017). Agroforestry Versus Farm Mosaic Systems—Comparing





Land-Use Efficiency, Economic Returns and Risks Under Climate Change Effects. *Science of The Total Environment*, 587–588, 22–35.

Piñeiro, V., Arias, J., Dür, J., Elverdin, P., Ibáñez, A.M., Kinengyere, A., Opazo, C.M., Owoo, N., Page, J.R., Prager, S.D. & Torero, M. (2020). A Scoping Review on Incentives for Adoption of Sustainable Agricultural Practices and Their Outcomes. *Nat Sustain*, 3, 809–820.

Ply Reporter. (2024). Poplar Timber Prices Touches New All Time High Mark. plyreporter.com.

Reed, J., Van Vianen, J., Foli, S., Clendenning, J., Yang, K., MacDonald, M., Petrokofsky, G., Padoch, C. & Sunderland, T. (2017). Trees for Life: The Ecosystem Service Contribution of Trees to Food Production and Livelihoods in the Tropics. *Forest Policy and Economics*, 84, 62–71.

Rizvi, R.H., Handa, A.K., Sridhar, K.B., Singh, R.K., Dhyani, S.K., Rizvi, J. & Dongre, G. (2020). Spatial Analysis of Area and Carbon Stocks Under *Populus deltoides* Based Agroforestry Systems in Punjab and Haryana States of Indo-Gangetic Plains. *Agroforest Syst*, 94, 2185–2197.

Shyamsundar, P., Cohen, F., Boucher, T.M., Kroeger, T., Erbaugh, J.T., Waterfield, G., Clarke, C., Cook-Patton, S.C., Garcia, E., Juma, K., Kaur, S., Leisher, C., Miller, D.C., Oester, K., Saigal, S., Siikamaki, J., Sills, E.O., Thang, T., Trihadmojo, B., Veiga, F., Vincent, J.R., Yi, Y. & Zhang, X.X. (2022). Scaling Smallholder Tree Cover Restoration Across the Tropics. *Global Environmental Change*, 76, 102591.

Singh, S. (2024). Promoting High Value Crops in Punjab: A Value Chain Analysis

Singh, S. & Singh, A. (2018). Socioeconomic Impact of Agroforestry in Ludhiana (Punjab). *The Indian Journal of Agricultural Sciences*, 88, 1859–1863.

Singla, C., Aggarwal, R. & Kaur, S. (2022). Groundwater Decline in Central Punjab–Is It a Warning? *Groundwater for Sustainable Development*, 16, 100718.

Sonker, A.P. & Kallummam, M. (2025). Trade and Sustainability Challenges in India: Possibilities for Paddy Crop in Punjab.

Taconi, F., Waha, K., Ojeda, J.J. & Leith, P. (2022). Drivers and Constraints of On-Farm Diversity. *A Review. Agron. Sustain. Dev.*, 42, 2.

TERI. (2020). Developing Voluntary Carbon Market Projects for Agroforestry Plantations in Five Selected Districts of Punjab.

TERI. (2021). Will India Attain Its Forestry NDC Target of Achieving 2.5–3 Billion Tonnes of CO₂ Equivalent Through Additional Forest and Tree Cover by 2030? *The Energy and Resource Institute*.

TreeKisan. (2024). Government Tree Plantation Schemes in India 2024.



Figures and Tables

Table 1: Descriptive statistics of household, farm, jurisdiction, market and government facilities by tree growers

Variable/ No. of observations	Description	Tree-Crop Farmers		Non-Tree-Crop Farmers
		Block plantation (poplar + wheat)	Boundary plantation	Rice + wheat farmers
No. of observations		131	44	282
Household and farm characteristics				
Operational land holdings (acres)		9.75 (1.18)	5.64 (0.82)	7.34 (0.5)
Age (years)	Integer	48 (1.1)	52 (2.26)	51 (0.77)
Years of formal education (years)	Integer	9 (0.35)	9 (0.93)	9 (0.20)
Distance of main plot from home (km.)	Integer	1.19 (0.16)	0.95 (0.29)	0.77 (0.06)
Hindu (%)	1=Yes/ 0=No	2	9	3
General caste (%)	1=Yes/ 0=No	72	82	84
Formal source of lending (%)	1=Yes/ 0=No	76	84	74
Tree growing experience	Integer	12 (2)	13 (4)	NA
Climate awareness (%)	1=Yes/ 0=No	52	55	53
Loss aversion attitude (%)	1=Yes/ 0=No	60	66	57
Tree growers in network (%)		70	43	25
Jurisdictional characteristics				
Amritsar district	1=Yes/ 0=No	23	25	28
Gurdaspur district	1=Yes/ 0=No	39	59	39
Ludhiana district	1=Yes/ 0=No	38	16	33





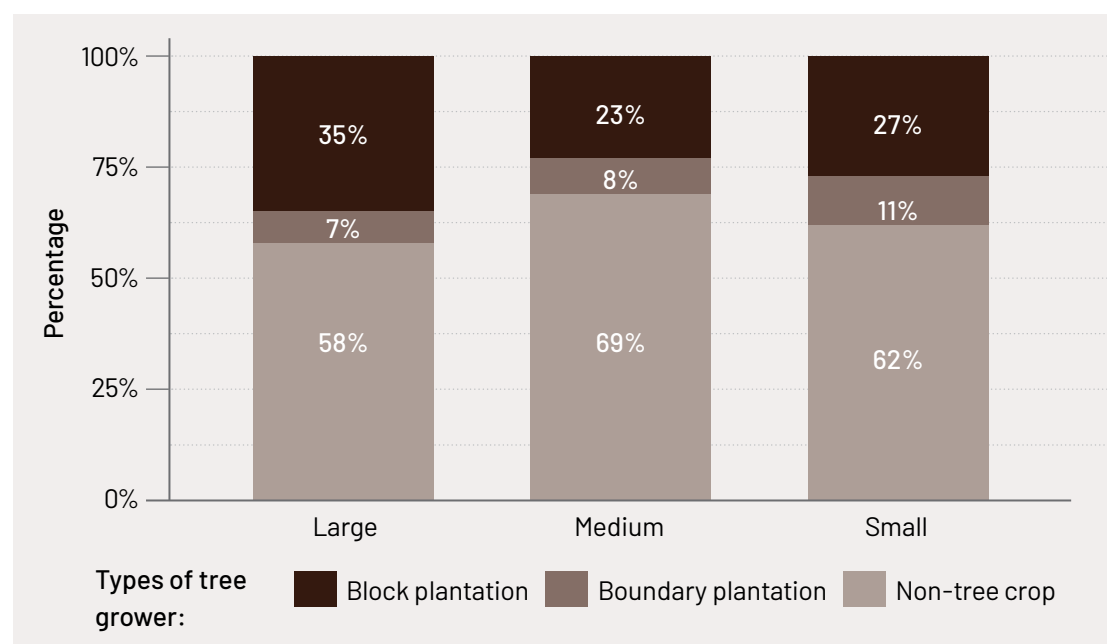
Variable/ No. of observations	Description	Tree-Crop Farmers		Non-Tree-Crop Farmers
		Block plantation (poplar + wheat)	Boundary plantation	Rice + wheat farmers
Distance to market and government facilities				
Distance of plot to all weather road (km)	Integer	0.06 (0.01)	0.08 (0.03)	0.15 (0.03)
Distance to agriculture science center (km)	Integer	13.6 (0.84)	13 (1.05)	11 (0.53)
Distance to district forest office	Integer	23.2 (1.21)	19.6 (1.96)	19.1 (0.82)
Distance to district agriculture office (km)	Integer	23.4 (1.35)	21 (2.12)	20.4 (0.88)
Distance to district administrative office (km)	Integer	28.4 (1.43)	24.3 (1.43)	25.2 (0.95)
Distance to forest range office (km)	Integer	15.2 (0.78)	14.3 (1.23)	10.6 (0.47)
Distance to timber market (km)	Integer	30 (1.62)	19.5 (2.24)	19.6 (0.96)
Distance to cereal market (km)	Integer	8.37 (0.61)	8.07 (0.98)	7.35 (0.34)
Distance to crop mandi (km)	Integer	5.56 (0.42)	7.73 (1.61)	5.41 (0)
Distance to pulse market (km)	Integer	9 (0.58)	10 (1.5)	8 (0.43)
Distance to vegetable market (km)	Integer	11 (0.78)	11.7 (1.66)	8.19 (0.44)
Distance to fruit market (km)	Integer	9.83 (0.51)	10.7 (1.53)	7.74 (0.40)
Distance to farm input market (km)	Integer	2.51 (0.18)	1.2 (0.2)	2.1 (0.12)
Agroforestry support				
Agroforestry program exposure without participation (%)	1=Yes/ 0=No	1	0	2
Farm households who received assistance to plant tree (%)	1=Yes/ 0=No	3	0	0

Source: Primary survey conducted during April–May 2025 in Punjab, India.

Note: Standard errors are reported in the parenthesis.



Figure 1: Agroforestry type by landholdings

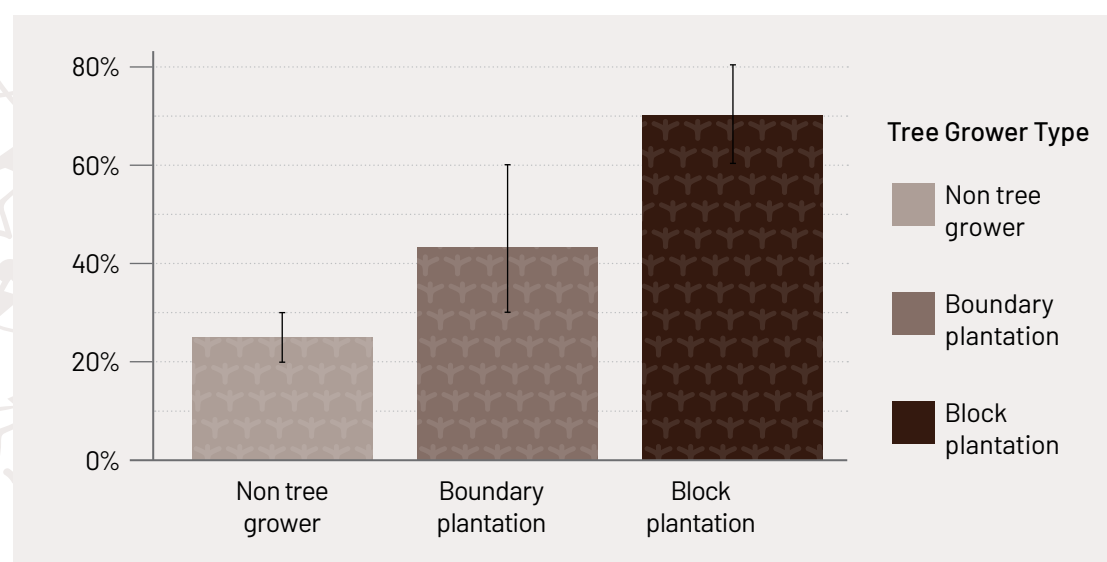


Sources: i) Primary survey conducted during April–May 2025 in Punjab, India;

ii) <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2085181#:~:text=The%20Government%20has%20taken%20several,2015%2D16%20is%20given%20below>

Notes: Small farms (total number of observations: 253) ≤ 5 acres of land; Medium farms (total number of observations: 70) ≤ 8.5 acres of land Large farms (total number of observations: 134) > 8.5 acres of land.

Figure 2: Percentage of tree growers in the network



Source: Primary Survey conducted during April–May 2025 in Punjab, India.

Note: Network: Each farmer was asked to identify three individuals with whom they interact most frequently. For each of these network contacts, respondents were further asked to report whether the individual grows tree and, if so, the species grown.

Table 2: Attributes of poplar-based agroforestry per acre and alternative farming system

Variable	Poplar and Wheat		Rice and Wheat
	Block plantation	Boundary plantation	
Number of observations	131	44	282
Total area of the main plot (average)	3.5 (0.3)	3.31 (0.39)	4.08 (0.23)
Tree-growing area of the main plot (acre)	2.42 (0.24)	NA	NA
Tree-growing area as percentage of operational area (%)	43 (3)	NA	NA
Total number of trees	837 (84)	146 (20)	NA
Trees grown per acre	360 (13)	66*	NA
Reported duration of tree growing of present lot (years)	1.5 (0.08)	1.3 (0.08)	NA

Source: Primary survey conducted during April–May 2025 in Punjab, India.

***Note:** Trees grown per acre per household in boundary plantation is estimated as total number of trees/plot area.

Table 3: Stream of costs and benefits of poplar-based agroforestry—block plantation (INR per acre per year, 2025 prices)

Year	Cash Out (INR)			Cash In (INR)	
	Average operational costs (A)	Average crop costs (B)	Average total costs (A+B)	Average wheat inter-crop revenues	Average tree harvest revenues
1	19,197 (1,200)	4,963	24,920	56,273 (5,250)	0
2	8,379 (552)	4,963	13,342	56,273 (5,250)	0
3	8,379 (552)	0	8,379	0	0
4	8,379 (552)	0	8,379	0	0
5	109,149 (3755)	0	109,149	0	719,786 (26,328)

Source: Primary survey (April–May 2025), Focus group discussion (Nov–Dec 2024), and additional referenced data.

Notes: i. Standard errors are reported in parentheses.

ii. Assumes 80% tree survival rate after five years, and poplar price of INR 1,000/quintal.



Table 4: Stream of costs and returns of poplar-based agroforestry—boundary plantation (INR per acre per year, 2025 prices)

Year	Cash Out (INR)			Cash In (INR)		
	Average operational costs (A)	Average crop costs (B)	Average total costs (A+B)	Average wheat inter-crop revenues	Average wheat inter-crop revenues (with crop loss)*	Average tree harvest revenues
1	5,775 (1,424)	32,525 (1,586)	38,300	130,308 (9,335)	130,308 (9,335)	0
2	2,846 (723)	32,525 (1,586)	35,371	130,308 (9,335)	130,308 (9,335)	0
3	2,846 (723)	32,525 (1,586)	35,371	130,308 (9,335)	130,308 (9,335)	0
4	2,846 (723)	32,525 (1,586)	35,371	130,308 (9,335)	125,398 (9,335)	0
5	21,405 (3,233)	32,525 (1,586)	59,151	130,308 (9,335)	125,095 (9,335)	132,562 (19,556)

Sources: Primary Survey (April–May 2025), Focus Group Discussion (Nov–Dec 2024), and additional referenced data. Standard errors are reported in parentheses;

***Note:** Assumes 80% survival rate after five years, and poplar price of INR 1,000/quintal. The reduction in crop revenue in year 4, and year 5 estimated at 3% and 4% respectively (Bhangu et al. 2024).



Table 5: Returns on investments (INR in 2025 prices)

	Present Value (INR)		Net Present Value (INR)		Annualized Rate of Return (INR)		Benefit–Cost Ratio	
	PV costs	PV benefits	NPV1 (without opportunity costs)	NPV2 (with opportunity costs)	ARR1	ARR2	BCR1 (household BCRs)	BCR2 (household BCRs)
	A	B	C	D	E	F	G	I
Block plantation (1)	1,07,579 (3,408)	5,35,808 (17,351)	4,32,631 (15,360)	1,27,829 (15,360)	1,14,127 (4,052)	33,721 (4,052)	5.28 (0.09)	1.29 (0.03)
Boundary plantation (2)	1,46,464 (6,422)	4,24,061 (29,567)	4,08,240 (28,722)	NA	1,07,693 (7,577)	NA	3.75 (0.11)	NA
Crop (no trees, or rice–wheat) (3)	1,21,512 (1,762)	4,26,091 (3,082)						

Sources: i) Primary Survey conducted during April–May 2025 in Punjab, India; ii) focus group discussion conducted during Nov–Dec 2023; iii) price data from

<https://treekisan.com/2021/06/26/how-to-know-poplar-tree-price-2022/#poplar-price-in-punjab>

Notes:

- i) Standard errors are represented in parentheses;
- ii) Discount rate (r) = 0.10;
- iii) Forgone income is average farm return for the farmer from alternative (paddy + wheat) system;
- iv) Payment to middleman is estimated @14% of revenue;
- v) Projected revenue is based on 80% survival rate after five years and poplar price INR 1000/ quintal;

vi) Net present value (NPV) ;
$$= \sum_{t=0}^T \frac{(B_t - C_t)}{(1+r)^t}$$

vii)
$$BCR - Household = \frac{1}{n} \sum_{t=1}^n \frac{B_{it}}{\sum_{t=1}^n \frac{C_{it}}{(1+r)^t}}$$

viii)
$$\frac{NPV * r}{[1 - (1+r)^{-5}]}$$

Annual rate of return (ARR) =;

- ix) NPV2 for block plantations subtracts the opportunity cost or the present value of net revenues lost from wheat + paddy from year 1 to year 5 and includes returns to wheat crops grown alongside tree crops in year 1 and 2;
- x) NPV2 for boundary plantation says NA because NPV1 for boundary plantation includes opportunity costs, i.e., reduction in crop revenue in year 4 and year 5, estimated at 3% and 4% respectively (Bhangu et al. 2024) is subtracted.

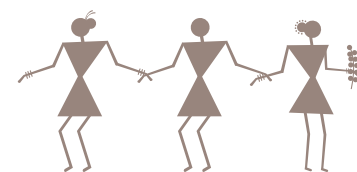


Figure 3: Average returns (with standard errors) per acre from agroforestry intercropping versus crop cultivation

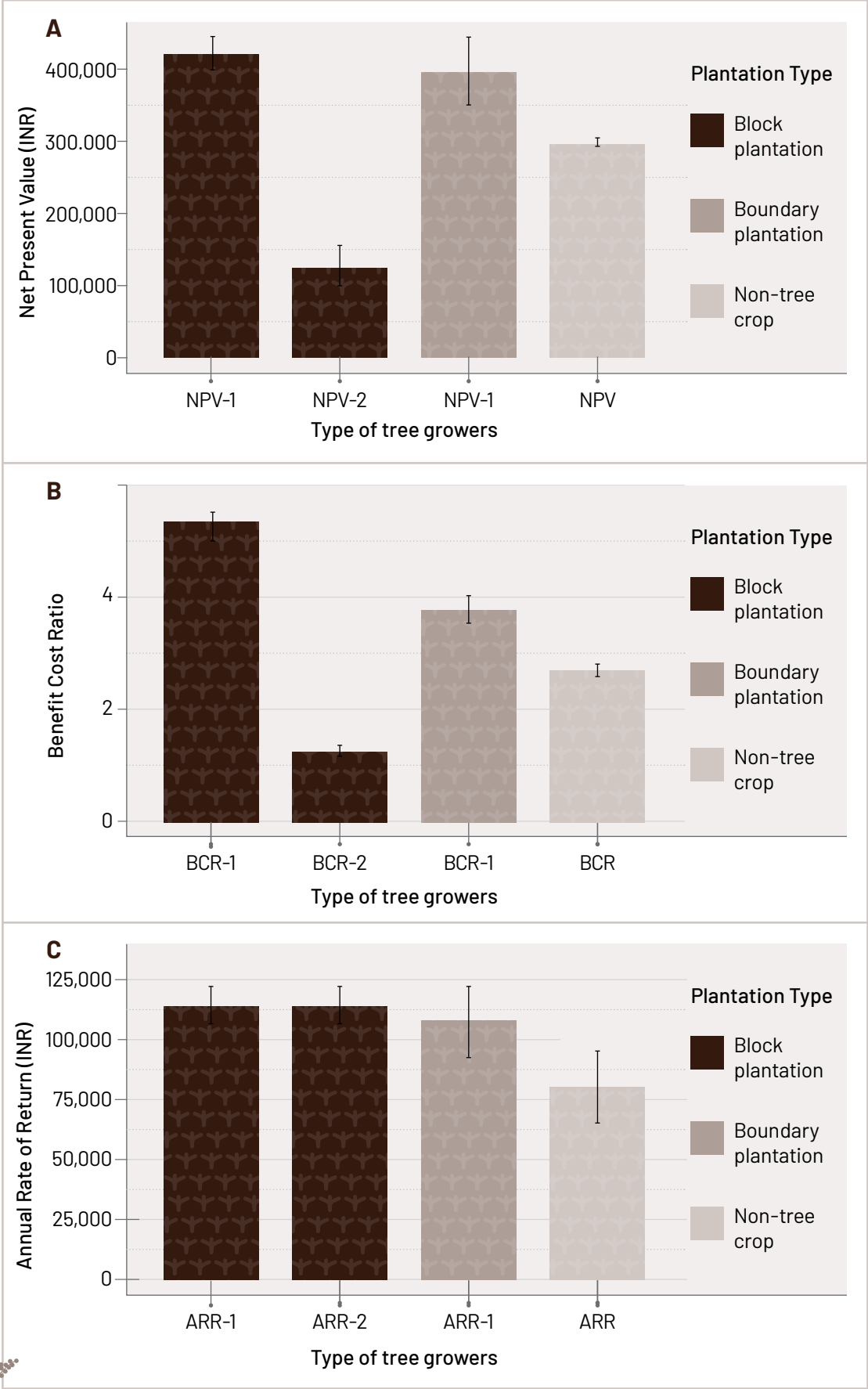
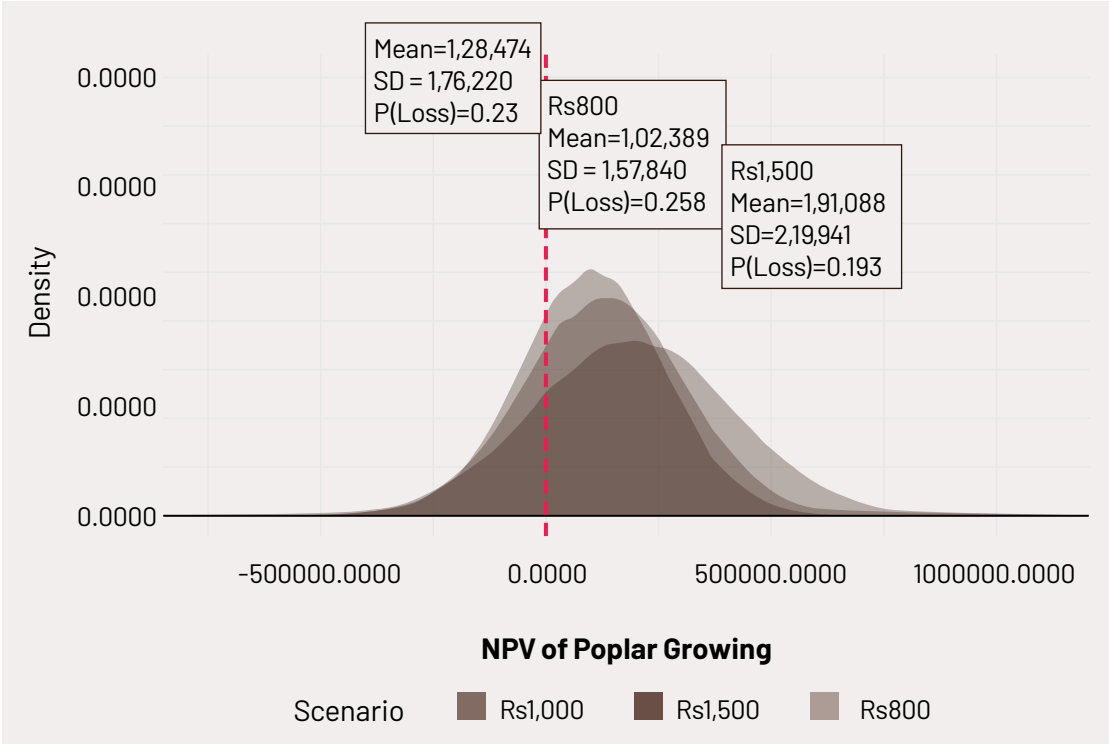


Figure 4: Monte Carlo simulation of NPV 2 (block plantations) under alternative poplar prices



Source: i) Primary Survey conducted during April–May 2025 in Punjab, India; ii) focus group discussion conducted during Nov–Dec 2023;

iii) <https://treekisan.com/2021/06/26/how-to-know-poplar-tree-price-2022/#poplar-price-in-punjab>;

iv) <https://www.plyreporter.com/article/153833/poplar-timber-prices-touches-new-all-time-high-mark>



Figure 5: Program card used as visual aid during survey's program explanation

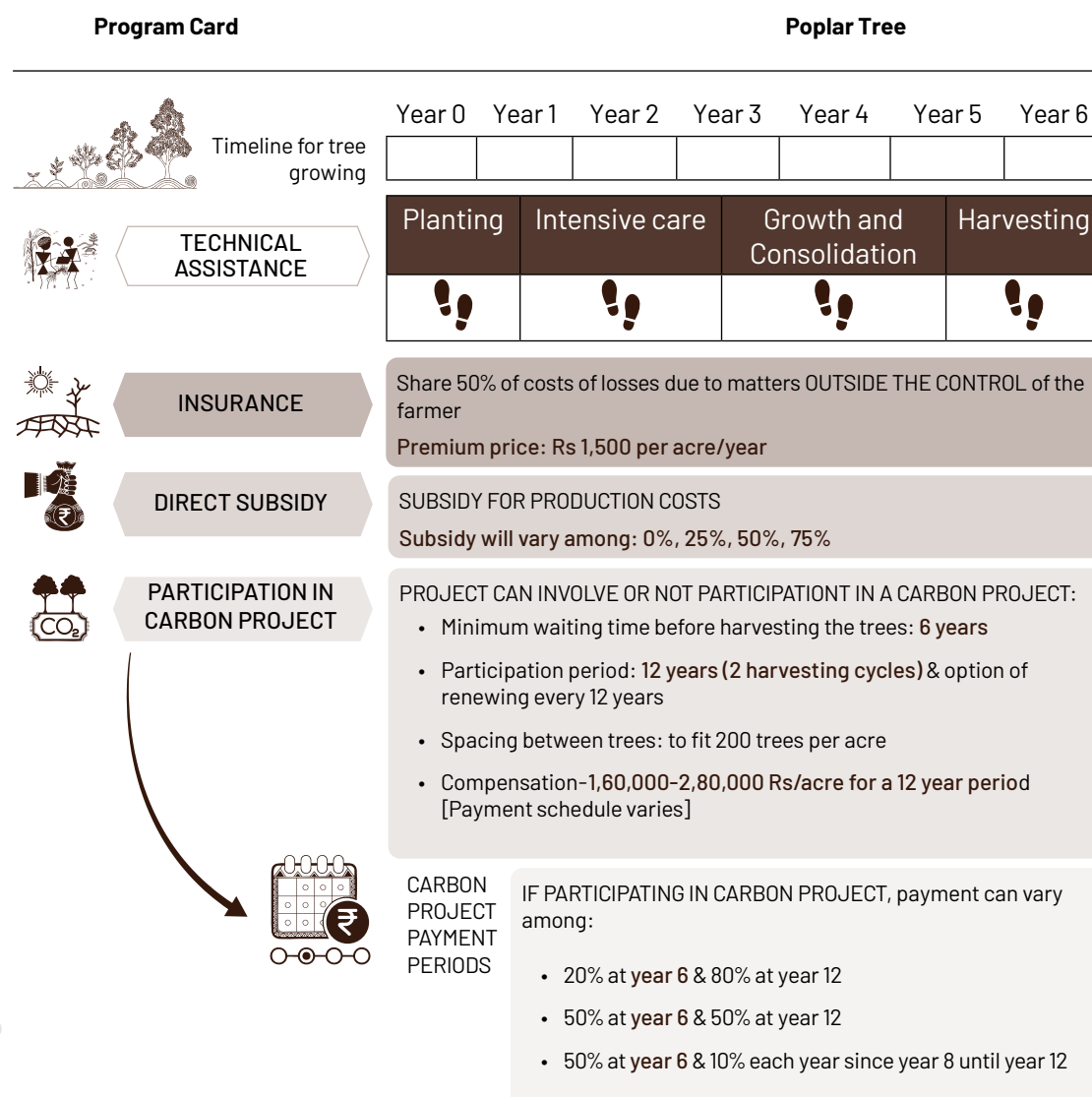


Figure 6: Example of choice card presented during survey



Poplar Tree

Choice Set # 4

	Program A	Program B	Program C
 INSURANCE	NO	YES	
 DIRECT SUBSIDY	25%	50%	
 PARTICIPATION IN CARBON PROJECT - Minimum time before harvesting trees - Additional payment	YES YES -1,60,000-2,80,000 Rs/acre for a 12 year period	NO — —	No participation in Poplar Program
 PAYMENT SCHEDULE	50% at year 6 & 10% each year since year 8 until year 12		
CHOICE OF PROGRAM	☐	☐	☐

Figure 7: Estimated adoption probability of agroforestry program with subsidy

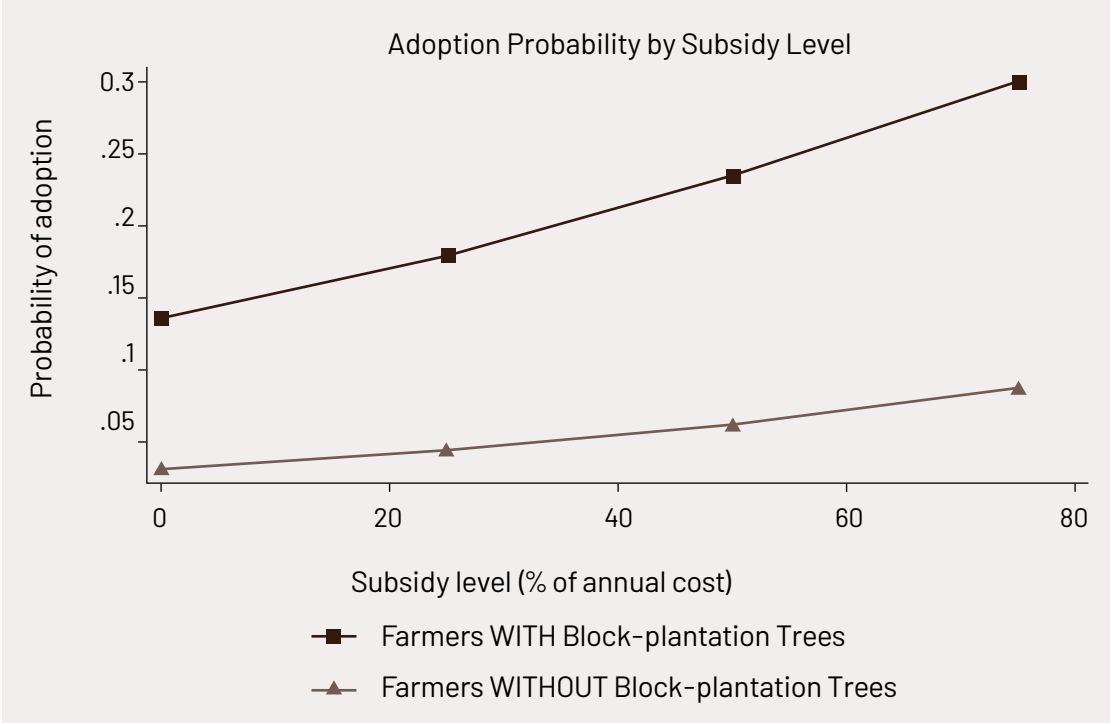


Table 6: Factors that cause uncertainty to farmers about incorporating agroforestry (% of sample)

Risk	Ranked 1st	Ranked 2nd
Fire generation	36	23
Potential pest	21	21
Uncertainty about weather and climate change	19	23
Animal attacks	4	8
Uncertainty of income/revenue/price	9	11
Uncertainty about getting buyer of timber	8	8
Time until harvest	3	6

Figure 8: Adoption probability of agroforestry program for farmers WITHOUT tree plantation with subsidy and INSURANCE

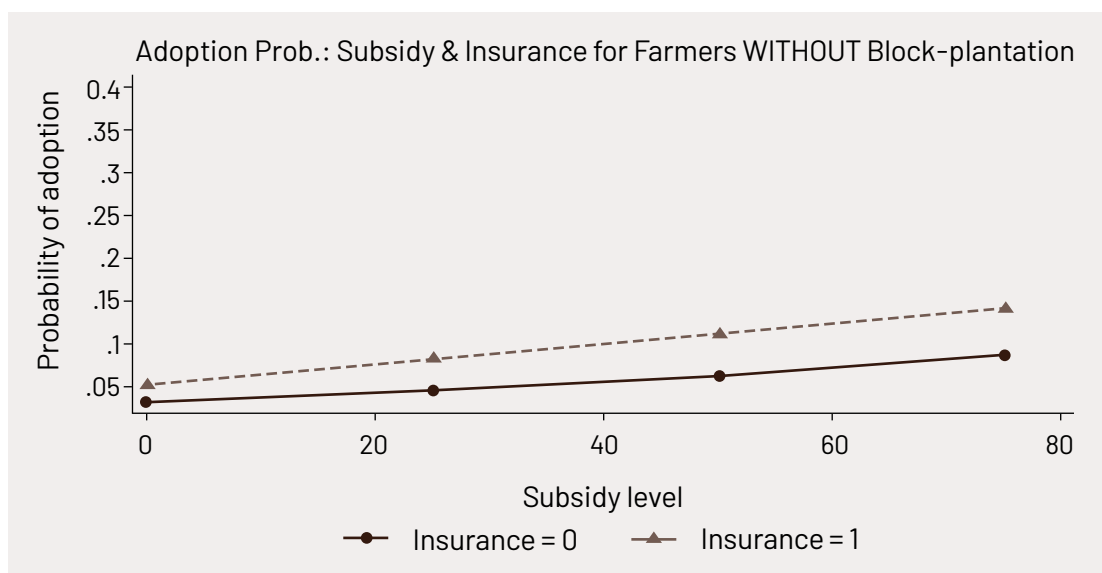


Figure 9: Adoption probability of agroforestry program for farmers WITH tree plantation with subsidy and INSURANCE

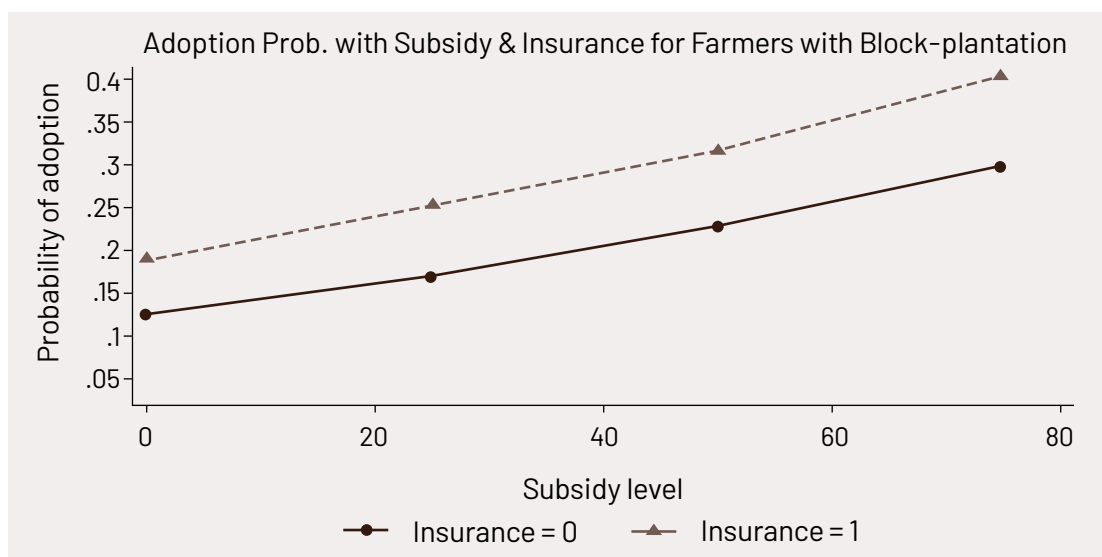


Figure 10: Adoption probability of agroforestry program for farmers WITHOUT tree plantation at 30% subsidy

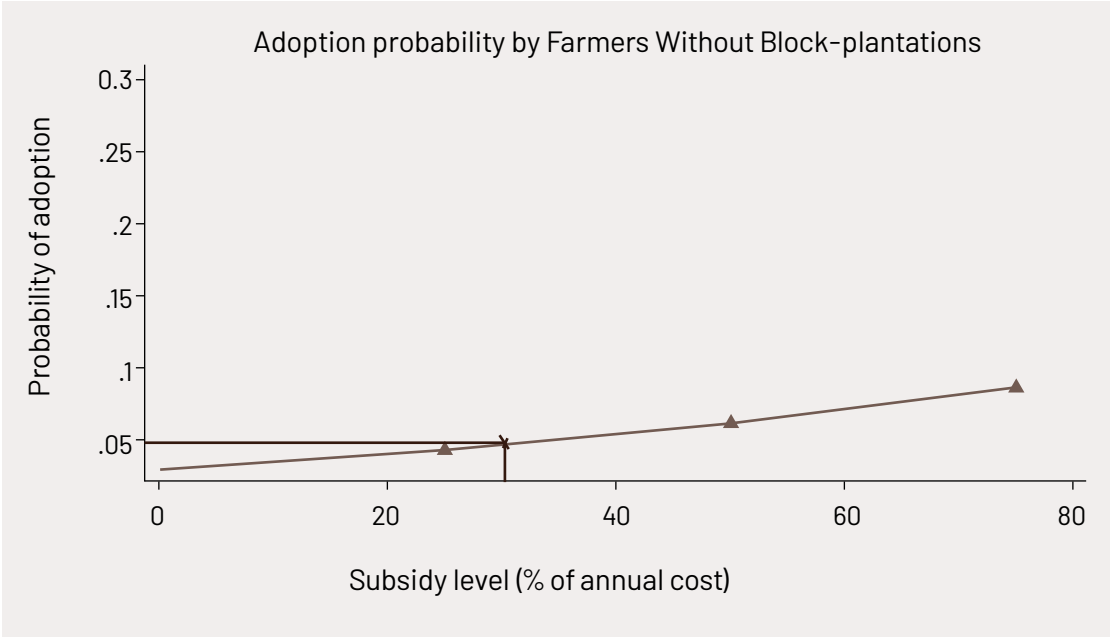


Figure 11: Adoption probability of agroforestry program for farmers WITH tree plantation at 30% subsidy

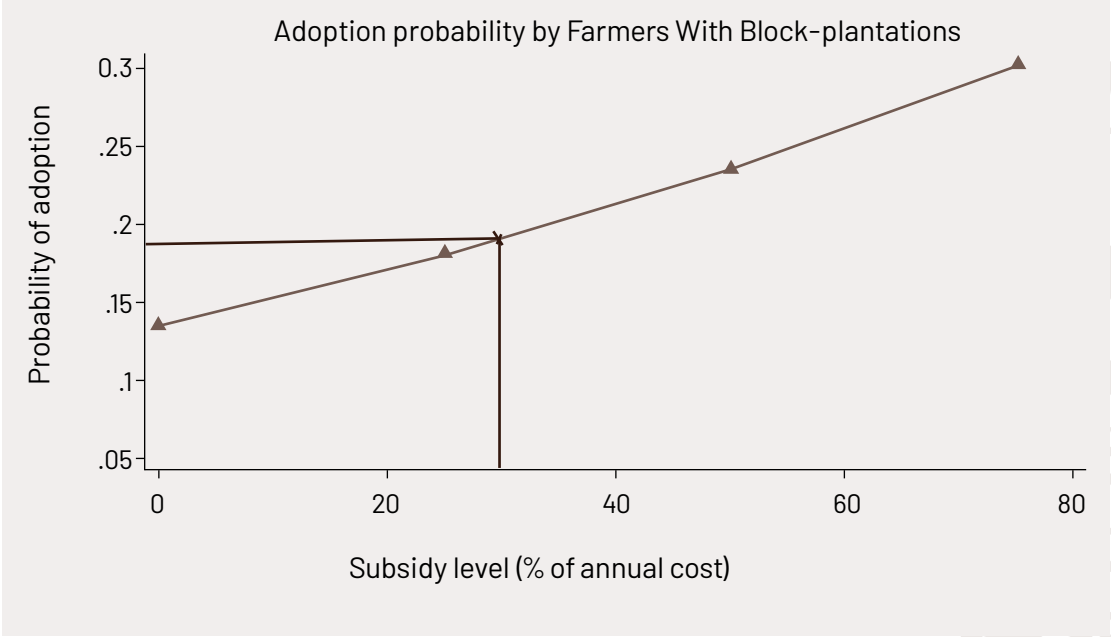


Table 7: Projections on increased area of poplar agroforestry and subsidy costs under 30% subsidy support

District	Farmer Type	Estimate Number of Farmers	Probability of Adoption under 30% subsidy	Number of Farmers Adopting 1 more acre of Poplar Agroforestry	Average Area Willing to Grow Poplar (acres)	Expected increased area of Poplar agroforestry (acres)	Estimated cost per acre per year 30% subsidy	Expected Cost of the Program (5-year) (INR) [USD]*
	With Block-Plantation Trees	3,302	18%	594	3.22	1,914	First year: INR 5,250/ year/ acre Next 4 years: INR 3,750/ year/acre	38,757,685 [437,940]
	Without Block Plantation trees	228,072	5%	11,404	2.08	23,719		480,318,790 [5,427,330]

*Does not include technical assistance costs (only subsidy costs)



Appendices

Table A1: Common agroforestry models in Punjab

Crop	Tree Species	Region
Wheat, mustard, pulses, sugarcane	Poplar	Central region
Marigold, berseem, potato, turmeric	Poplar	Central region
Potato	Eucalyptus	Pan-region
Sorghum, bajra, wheat-paddy system	Eucalyptus	Central and south region
Sorghum, pearl millet, cluster beans	<i>Butea monosperma</i> , <i>Grewia optiva</i> , <i>Anogeissus latifolia</i> , <i>Terminalia belerica</i> , <i>Bauhinia variegata</i> , <i>Celtis australis</i> , <i>Zizyphus mauritiana</i>	Sub-montane foothill zone (Kandi area)
Multiple and variety of crops	<i>Dalbergia sissoo</i> , <i>Acacia nilotica</i>	Pan-region
Multiple and variety of seasonal crops	Mango and citrus	Sub-montane foothill zone (Kandi area)

Table A2: Performance in Sub-Mission on Agroforestry, Punjab

Year	Physical Achievement		Financial Achievement (Amount in INR)		
	Area (Ha)	Plantation (No.)	Centre	State	Total
2016-17	356	4,27,638	15,53,657	10,36,199	25,89,856
2017-18	45	2,05,869	10,21,921	6,81,288	17,03,209
2018-19	346	2,08,911	9,83,457	6,57,502	16,40,959
2019-20	54	1,14,164	8,08,307	4,79,865	12,88,172

Note A1. A Note on Assumptions Underlying Returns on Investment Analyses

Cost of planting and harvesting data

The costs of poplar planting are collected in a phase-wise manner. Data on poplar cultivation were collected to estimate the costs and returns for both block and boundary plantation systems.

- [Table 3:](#) In our sample, 76 farmers were in the first year of tree cultivation, 33 were in the second year, 9 in the third year, and only 3 and 2 farmers were in the fourth and fifth years, respectively. The first-year cost captures land preparation and planting costs, including both labor and non-labor inputs, such as machinery, fertilizers, manure and agrochemicals, used for land levelling, tillage, sowing, planting and irrigation. The second-year cost covers similar activities—excluding land levelling and tillage—and adds pruning operations. Owing to the limited number of observations beyond the first year, we assume that tree-growing expenditures from years two to four are identical to first-year expenditures plus pruning cost, excluding land preparation and planting costs. This assumption is consistent with guidance from our survey agency, Datakosh, following consultations with farmers regarding typical management practices. Expenditures in the fifth year only include a 14% commission paid to intermediaries at the time of harvest for harvesting, transportation and selling.
- [Table 4:](#) In our sample, only 44 farmers practiced boundary plantation. Among them, 27 farmers were in the first year of cultivation, while 16 were in the second year (Phase 1). As no observations were available for trees older than two years under boundary plantation, and observations beyond the first year were limited, we followed the same approach used for block plantations and extrapolated the costs for the second through fourth years, as well as for the fifth year. Because only four farmers in the sample had completed the harvesting cycle, information obtained through focus group discussions (FGDs) was used to supplement harvest-related data. Farmers reported that roundwood is generally sold through intermediaries who charge a 14% commission on sales. FGDs also indicated that under high-density plantations, the average yield is approximately 2.5 quintals of timber per tree.

Revenue data

- [Table 5:](#) The market price of poplar varies by log girth, with logs above 18 inches selling for around INR 1,240 per quintal and logs with a 10–14 inch girth selling for approximately INR 760 per quintal (Tree Kisan, 2025). For analytical purposes, we adopt the mid-point estimate of INR 1,000 per quintal.

We apply an 80% tree survival rate and a 10% discount rate, following Chavan and Dhillon (2022) and Bhangu and Kaur (2018), to compute the net present value (NPV) and benefit–cost ratio (BCR).

The boundary plantation estimates incorporate opportunity costs, whereby reductions in crop revenue of 3% in Year 4 and 4% in Year 5 are deducted to account for yield losses (Bhangu et al., 2024).

Monte Carlo simulation

- Monte Carlo simulation is employed to model the financial performance of block plantations under uncertainty by treating key parameters in the net present value (NPV) calculation as stochastic rather than deterministic. In this approach, essential variables such as wheat intercropping revenue, timber harvest revenue, and operational and crop-related costs are assigned probability distributions instead of fixed values, with normal distributions assumed for tractability. Baseline assumptions include a poplar roundwood price of INR 1,000 per quintal.
- The principal sources of uncertainty incorporated in the model arise from fluctuations in timber prices. To reflect different degrees of uncertainty, the analysis specifies three scenarios—Scenario 1 (benchmark): poplar price = INR 1,000 per quintal; Scenario 2 (low price): poplar price = INR 800 per quintal; Scenario 3 (high price): Poplar price = INR 1,500 per quintal.
- For each simulation iteration, random draws of NPV are generated assuming a normal distribution with a baseline population mean of INR 127,829 and a standard deviation of INR 1.75 lakhs, using the NPV framework with a 10% discount rate. This procedure is repeated 100,000 times to generate a comprehensive probability distribution of possible NPV outcomes. The resulting distribution provides information not only on the expected NPV, but also on the dispersion of outcomes and the probability of negative NPV (loss).

Table A3: Conditional logit estimation of choice experiment components to analyze program adoption

	Coefficient	Std. Err.	Z	P > z	[95% conf. interval]	
Insurance	0.5523145	0.0629426	8.77	0.000	1.535643	1.965368
Subsidy	0.0142462	0.0012106	11.77	0.000	1.011944	1.016758
Carbon Project	0.3325044	0.0356366	9.33	0.000	1.300382	1.495336
position3	1.513525	0.1155187	13.1	0.000	3.622312	5.696987

[Std. Erro. Adjusted for 457 clusters -By Respondents-]

Wald chi 2 = 264.55 (Prob > chi 2) = 0.000)

Log pseudolikelihood = - 1846.2838

Table A4: Results of conditional logit estimations with interaction variables to evaluate heterogeneity of responses by demographic and contextual variables

Models [Coefficients/p-values]											
	(1)	(2)	(6)	(7)	(8)	(19)	(20)	(21)	(24)	(27)	(30)
	Program Chosen*	Program Chosen*	Program Chosen*	Program Chosen*	Program Chosen*	Program Chosen*	Program Chosen*	Program Chosen*	Program Chosen*	Program Chosen*	Program Chosen*
Attributes of Choice Model											
Insurance	0.543	0.311	0.397	0.539	0.363	0.537	1.290	0.548	0.547	0.539	0.538
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Subsidy	0.015	0.015	0.014	0.014	0.015	0.014	0.014	0.010	0.010	0.014	0.031
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Carbon Project	0.731	0.907	0.900	0.770	0.900	1.695	0.895	0.910	0.908	0.895	0.888
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Interaction Terms that Show Statistical Significance p < 0.05											
Need Loan * Carbon Project	0.404										
	0.013										
Need Loan * Insurance		0.546									
		0.000									
Risk Pests * Insurance			0.326								
			0.028								
Adopter * Carbon Project				0.319							
				0.050							
Adopter * Insurance					0.442						
					0.003						
Farmer Age * Carbon Project						-0.016					
						0.011					
Farmer Age * Insurance							-0.015				
							0.005				
Need Loan * Subsidy								0.012			
								0.000			
Adopter * Subsidy									0.011		
									0.000		
Network Grow Tree * Subsidy										0.007	
										0.015	
Farmer Age * Subsidy											0.000
											0.003
_cons (Level 1)	-0.019	-0.015	-0.017	-0.016	-0.017	-0.010	-0.017	-0.017	-0.018	-0.015	-0.013
	0.782	0.820	0.797	0.814	0.796	0.878	0.805	0.803	0.794	0.824	0.845
_cons (Level 2)	1.674	1.681	1.672	1.670	1.673	1.663	1.666	1.674	1.672	1.666	1.661
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Log Pseudo-Likelihood	-1813.064	-1807.491	-1816.272	-1816.202	-1812.336	-1812.009	-1813.772	-1800.020	-1802.371	-1818.791	-1809.137
Wald chi2	208.699	215.864	209.608	209.273	209.988	214.474	213.489	210.134	206.554	543.416	211.952
Observations	5484	5484	5484	5484	5484	5484	5484	5484	5484	5484	5484



Table A5: Census questionnaire used for sampling in every selected village

Consent Question: “Hello, I am XYZ from TNC and Datakosh. We will be conducting a survey to understand poplar plantation along with crop cultivation in the coming weeks. Right now, we are listing participants. Would you like to participate in the survey and answer a couple of questions right now?” – Yes/No

If YES proceed to House Listing Questionnaire

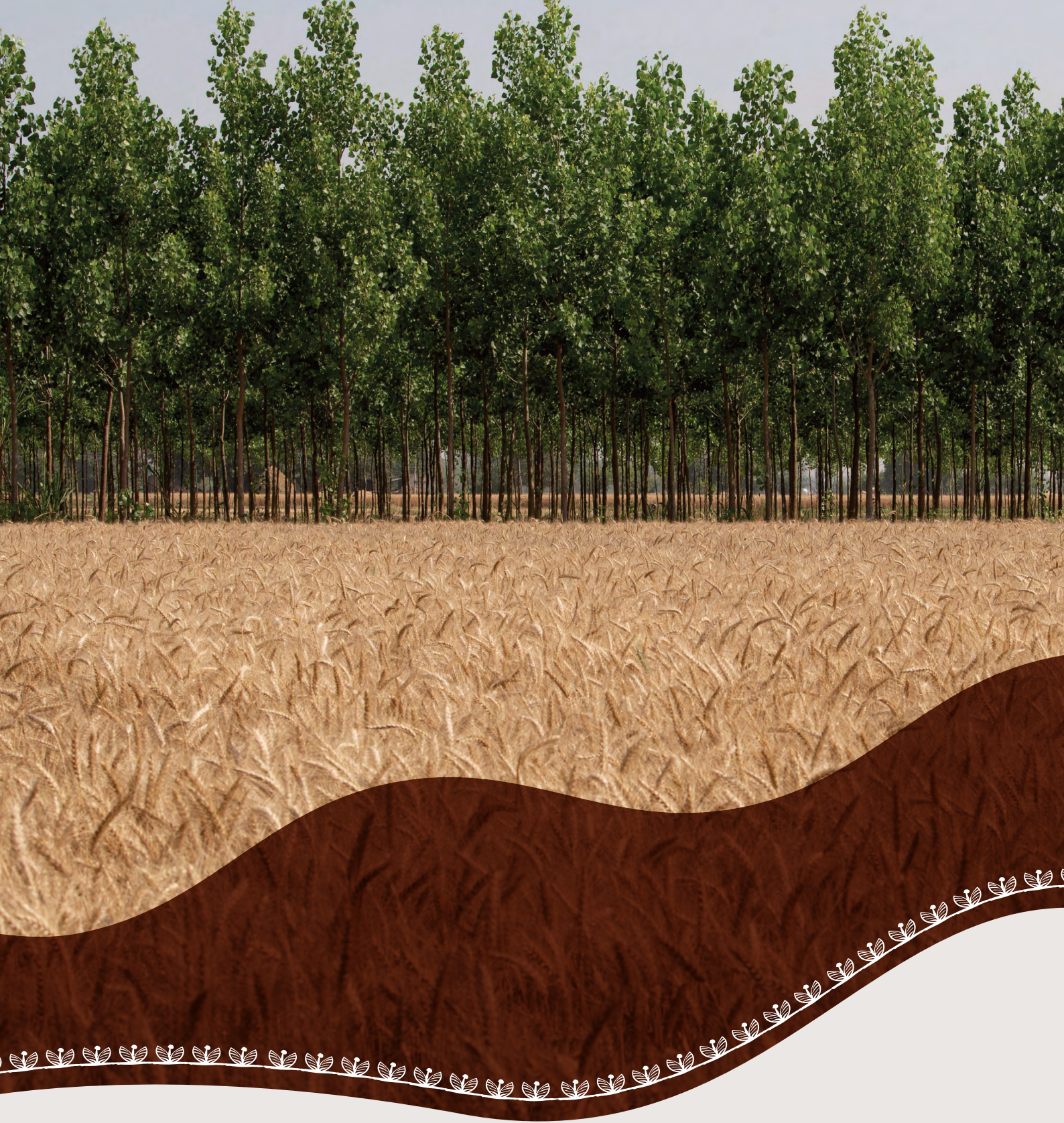
H.1	
Enumerator name	
Date of interview	
Time of interview	

H.2: Demography			
District name		State code	
Block name		Block code	
Village name		Village code	

H.3: Household contacts	
1. Name of respondent	
2. Are you head of the household?	Yes = 1, No = 0
3. Name of HH head (main farmer of the household)	(Please write full name)
4. Father/Spouse name	
6. Contact/Phone number of the farmer	

H.4: Farming and Land information	
1. Did you cultivate land in the last 12 months (Kharif-2024 and Rabi-2024-25)	Yes = 1, No = 0 (Do not proceed if answer is no)
2. How much land do you own?	-----
3. Unit of land	1 = Acre, 2 = Killa, 3 = Kanal, 4 = Bigha, 5 = Katha, 6 = Hectare, 7 = Karam, 8 = Marla, 9 = Murabba, 10 = Biswa, 99 = Others (please specify)
4. Total land cultivated in the last 12 months?	----- (This is total of (owned land cultivated + leased-in) - Leased-out)
5. Did you grow or harvest any tree plantations in the past 12 months? (Include the tree plantation of at least 6 months old.)	Yes = 1, No = 0 (If no, end the questionnaire)
6. Which of the following tree plantations did you grow/harvested in the past 12 months?	1 = Poplar, 2 = Eucalyptus, 3 = Sheesham, Other = 99
7. Area of the selected tree plantation	
8. Number of trees of selected species	----





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The Nature
Conservancy

