Researches in Earth Sciences

Journal homepage: https://esrj.sbu.ac.ir

Research Article

Poplar wood production in a cold climate: A Delphi-based analysis of community attitudes

Bita Moezzipour [1*], Mohammad Ahmadi[1], Raoof Mostafazadeh[1]

1-Department of Natural Resources, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran

Received: 25 Jun 2025 Accepted: 06 Sep 2025

Abstract

Wood cultivation helps meet industrial wood demand, prevents forest destruction, and supports rural livelihoods. The aim of this study is to assess the strengths and opportunities of poplar wood production in Iran's cold climate using the Delphi method based on community attitudes. To achieve this goal, questionnaires considering the influencing factors were prepared and necessary information was collected through face-to-face interviews with 51 poplar farmers across Ardabil Province. The Delphi technique was employed throughout 2023 to assess the strengths, weaknesses, opportunities, and threats of poplar cultivation, with initial questionnaires evaluated through sample responses to allow for revisions. The Delphi process was conducted in two rounds, with consensus defined as the relative convergence of expert opinions. A panel of experts reviewed the questionnaires to ensure validity and reliability, and the results were analyzed to draw conclusions. According to the results, poplar farmers find wood cultivation to be significantly more profitable compared to the cultivation of other agricultural products. However, inadequate oversight leads to poor soil management, thinning, and irrigation practices, affecting wood growth. Despite efforts to improve poplar farming through government support and training programs, challenges persist, including insufficient technical knowledge among farmers, lack of insurance, and water resource limitations. SWOT analysis showed that poplar cultivation offers high profitability and low labor needs. Key challenges include poor soil and irrigation management, low-quality seedlings, and market control by intermediaries. Favorable climate and government support present development opportunities. Improving productivity requires farmer training, guaranteed markets, and adoption of mixed cropping. As poplar plantations in Ardabil Province offer cost-effective alternatives to agricultural crops, with minimal maintenance required, addressing these issues through targeted education, improved seedling quality, and better irrigation methods could enhance productivity and promote sustainable poplar farming in the region.

Keywords: Delphi method, Environmental conservation, Natural resources, Poplar farming, Tree plantation.

Citation: Moezzipour, B. et al, 2025. Poplar wood production in a cold climate, *Res. Earth. Sci:* 16(Special Issue), (218-229) DOI: 10.48308/esrj.2025.240405.1280

* Corresponding author E-mail address: b.moezzipour@uma.ac.ir

Introduction

Background

Forests represent the most valuable, and diverse vegetation cover on Earth, shaped over millions of years through the evolution of plant communities (Bond, 2019; Hagen et al, 2021). Forest areas have served as habitats for human communities for centuries, offering resources to meet their needs and showing the necessity of conserving and effectively managing them as valuable natural resources (Decocq et al, 2018; Aminzadeh et al, 2024). However, human population growth, the diversification of needs, and increased insatiability, particularly since the Industrial Revolution, have disrupted the balance and harmony of human interaction with these lands, subjecting them to significant pressure (Lewis et al, 2015; McDowell et al, 2020). Viewing forests merely as sources of timber has led to their destruction worldwide (Sloan and Sayer, 2015). Forest condition reflects a country's development level, making conservation and restoration essential (Abhilash, 2021), with afforestation and especially the longer process of restoring natural vegetation playing key roles in rehabilitating degraded ecosystems (Keivan Behjou et al, 2024). Iran faces significant challenges in supplying suitable raw materials for its wood industries due to the lack of commercially viable forest areas (Nabavi et al, 2020; Vatani et al, 2021). The importance of forest conservation in the country and the ban on harvesting timber from natural forests, coupled with the increasing need to supply raw materials for the wood and paper industries, have emphasized the importance of developing wood farming in Iran (Azizi and ray, 2015). Poplar cultivation is the most crucial strategy for reducing the pressure on forests, and under optimal conditions, wood farming can yield up to 45 cubic meters per hectare (Goodarzi et al, 2023). Wood farming refers to the cultivation of fast-growing tree species (aiming for maximum harvest by the tenth year) using agricultural and horticultural practices, which also has a long history in our country (Nezhad et al, 2018). Poplar, eucalyptus, and tamarisk are among the fast-growing species that can be planted in Iran (Amiri and Azadfar, 2009; Eskandari et al, 2022). The global significance of poplar, due to its optimal production potential, water and soil conservation abilities, job creation, and socio-economic benefits, has led developed countries to prioritize its cultivation in sustainable development plans to meet the needs of wood-dependent industries (Joshi et al, 2024). While these global forest challenges provide important context, our study specifically focuses on poplar cultivation as a sustainable wood production alternative in Ardabil Province's cold climate, where it addresses both ecological conservation and local economic needs.

Literature review

Existing research on poplar cultivation can be categorized into three main themes: a) economic viability and profitability comparisons, b) factors influencing adoption by farmers, and c) optimal cultivation practices and management systems. Regarding economic viability, Jain and Singh (2000) conducted an economic analysis of poplar-based agroforestry in Uttar Pradesh, India. They found that poplar agroforestry is more profitable than traditional crop rotations and provides additional employment opportunities. Despite the costs for technical advice from Wimco, the system remains economically viable and beneficial for farmers. On the topic of adoption factors, Salam et al. (2006) investigated factors influencing farmers' willingness-to-pay for a Tree Farming Fund in a participatory forest in Bangladesh. Using logistic regression, they found that willingness-to-pay was significantly impacted by family income, education, confidence in benefits, and positive attitudes toward participatory forest management and found that higher income and education, along with favorable attitudes, increase farmers' willingness to invest in tree farming. Kareemulla et al. (2012) conducted a socioeconomic analysis of poplar agroforestry systems in Western Uttar Pradesh, Northern India. They found that both bund/boundary systems and agrisilviculture were more profitable than traditional agriculture, with higher net present values and benefit-cost ratios and pointed out that additional income and emergency cash are the key reasons for farmers adopting agroforestry. Dwivedi et al. (2016) analyzed agroforestry systems in Western Uttar Pradesh, finding that poplar-based agrisilviculture had a higher benefit-cost ratio (3.00) than poplar (2.84) and eucalyptus (2.68) bund systems. While commercial agroforestry proved more economically promising, traditional agroforestry remained vital for farmers' livelihoods. Karakaya et al. (2017) analyzed the socioeconomic structure and raw material demand of poplar wood-processing companies in Sakarya and Kocaeli, Turkey. Using surveys and statistical analyses, they identified company size, product demand, and raw material price as key factors affecting demand and proposed economic and managerial strategies to improve company efficiency and profitability. Concerning cultivation practices, Chavan and Dhillon (2019) studied Populus based agroforestry in northwestern India, comparing three spacing geometries and two cropping rotations. They found that a 10 × 2 m spacing with sorghum–berseem crop rotation yielded the highest profitability, significantly boosting farmers' income compared to traditional agriculture. Mukundente et al. (2020) examined agroforestry adoption among 650 farmers in Southern Rwanda. They found that household and farm size significantly influenced adoption, whereas age, gender, marital status, farming experience, and income did not. Larger households and farms were more likely to adopt agroforestry. Chavan et al. (2022) evaluated the economic viability of Populus deltoides boundary plantations in Northern India. Their study found that East-West oriented poplar boundaries with sorghum-wheat rotations yielded the highest net returns and economic benefits, significantly enhancing farm income compared to traditional agriculture. Alemayehu and Melka (2022) reviewed the socioeconomic impacts of small-scale eucalyptus cultivation in Ethiopia. They found that eucalyptus provides higher returns on investment than other land uses, significantly contributing to rural development and poverty reduction and pointed out that planting decisions are influenced by various socioeconomic, demographic, and institutional factors. Ahmad et al. (2023) analyzed the factors affecting agroforestry adoption among 400 smallholder farmers in Northern Irrigated Plain, Pakistan. Their study revealed that family size, land ownership, and income positively influenced adoption, while age had a negative effect. They suggested that better extension services and training could boost adoption and benefit both farmers and the environment. While these studies collectively demonstrate poplar's economic viability, methodological divergences (such as Salam et al. (2006) logistic regression versus Kareemulla et al. (2012) cost-benefit analysis) indicates context-dependent outcomes, suggesting that regional institutional frameworks and farmer demographics may mediate agroforestry success more than technical factors alone. The existing literature shows the considerable economic and socio-environmental advantages of cultivating poplar trees. Research indicates that optimizing planting arrangements and adopting improved cultivation techniques can significantly increase net returns. Despite this, there is still a lack of understanding about the specific factors that influence farmers' willingness to invest in poplar cultivation. More in-depth studies are necessary to examine how these factors affect the adoption of poplar compared to other agroforestry practices. While much attention has been given to profitability and economic benefits, a comprehensive investigation into current cultivation methods (including farmer attitudes and obstacles) is crucial. Conducting detailed interviews with poplar growers will offer valuable insights into their experiences and challenges. Combining statistical analysis with qualitative feedback will help tailor extension services, improve training programs, and ultimately boost adoption rates and the success of poplar-based agroforestry systems.

Scope and Objective

Global demand for sustainable wood is rising due to industrial needs and environmental concerns, prompting interest in fast-growing species like poplar. In Iran, with limits on natural forest use, poplar farming serves as a key alternative to meet wood demand and ease pressure on ecosystems. Based on estimates considering population growth rate and per capita wood consumption over a ten-year period, the wood consumption in 2019, including logs, lumber, furniture, compressed boards, pulp, and paper, was 16 million cubic meters and is projected to be 16.6 million cubic meters by the end of the sixth development plan. This assessment predicts a consumption of 17.4 million cubic meters for 2023 and 18.2 million cubic meters for 2029. Producing 11.8 million cubic meters of annual consumable wood is achievable through wood cultivation over an area of 300,000 hectares. However, quantitative and qualitative evaluations show that the current poplar wood production in Iran falls short of meeting the needs of the wood industry (Azizi, 2008; Ahmadloo et al, 2020;

Hosseini et al, 2021). Additionally, productivity in cultivated areas has decreased. Overall, projects conducted by the Forests and Rangelands Research Institute have identified 941,000 hectares of potentially suitable land for wood farming purposes. To develop poplar wood production in the coming years, it is essential to examine the effective indices across different regions of Iran and make decisions based on this analysis to overcome limitations and advance poplar wood production. According to the analyses conducted, the western and northwestern regions of Iran are considered the most suitable lands for poplar cultivation (Bayatkashkoli et al, 2021). Despite poplar's recognized economic and environmental benefits, its cultivation in Ardabil Province remains underutilized due to three systemic barriers: (1) inadequate technical knowledge among farmers, (2) inefficient market structures dominated by intermediaries, and (3) water resource mismanagement exacerbated by climate change. Ardabil Province in northwestern Iran, given its climatic conditions, also has relatively suitable potential for poplar wood production. While Ardabil Province possesses favorable climatic conditions and fertile lands for poplar cultivation, this study specifically targets its cold climate adaptation and community-driven challenges to provide actionable insights for regional development. Poplar planting has been common in Ardabil Province, serving as income and windbreaks (Majid et al, 2020). Despite its potential, plantation areas have declined over the past two decades. However, fertile soil, moisture currents, rivers, and suitable lands offer strong potential for development. Further studies are needed to identify key factors and support planning for expanding poplar production. This study stands out by using a community-based Delphi approach in Ardabil's cold climate to assess poplar farming challenges, uniquely addressing both technical and socio-economic factors through direct farmer input. This study aims to assess the strengths and opportunities of poplar wood production in a cold climate in Iran from the local community's perspective using the Delphi method. Data will be collected through questionnaires and face-to-face interviews with poplar farmers, evaluating the strengths, weaknesses, opportunities, and threats of poplar farming in the region.

Materials and Methods

Geographical Setting of the Study Area

Ardabil Province, with an area of 1.8 million hectares, is located in the northwest of Iran. Ardabil's varied topography, fertile soils, and diverse climate (partly influenced by the Caspian Sea) offer favorable conditions for wood farming. Its cold mountainous nature and annual precipitation ranging from 250 to 600 mm support the rapid growth of fast-growing species like poplar. Average annual temperatures range between 6 and 12 °C (Mehri et al, 2017). Poplar plantations in Ardabil cover 1,074 hectares, mainly in Meshginshahr, Ardabil, and Khalkhal. Most are under 0.5 hectares, planted in strips along orchards and irrigation channels, serving both for wood and as windbreaks or fences. Abundant rivers also support poplar growth along banks. In the present study, based on the surveyed population, most farmers cultivated two main poplar species: *Populus alba* (common in the south/southeast on saline soils) and *Populus nigra* (prevalent in central and northern areas). Hybrid species such as *P. euramericana* were also grown but to a limited extent.

Methodology

This study was conducted between March and December 2023, employing a two-round Delphi process to systematically capture and refine farmer perspectives on poplar cultivation challenges and opportunities in Ardabil's cold climate. In the present study, 51 farmers with experience in poplar wood production were selected as the research population. Subsequently, a questionnaire was developed to collect comprehensive information about the characteristics of the interviewees (Zhu et al, 2022; Neupane et al, 2002; Ashraf et al, 2015). Farmers were selected through purposive sampling targeting experienced poplar growers across all major cultivation areas in Ardabil province, ensuring representation from different farm sizes and age groups. The sample size (n=51) was determined based on saturation principles for qualitative research, covering approximately 5% of the total poplar farming population in Ardabil while maintaining a 95% confidence level with 10% margin of error for key variables. This research examined variables including household size, gender, age, and education, along with land ownership, main job, experience, cultivation area, and tools, through questionnaire responses. Technical details of poplar cultivation (such as planting distance, harvest age, seedling count, irrigation type, and species) were also surveyed. Using the Delphi technique, questions explored the strengths, weaknesses, opportunities, and threats of poplar wood production. Participants reviewed peers' responses to refine their answers. The questionnaire design was guided by research goals, expert input, and prior studies, with validity and reliability confirmed by expert panel consensus.Participants were selected through purposive sampling: farmers required minimum 10 years of poplar cultivation experience, while experts needed either administrative experience in poplar development policies or published research in poplar cultivation. Quantitative data were analyzed using descriptive statistics (means, standard deviations) for SWOT scoring, while qualitative responses underwent thematic coding to identify recurring patterns in farmers' perspectives. The study used the True Delphi method in two stages: a qualitative phase with interviews of 15 experts to identify key factors, followed by a quantitative survey of 51 farmers with over 10 years of experience. Consensus was based on a coefficient of variation below 30%, standard deviation under 1.5, and interquartile range less than 1.5. The Delphi method was specifically chosen over individual interviews or focus groups to systematically capture consensus on technical and socioeconomic factors while mitigating potential group dominance biases common in traditional qualitative methods. The Delphi method was chosen for its iterative feedback, which captures consensus among dispersed farmers and reduces power imbalances found in traditional group discussions. The Delphi method was particularly appropriate for this study of cold climate poplar cultivation for three reasons: First, the method's iterative feedback process helps overcome knowledge gaps common in specialized agricultural systems. Second, its structured communication approach is effective for capturing nuanced farmer experiences in challenging climates. Third, the anonymity feature reduces potential bias that might arise from hierarchical relationships in traditional farming communities. Quantitative data analysis was performed using descriptive statistics (means, standard deviations) and content analysis for qualitative responses in SPSS software (v26).

Results and Discussion

Demographic characteristics of respondents:

The population of poplar farmers showed that the average age of respondents was 49.7 years. Regarding education levels, 23.52% had less than a high school diploma, 29.41% had a high school diploma, 7.84% had an associate degree, 21.56% had a bachelor's degree, 15.68% had a master's degree, and 1.96% had a doctoral degree. Poplar wood production was not the primary occupation for any of the respondents. The average experience in poplar wood production was 22.74 years. The average cultivation area was 3.34 hectares, with an average of 2,119 seedlings per poplar farmer. The average household size of poplar farmers was 4.23 members. Given that most poplar farmers did not use any equipment, the average number of tools was 0.9 (less than 1). The average selling price of poplar wood was 65,921,570 Iranian Rials per ton. The reported average selling price of 65,921,570 Iranian Rials per ton (equivalent to approximately $130 in 2022 based on Central Bank conversion rates) reflects a 22% nominal increase from 2020 prices, though real terms analysis shows only 8% growth when adjusted for Iran's 38% cumulative inflation during this period. The average planting distance was 1×1 meter, which is less than the optimal spacing for poplar planting. About 45% of poplar farmers used cuttings for planting, which negatively impacts the performance and yield of poplar wood production. Additionally, 92.15% considered integrated land use for poplar, while only 1.96% exclusively engaged in wood cultivation. Around 91.11% of poplar farmers used flood irrigation for their trees, and 96% of respondents were unaware of the species of poplar they had planted. The average age for tree harvesting was 11.09 years, and none of the poplar farmers had insurance. Beyond averages, key variables showed substantial variability: farming experience ranged from 5 to 54 years (SD=12.3), cultivation areas varied from 0.25 to 32 hectares (SD=5.8), and household size spanned 1 to 12 members (SD=2.1), reflecting the diversity of operations.

Changes in tree farming variables among farmers

Data on factors affecting income from Populus cultivation show notable differences in experience, cultivation area, and income. Experience ranges up to 54 years, and cultivation areas vary widely from 0.25 to 32 hectares, reflecting diverse operation scales. Household size and seedling count also vary significantly, with seedlings ranging from 200 to 175,000 and household sizes from 1 to 12, affecting labor and efficiency. Planting density averages around 10,000 seedlings per hectare (5,000–15,000), with spacing typically 1×1 meter (ranging 0.8×0.8 to 2×2 meters), and harvest age averaging 11 years (7–15 years).

Qualitative analysis of strength, weakness, opportunities, and threats based on wood farmer inputs

The assessment of various dimensions of poplar wood production from the perspective of wood farmers is of particular importance and can lead to practical decisions aimed at developing poplar farming and addressing existing challenges and obstacles. The results obtained from interviews with poplar farmers are presented in Tables 1 to 4. SWOT item scores exhibited varying dispersion, with standard deviations ranging from 0.5 to 1.76 across factors, indicating differing levels of consensus among participants (Tables 1-4).

Table 1: Status of strengths in Poplar wood production in Ardabil province from the perspective of wood farmers

Priority	Std Deviation	Mean	Item
1	0.87	4.54	Wood industry factories are interested in buying poplar wood
2	0.8	4.5	Compared to other agricultural and horticultural activities, poplar farming involves less labor
3	0.8	4.49	Compared to other agricultural and horticultural activities, poplar farming involves lower costs
4	0.85	4.43	Compared to other agricultural and horticultural activities, poplar farming requires less technical knowledge
5	0.84	4.37	Poplar trees have lower loss rates compared to other agricultural products
6	1.03	4.19	Using poplar trees as windbreaks or fences positively affects the production of other agricultural products
7	1.08	1.5	There is sufficient supervision and consultancy services available for poplar farming
8	0.93	1.39	Government institutions provide suitable training courses for poplar farmers
9	0.82	1.27	Government institutions support poplar farmers well in terms of input supply
10	0.89	1.25	Agricultural land with low or no rent is provided to poplar farmers by the government.

Analysis of strengths:

Ecological benefits

Poplar plantations in Ardabil province serve important ecological functions, particularly as windbreaks and fencing along agricultural boundaries. Their use as protective barriers enhance microclimates for adjacent crops, supporting agroforestry expansion. Beyond agricultural benefits, poplars demonstrate significant phytoremediation potential, absorbing heavy metals like lead, nickel, and cadmium from polluted soils and water, a critical advantage for environmental restoration. One effective method for mitigating soil and water pollution, especially in reducing heavy metals, is the use of suitable plant and tree species (Yadav et al., 2010; Hu et al., 2013). However, the current practice of relying on cuttings (45% of plantations) rather than certified seedlings reduces yield potential by 15–20% and increases pest vulnerability, undermining these ecological benefits.

Advisory needs

Government assessments reveal systemic gaps in plantation management: 70% of soils remain unimproved, 60% of stands lack proper thinning, and 18% suffer from inefficient irrigation. These issues stem from limited technical knowledge among farmers, 96% cannot identify poplar species, and 91% rely on flood irrigation. The predominance of farmers with only high school education (52.93%) exacerbates these challenges. While extension services exist, their impact is constrained by low engagement; only 1.5% of farmers report adequate advisory support. Targeted interventions, such as field visits by forestry experts, model farm demonstrations, and accessible training on irrigation, pest control, and soil management, are urgently needed to address these gaps.

Knowledge transfer mechanisms

Effective dissemination of research-based practices remains a bottleneck. Despite extensive scientific studies on optimal poplar cultivation, knowledge uptake is hindered by farmers' low literacy rates and the absence of structured training programs. Proposed solutions include establishing specialized forestry associations, expanding vocational education centers, and strengthening linkages between research institutions, extension services, and farmers. The government's seedling distribution program (though commendable) requires quality improvements, as poor-quality saplings compromise plantation success. Additionally, integrating modern knowledge-transfer tools (e.g., digital platforms for marketing and peer learning) could bridge gaps, particularly for younger farmers. Institutional reforms, such as insurance schemes and guaranteed purchase contracts, could further incentivize the adoption of improved practices.

Table 2: Status of weakness in Poplar wood production in Ardabil province from the perspective of wood farmers

Priority	Std Deviation	Mean	Item
1	0.72	4.7	Sufficient fertilizer and pesticide supply from governmental institutions is not available
2	0.87	4.45	Brokers and intermediaries heavily influence the poplar wood market.
3	1.05	4.07	Adequate free and high-quality seedlings/saplings are not available
4	1.76	3.33	It is challenging to implement pressurized irrigation methods in poplar wood production.
5	1.3	3.29	Not having a plan or specific customers for selling poplar.
6	1.38	2.8	Poplar trees have been repeatedly affected by fires and pest attacks.
7	1.05	2.62	Earning more income from other activities compared to poplar wood production.
8	1.04	2.52	The selling price of poplar wood is low.
9	1.08	2.5	The time to profit and return on investment in poplar wood is lengthy.
10	1.04	2.45	Not satisfied with the income from forestry.
11	1.35	2.33	Sufficient water resources for poplar wood production are not available.
12	1.19	2.31	Lack in sufficient technical knowledge about planting poplar, irrigation methods, planting, and pest control.
13	1.15	2.09	Profitability from poplar farming is lower compared to other agricultural products.
14	0.52	0.2	Not having the interest and motivation to continue planting poplar in the future.

Analysis of weaknesses

Structural and knowledge gaps in farming practices

The study reveals critical gaps in poplar cultivation practices, with 70% of plantations lacking soil improvement, 60% unthinned, and 18% suffering from inefficient irrigation. These issues stem from farmers' limited technical knowledge, 96% cannot identify poplar species, and 91% rely on flood irrigation despite its 30–40% lower water-use efficiency compared to drip systems (Modirrahmati and Baghery, 2003). Training programs should prioritize practical workshops and demonstration farms to enhance farmers' skills and knowledge. Practical workshops, held quarterly by provincial agricultural extension offices, should focus on hands-on sessions covering soil testing, thinning techniques, and irrigation scheduling. Additionally, 2 to 3 model demonstration farms should be established in each county to showcase optimal agricultural practices. These farms would serve as learning hubs, where pre- and post-training yield assessments can be conducted to evaluate the effectiveness of the training programs.

Market dysfunction and input shortages

Brokers dominate the poplar wood market, creating price disparities of 55,000–110,000 IRR/kg (mean: 65,921,570 IRR/ton) across Ardabil. This contrasts sharply with Mazandaran Province, where cooperative-driven pricing stabilizes sales at 85,000–95,000 IRR/kg (Bozorgmehr et al., 2014). The key interventions include improving input access by subsidizing fertilizers and pesticides through a voucher system, aiming to cover 50% of the costs for smallholder farmers. Additionally, market reforms will involve launching a digital platform to facilitate direct sales between farmers and industry stakeholders. This platform will be piloted in Meshginshahr County, with transaction transparency monitored on a quarterly basis.

Seedling quality and regional disparities

Ardabil's reliance on low-quality cuttings (45% of plantations) reduces yields by 15–20% compared to nurseries in Gilan Province, where certified seedlings achieve 25 m^3/ha/year yields (vs. Ardabil's 18 m^3). It is recommended to establish partnerships with the Forests and Rangelands Research Institute to facilitate the distribution of climate-adapted saplings, aiming for an 80% adoption rate by 2026. Additionally, conducting annual yield comparisons with the West Azerbaijan region (specifically the Urmia area) is suggested to identify and implement best agroforestry practices.

Institutional and educational deficits

Only 1.5% of farmers report adequate advisory support, reflecting systemic gaps. The proposed measures include both certification programs and policy integration. First, a 12-month "Poplar Master Farmer" curriculum should be developed by Ardabil University, offering modules on pest control (such as poplar aphid management) and product marketing. Second, it is recommended to integrate poplar farming education into the national agricultural extension curriculum, following the successful model implemented in Uttar Pradesh, India (Jain and Singh, 2000). Addressing these weaknesses requires segmented strategies, quantifiable targets, and cross-provincial learning to align Ardabil's poplar sector with high-performing regions.

Table 3: Status of opportunities in Poplar wood production in Ardabil province from the perspective of wood farmers

Priority	Std Deviation	Mean	Item
1	0.5	4.84	Preventing environmental problems and preserving natural forests are of great importance.
2	0.73	4.66	The climatic and soil conditions of Ardabil province are suitable for poplar wood production.
3	1.01	4.62	The existence of a specific government agency helps in the development of poplar farming.
4	1.20	3.39	Mixed cultivation of poplar with other agricultural products seems to be a suitable method.
5	1.09	2.35	The use of wastewater can be beneficial for meeting the water needs of poplar farming.
6	1.09	2.19	New species of poplar with higher yields are being produced.
7	1.22	2.09	The establishment and operation of wood industry factories in the province has increased.
8	0.9	1.78	More attention should be paid to the importance of poplar farming in the media.
9	0.9	1.7	Supportive laws for poplar farmers have been developed.
10	1.08	1.33	Conditions for exporting wood products in the province have been provided.

Opportunities Analysis:

Poplar farming offers major environmental benefits, including reduced damage and forest conservation, an advantage recognized by both farmers and experts in Ardabil province. The development of composite product production lines and reliable raw material supply are key drivers of its expansion. Over recent decades, Iran's Forests and Rangelands Research Institute has advanced poplar cultivation through research on climate adaptation and cost-effective forestry practices. Mixed farming with poplar is also seen as a promising method to boost farmer livelihoods and rehabilitate degraded lands. However, agroforestry still lacks widespread adoption. Promoting high-yield, climate-adapted varieties and scientific practices in planting, maintenance, and harvesting (especially near rivers and wastewater treatment sites) can strengthen both environmental outcomes and the wood industry's resource base.

Table 4: Status of threats in Poplar wood production in Ardabil province from the perspective of wood farmers

Priority	Std Deviation	Mean	Item
1	0.62	4.82	Pricing of poplar wood by brokers and intermediaries.
2	0.65	4.76	Lack of government-guaranteed purchase of poplar products from farmers.
3	0.87	4.6	Absence of a defined and cohesive market for poplar product sales.
4	0.86	4.33	Lack of production cooperatives or supportive organizations for poplar tree farmers.
5	0.81	4.23	Absence of an independent institution for poplar wood management in the province.
6	0.81	3.98	Government emphasis on productive tree cultivation over unproductive products.
7	1.26	2	Climate changes and reduction in water resources.
8	0.82	1.25	Continuous increase in production costs of poplar products compared to the past.

A major challenge in poplar farming development is the lack of reliable data on active farmers and wood demand. A registration system is expected to continuously update this information. Wood prices vary up to 30% between farm gate and factory yard, partly due to brokers filling the gap caused by the absence of farming cooperatives. Establishing cooperatives could stabilize prices, increase farmer income, and improve communication between farmers and industries. The analysis indicates strong opportunities to grow Ardabil's poplar sector but notes key challenges. Market restructuring could boost incomes by reducing broker margins and raising producer prices through 3-5 cooperatives. Leveraging national and international organizations and media can support poplar cultivation development. Cooperatives also reduce economic risks and help expand production. The wood and paper industries lack a dedicated authority, hindering coordination; creating a specialized section within relevant governmental bodies would improve organization and data management. Raising awareness and promoting tree planting culture is vital, as knowledge about poplar farming in Ardabil province remains low even among experts. Educational programs tailored to farmers' needs, based on proper needs assessment, are essential to support sustainable wood cultivation and forest conservation. The results related to the prioritization of educational needs from the perspective of poplar farmers in Ardabil province are presented in Table 65.

Table 5: Educational priorities needed by Poplar farmers in Ardabil province

Priority	Std Deviation	Mean	Item
1	0.77	4.6	Ways to increase wood yield per hectare
2	0.85	4.52	Amount of pesticides and fertilizers used in poplar wood production
3	0.72	4.41	Methods of pest control in poplar wood production
4	0.65	4.25	Appropriate timing and method of irrigation for poplar crops
5	0.65	4.17	Precise methods for planting poplar seedlings or cuttings
6	0.66	4.13	Improved marketing strategies for poplar products
7	1.01	4.03	Harvesting process of poplar products
8	0.86	4.01	Types of poplar sales methods
9	1.03	3.66	Utilizing the internet for marketing poplar products
10	1.02	3.6	Customer engagement strategies for poplar products
11	1.11	3.56	Utilizing social media networks for marketing poplar products

Due to the low literacy level among poplar farmers, there is a strong need for relevant training courses on poplar cultivation organized by relevant authorities. The results indicate that most poplar farmers lack knowledge about the species of poplar they are planting and do not properly observe planting distances, which significantly affects the annual growth and yield of trees. Farmers' inability to identify poplar species (96% unaware) suggests they may be cultivating suboptimal varieties for local conditions, potentially explaining the 11.09-year average harvesting period-significantly longer than the 7-8 year optimal cycle for suitable cold-climate varieties. Additionally, nearly all poplar farmers were using flood irrigation methods and were unfamiliar with modern irrigation techniques, indicating the necessity for training in this area. Recently, one of the challenges faced by poplar farmers has been pest infestations, emphasizing the need for training on pest control methods. Support and backing from government agencies and organizations play a crucial role in improving tree growth performance and boosting the motivation of poplar farmers.

Conclusion

The Delphi-based analysis of 51 poplar farmers in Ardabil Province reveals three critical insights supported by quantitative data: First, market inefficiencies cause substantial price disparities (55,000-110,000 IRR/kg), with brokers capturing 30% of potential farmer income.

Second, technical gaps persist, with 70% of plantations lacking soil improvement and 91% using inefficient flood irrigation, reducing yields by 18-22% compared to optimized systems. Third, the 11.09-year average harvest cycle exceeds the 7-8 year optimum for cold-climate varieties, indicating cultivar mismatches. The study's key results are summarized in a SWOT framework. Strengths include high industrial demand (4.54), low labor needs (4.5), and favorable climate (4.66). Major weaknesses are input shortages (4.7), broker dominance (4.45), and poor irrigation (3.33). Opportunities focus on environmental benefits (4.84), mixed cultivation (3.39), and wastewater irrigation (2.35). Threats include price manipulation by intermediaries (4.82), water scarcity, and climate change (both 2.0). This SWOT indicates current strengths and challenges while identifying key growth areas for poplar cultivation in the region. To harness the potential of poplar farming in Ardabil, a five-year plan with quantitative goals is proposed. Market reform aims to establish four agricultural cooperatives by 2025, reduce broker profit margins by 40%, and increase producer prices by 15%, from 65,921,570 to 75,800,000 IRR per ton. Empowerment efforts include training 80% of farmers in pressurized irrigation by 2026 through eight annual workshops in each county, developing three model farms that boost yield by 22%, and providing digital extension services to 60% of farmers under 50 years old. Genetic improvement focuses on replacing 45% of cuttings with certified seedlings by 2027, prioritizing cold-climate–adapted varieties to shorten the harvest cycle to eight years. Water optimization plans involve using wastewater to irrigate 30% of farms by 2028, resulting in an 18% saving of freshwater resources. The implementation framework requires coordination among various stakeholders. The government will provide a 50% subsidy for irrigation systems and seedlings. The private sector is responsible for establishing two new processing factories with guaranteed product purchase. Universities, specifically Ardabil University, will offer certified training programs. Non-governmental organizations will facilitate the formation of cooperatives and support market linkages. In conclusion, Ardabil's poplar sector could see a 35-40% productivity increase by applying these strategies. Favorable climatic conditions (temperatures between 6-12°C and rainfall from 250-600 mm) combined with strong farmer motivation (82% willing to expand cultivation) create a solid foundation. However, systematic changes in market structure, knowledge transfer, and resource management are essential for sustainable development. Future research should monitor cooperatives' impact on price stability and evaluate improved poplar varieties' performance under climate change scenarios. One major challenge was the dominance of brokers in the market. To address this, the establishment of sales cooperatives with at least 50 members was proposed, aiming to reduce broker-driven price fluctuations by 40%. Another issue was the prevalent use of flood irrigation, which the study suggested replacing with pressurized irrigation systems through targeted training programs; this change is expected to cut water consumption by 30% within three years. Lastly, poor-quality seedlings were recognized as a limiting factor, and the creation of equipped nurseries under the supervision of Agricultural Jihad was recommended, with an expected yield increase of 20% per hectare.

Acknowledgment

There has been no support from any organization to carry out this project.

References

Abhilash, P.C., 2021. Restoring the unrestored: strategies for restoring global land during the UN decade on ecosystem restoration (UN-DER). Land, 10(2), 201. https://doi.org/10.3390/land10020201

Ahmad, S., Xu, H. and Ekanayake, E.M.B.P., 2023. Socioeconomic determinants and perceptions of smallholder farmers towards agroforestry adoption in northern irrigated plain, Pakistan. Land, v. 12(4), 813 p. https://doi.org/10.3390/land12040813

Ahmadloo, F., Ghasemi, R. and Modirrahmati, A., 2020. Introduction of successful and high yielding poplar clones for cultivation in the central regions of the country. Iran Nature, v. 4(6), p. 53-70.

Alemayehu, A. and Melka, Y., 2022. Small scale eucalyptus cultivation and its socioeconomic impacts in Ethiopia: A review of practices and conditions. Trees, Forests and People, v. 8, 100269. https://doi.org/10.1016/j.tfp.2022.100269

Aminzadeh, Z., Esmali Ouri, A., Mostafazadeh, R. and Nasiri Khiavi, A., 2024. Assessing the performance of machine learning algorithms for analyzing land use changes in the Hyrcanian forests of Iran. Environmental Science and Pollution Research, p. 1-11.

Amiri, M. and Azadfar, D., 2009. Identification of Populus clones (Populus nigra L.) in primary phase, s growth in the north of Lorestan province. Iranian Journal of Biology, v. 22(1), p. 151-160.

Ashraf, J., Pandey, R., de Jong, W. and Nagar, B., 2015. Factors influencing farmers' decisions to plant trees on their farms in Uttar Pradesh, India. Small-scale Forestry, v. 14, p. 301-313. https://doi.org/10.1007/s11842-015-9281-z

Azizi, M., 2008. A model of supplying poplar wood for Iranian paper & wood factories. Journal of Forestry Research, v. 19, p. 323-328. https://doi.org/10.1007/s11676-008-0058-1

Azizi, M. and Ray, C., 2015. Introducing a status of access to raw material resources for manufacturers of cellulosic industries. Forest Policy and Economics, v. 51, p. 17-28. https://doi.org/10.1016/j.forpol.2014.11.002

Bayatkashkoli, A., Azizi, M. and Faezipour, M., 2021. Quantitative analysis of poplar plantations in four Iranian Provinces (Case of the study: East Azerbaijan, Zanjan, Ardabil and Kermanshah). Iranian Journal of Wood and Paper Industries, v. 12(3), p. 375-389.

Bond, W.J., 2019. Open ecosystems: ecology and evolution beyond the forest edge. Oxford University Press. https://doi.org/10.1093/oso/9780198812456.001.0001

Bozorgmehr, A., Nemati, A. and Zakeri, E., 2014. Characterizing the Socioeconomic factors influencing poplar plantation in North Khorasan Province. Iranian Journal of Forest and Poplar Research, v. 22(4), p. 711-723.

Chavan, S.B. and Dhillon, R.S., 2019. Doubling farmers' income through Populus deltoides-based agroforestry systems in northwestern India. Current Science, v. 117(2), p. 219-226. https://doi.org/10.18520/cs/v117/i2/219-226

Chavan, S.B., Dhillon, R.S., Sirohi, C., Keerthika, A., Kumari, S., Bharadwaj, K.K. and Yessoufou, K., 2022. Enhancing farm income through boundary plantation of poplar (Populus deltoides): An economic analysis. Sustainability, v. 14(14), p. 8663. https://doi.org/10.3390/su14148663

Darvish, A.K., Chizari, M. and Mirdamadi, S.M., 2008. Analysis of socio-economic factors influencing on adoption of agroforestry among poplar farmers in northern part of Iran.

Decocq, G., Andrieu, E., Brunet, J., Chabrerie, O., De Frenne, P., De Smedt, P. and Wulf, M., 2016. Ecosystem services from small forest patches in agricultural landscapes, Current Forestry Reports, v. 2, p. 30-44. https://doi.org/10.1007/s40725-016-0028-x

Dwivedi, R.P., Kareemulla, K., Singh, R., Rizvi, R.H. and Chauhan, J., 2016. Socio-economic analysis of agroforestry systems in Western Uttar Pradesh. Indian Research Journal of Extension Education, v. 7(3), p. 18-22.

Eskandari, S., Behnamfar, K., Pourghasemi, H.R. and Tiefenbacher, J.P., 2022. Provision of eucalyptus wood farming potential map in Iran: An application of land cover, ecological, climatic, hydrologic, and edaphic analysis in a GIS-based fuzzy AHP framework. Ecological Indicators, v. 136, 108621. https://doi.org/10.1016/j.ecolind.2022.108621

Goodarzi, G.R., Ahmadloo, F. and Calagari, M., 2023. Determining the most suitable planting spacing for superior poplar clones in Markazi province based on wood production performance. Forest and Wood Products, v. 76(1), p. 75-89.

Hagen, O., Skeels, A., Onstein, R.E., Jetz, W. and Pellissier, L., 2021. Earth history events shaped the evolution of uneven biodiversity across tropical moist forests. Proceedings of the National Academy of Sciences, v. 118(40), e2026347118. https://doi.org/10.1073/pnas.2026347118

Hosseini, S.S., Shahnabati, N., Salami, H., Yazdani, S. and Calagari, M., 2021. Estimating the demand for poplar wood in the wood and paper industries of Iran. Iranian Journal of Forest and Poplar Research, v. 29(1), p. 65-76.

Hu, Y., Nan, Z., Su, J. and Wang, N., 2013. Heavy metal accumulation by poplar in calcareous soil with various degrees of multi-metal contamination: implications for phytoextraction and phytostabilization. Environmental Science and Pollution Research, v. 20(10), p. 7194-7203.

Jain, S.K. and Singh, P., 2000. Economic analysis of industrial agroforestry: poplar (Populus deltoides) in Uttar Pradesh (India). Agroforestry Systems, v. 49, p. 255-273. https://doi.org/10.1023/A:1006388128069

Joshi, R., Sharma, B. and Singh, H., 2024. Poplar Plantation as an Agroforestry Approach: Economic Benefits and Its Role in Carbon Sequestration in North India. Journal of Resources and Ecology, v. 15(4), p. 880-888. https://doi.org/10.5814/j.issn.1674-764x.2024.04.009

Karakaya, S., Daşdemir, İ. and Ercan, M., 2017. Socioeconomic structure and analysis of the demand for wood raw materials in the poplar wood-processing companies of the Sakarya and Kocaeli provinces in Turkey. Journal of Sustainable Forestry, v. 36(6), p. 623-646.

Kareemulla, K., Rizvi, R.H., Kumar, K., Dwivedi, R.P. and Singh, R., 2005. Poplar agroforestry systems of western Uttar Pradesh in northern India: a socioeconomic analysis. Forests, Trees and Livelihoods, v. 15(4), p. 375-381.

Keivan Behjou, F., Mostafazadeh, R. and Alaei, N., 2024. Effects of Forest Logging Systems on the River Flow Regime Indices Using Graphical Techniques: A Case Study in a Small Natural Forest. Hydrology, v. 11(7), 94 p.

Khayati Nezhad, S., Hosseinzadeh, O., Hajjarian, M. and Abdi, M., 2018. Strategic planning for wood farming development (Case study: Urmia). Iranian Journal of Wood and Paper Industries, v. 8(4), p. 533-548.

Lewis, S.L., Edwards, D.P. and Galbraith, D., 2015. Increasing human dominance of tropical forests. Science, v. 349(6250), p. 827-832.

Majid, A., Mohammad, F. and Ali, B., 2020. A quantitative study of poplar plantation situation in four Iran provinces. Economics, Management and Sustainability, v. 5(1), p. 17-28.

Masse, S., Marchand, P.P. and Bernier-Cardou, M., 2014. Forecasting the deployment of short-rotation intensive culture of willow or hybrid poplar: Insights from a Delphi study. Canadian Journal of Forest Research, v. 44(5), p. 422-431.

McDowell, N.G., Allen, C.D., Anderson-Teixeira, K., Aukema, B.H., Bond-Lamberty, B., Chini, L. and Xu, C., 2020. Pervasive shifts in forest dynamics in a changing world. Science, v. 368(6494), eaaz9463.

Mehri, S., Mostafazadeh, R., Esmaliouri, A. and Ghorbani, A., 2017. Spatial and Temporal Variations of Base Flow Index (BFI) for the Ardabil Province River, Iran. Journal of the Earth and Space Physics, v. 43(3), p. 623-634. https://doi.org/10.22059/jesphys.2017.60293

Modirrahmati, A.R. and Baghery, R., 2003. Poplar Clones Trial for three year short rotation system. Iranian Journal of Forest and Poplar Research, v. 11(4), p. 613-637.

Mukundente, L., Ndunda, E. and Gathuru, G., 2020. Socio-economic and institutional factors affecting smallholders' farmers to adopt agroforestry practices in southern province of Rwanda. International Journal of Agricultural Science and Food Technology, v. 6(1), p. 068-074.

Nabavi, V., Azizi, M., Tarmian, A. and Ray, C.D., 2020. Feasibility study on the production and consumption of wood pellets in Iran to meet return-on-investment and greenhouse gas emissions targets. Renewable Energy, v. 151, p. 1-20.

Neupane, R.P., Sharma, K.R. and Thapa, G.B., 2002. Adoption of agroforestry in the hills of Nepal: a logistic regression analysis. Agricultural Systems, v. 72(3), p. 177-196.

Nezhad, S.K., Hosseinzadeh, O., Hajjarian, M. and Abdi, M.R., 2018. Strategic planning for wood farming development (Case study: Urmia).

Salam, M.A., Noguchi, T. and Alim, M.A., 2006. Factors affecting participating farmers' willingness-to-pay for the Tree Farming Fund: a study in a participatory forest in Bangladesh. Environmental Monitoring and Assessment, v. 118, p. 165-178.

Singh, A.S., 2017. Common procedures for development, validity and reliability of a questionnaire. International Journal of Economics, Commerce and Management, v. 5(5), p. 790-801.

Sloan, S. and Sayer, J.A., 2015. Forest Resources Assessment of 2015 shows positive global trends but forest loss and degradation persist in poor tropical countries. Forest Ecology and Management, v. 352, p. 134-145.

Vatani, L., Najafi, A., Rafiee, A.A. and Shamsi, S.S., 2021. Analytic Network process as an approach to prioritize wood raw material for wood and paper factories. ECOPERSIA, v. 9(3), p. 169-177.

Yadav, R., Arora, P., Kumar, S. and Chaudhury, A., 2010. Perspectives for genetic engineering of poplars for enhanced phytoremediation abilities. Ecotoxicology, v. 19(8), p. 1574-1588.

Zhu, M., Shen, C., Tian, Y., Wu, J. and Mu, Y., 2022. Factors affecting smallholder farmers' marketing channel choice in China with multivariate logit model. Agriculture, v. 12(9), 1441 p.