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Agroforestry Methods as a Substitute for Sustainability in the Economy and Environment

Maninder Kaur[1], Dr. Balwinder Singh Tiwana[2]

[1]Research Scholar, Department of Economics, Punjabi University, Patiala-147002, (Punjab)
[2]Former Professor and Head, Department of Economics, Punjabi University Patiala-147002, (Punjab)

Abstract
Agroforestry is agriculture that includes raising livestock and crops alongside trees on the same piece of land at a point in time. The world's main issue today is the shrinking area covered by forests. Roads, industry, urbanization, and population are all growing geometrically. More land must be covered by tree plantations to meet the increasing requirements, yet horizontal expansion of the area covered by trees is not feasible. Under such situations, agroforestry based on poplar can prove to be an appropriate choice as it meets the demand for wood products and helps in enhancing people's economic status.
The main objectives of the study are to review the application of poplar-based agroforestry and to examine how this land use system preserves ecological systems in comparison to monocultures while also helping to create jobs and revenue. For this study, the data are collected from a variety of sources, including books, websites, research papers, and articles. Poplar wood contributes to carbon sequestration, which reduces greenhouse gas emissions and CO2 in the atmosphere. Additionally, farmers can earn profit from the carbon market by exchanging carbon. It is possible to use ethanol made from poplar biomass in place of fossil fuels. The research is expected to infuse farmers with renewed optimism in the agriculture industry and can support government initiatives aimed at increasing farmers' income and protecting the environment.

Keywords*:* Agroforestry based on Poplars, Financial Stability, Sustainable Environment

Introduction

Being one of the most climate-vulnerable nations, India has a larger need for preservation and agricultural adaptation techniques to lessen the negative effects of the changing climate on important biological resources, vegetation, and natural ecosystems. To fulfill the developmental aims and ambitions of a developing economy, India's energy requirements are predicted to increase two to 2.5 times by 2047. The pace of the transition to cleaner energy would need to take into account multiple demands on the limited resources available for sustaining both economic and social growth as well as for enhancing resistance to climate change (Economic Survey 2023–24). An efficient transition to a diverse mix of renewable power sources, with a sizable portion coming from non-fossils, as well as improvements in energy generation and utilization effectiveness are necessary to reach Net Zero by 2070. India's transition to greener sources of energy must prioritize the gradual integration of energy from renewable sources into the nation's energy mix.
Additionally, poplar is one of the referred to as energy crops that may enhance agricultural-environment linkages in theory. The Intergovernmental Panel on Climate Change's (IPCC) recommendations have been

followed in the comparison and evaluation of crops along with poplar plantings as sinks of carbon. When it comes to sequestering abundant carbon dioxide in the atmosphere, growing poplars seems to be a more advantageous option than cultivating crops. Intercropping-based agroforestry production methods have been proven to be more profitable than isolated crop and tree cultures. In the agricultural forestry system, trees also helped with the storage of carbon and decreased loss of nitrogen from soil leaching. Timber from agroforestry varieties of trees is valued added to ensure farmers receive a healthy profit.

The Salicaceae family historically consisted of Populus and Salix (willows). Populus alba, or white poplar, was known as 'arbor populi' or 'people's tree' in ancient Rome. The genus Populus encompasses 44 species across five divisions: white poplars (leucine), black poplars (Aigeiros), balsam poplars (Tecamahaca), Leucoides, and Turanga. These species are prevalent in temperate and subtropical regions of the Northern Hemisphere. (Naithani et al., 2012)

Agroforestry is a type of agriculture that involves growing trees with crops and livestock on the same piece of land. Although there is no definitive proof of when agroforestry began in India, this tradition can be traced back to Burma's tannoy system. The taunngya technique was designed to increase forest cover while lowering planting expenses.

France pioneered the National Poplar Commission in 1942, leading to the International Poplar Commission in 1947, institutionalizing poplar plantations in Europe. Asian countries followed suit to meet timber and fuelwood needs. India's National Poplar Commission, established in 1965, catalyzed substantial poplar growth, notably in Haryana, Punjab, Uttar Pradesh, and Himachal Pradesh, supplementing historic Kashmiri cultivation. (Naithani et al.,2012)

As demand for forest products grew with development, natural forests were strained. Meeting rising needs through extensive tree plantations proved impractical. Poplar-based agroforestry emerged as an optimal solution, satisfying wood and food grain demands while bolstering socio-economic livelihoods.

Poplar plantations are popular among Indian farmers for a variety of reasons. In many nations, it contributes to appropriate farm income (Prevosto,1979). Its rapid growth, deciduous nature, strong market demand, soil enrichment, and high productivity (10 to 30 m3/ha/yr) on a short period 8-to-12-year rotation time (Mushtaq et al.,2018).

Poplar also had an edge over other commercial trees because of its potential to provide biomass for energy production (Zsuffa & Morgan, 1984). This paper presents the review of literature on poplar-based agroforestry, its usage, and the role of this land use system in income and employment generation.

Objectives of the study

1. To review poplar-based agroforestry and utilization of poplar wood in different parts of the world.
2. To know the contribution of this land use option in income and employment generation rather than monoculture.

Research Methodology

The study is based on secondary sources of data. Various articles, research papers, books, and websites are used to collect data.

Review of Literature

Morley Peter M. and Balantinecz John J. (1993) have shown that the utilization of poplar in Canada has significantly shifted from its historical perception as a weed tree to becoming a valuable resource in

both primary and secondary industries. A survey conducted in 1990 highlighted this trend, revealing expanding usage in various sectors. Notably, key industries in Ontario and Quebec employ aspen poplar extensively for furnishing, while Alberta to Quebec see significant use in wafer board manufacturing. Secondary sectors also witness a rise in poplar utilization, with match splints and hockey stick handles predominantly made from this resource. This transformation is attributed to government policies mandating comprehensive wood resource utilization and the diverse applications of poplar wood, including in construction and furniture manufacturing. Overall, poplar's future in Canada appears promising, propelled by its versatility and increasing demand across industries.

Balantinecz et al. (2001) have described that over the past two decades poplar has risen in importance in North America, overcoming its initial stigma as a "weed tree." Its versatile applications span from pulp and paper to furniture components and match splints. However, further research is crucial for refining clone selection to tailor poplar wood properties to specific sites and end uses. The future looks promising for poplar utilization, with wood fiber demand escalating due to global population growth and industrialization. Advances in biotechnology and genetic transformation offer opportunities to enhance not only poplar growth rates but also key wood qualities, including chemical composition and durability.

Warrier (2010) recognized that the drought tolerance of P. deltoids is a crucial trait, making it somewhat resilient to short-term inundation and compatible with water-logged soils. Its unique growth pattern, with close branches and leafless winters, reduces solar energy and rainwater absorption, making it suitable for co-cultivation with crops. In Northern India, poplars are commonly intercropped with cash crops like sugarcane, wheat, maize, and others. Research from the Forest Research Institute in Dehradun highlights the economic benefits of poplars in agroforestry systems, acting as a "saving bank" for farmers. Poplar trees can be harvested at 8 years of age, providing liquid funds, while younger trees are a valuable source of cellulose fiber for various paper grades.

Dhiman (2012) described in a case study of WIMCO's poplar initiative, that researchers examined how tree cultivation transformed rural Uttar Pradesh. In the 1970s, WIMCO, a match manufacturing company with factories in Bareilly, promoted poplar as match wood in Uttar Pradesh and neighboring States. WIMCO established a robust supply chain for saplings, wood procurement, and processing. Poplar became a cash crop for farmers, generating over 6 million man-days of work in nursery, plantation, harvesting, shipping, and wood processing. The initiative also led to the establishment of over 4000 private nurseries, offering farmers self-employment and sustainable livelihoods, especially in underdeveloped rural areas.

Ahuja (2016) has looked into the possibility of employment in poplar-based agroforestry. The majority of workers were employed by poplar on agricultural lands in various activities such as seedling development, tree planting, cultural operations, harvesting, and transportation. With 10-12 percent of farmland under poplar and other fast-growing agroforestry species, ten million people will be able to survive over a six-year rotation period. The complete wood-based value chain, which includes contractors, commissions, agents, traders, and industrial labor, provides a sustainable livelihood for 22 million people.

Sharma et al. (2020) conducted a study in Una District, Himachal Pradesh, which evaluated the economics of poplar-based agroforestry and the factors affecting its adoption. Using a multistage random sampling method, 60 households from each of the four farm categories were selected. Net Present Worth (NPW) for agriculture was Rs. 1.21 lakhs, while for poplar-based agroforestry, it was Rs. 6.44 lakhs after an eight-year rotation period in 2016-17. Agroforestry had a higher Benefit-Cost (B: C) ratio of 2.10 compared to agriculture's 1.18. Poplar-based agroforestry contributed 48.42% to total income, surpassing

agriculture's 42.60%. Land ownership, non-farm worker count, and family size influenced agroforestry adoption. Stable prices and financing are essential to encourage agroforestry adoption.

Contribution of Poplar-based Agroforestry to income generation

The table shows that a study was conducted in the Yamuna Nagar district of Haryana to examine the feasibility of poplar-based agroforestry on farmers' income. It was calculated that a farmer growing rice-wheat at his farm for seven years could earn Rs. 3,27,703/ha. In contrast, a farmer with poplar-based agroforestry at his Agri silviculture system with 500 poplar trees could earn Rs. 5,94,811 in the first four years of rabi and fallow in the kharif season. If the government provided an incentive for carbon sequestered by agroforestry, the farmers could earn Rs. 8,98,537 (Singh, M. et al, 2020).

Table-1 Comparison of net income from rice-wheat crop rotation and Poplar-based Agroforestry system in Yamuna Nagar, Haryana

Year	Net income from the rice-wheat system (Rs. /ha)			Net income from Poplar-based Agroforestry system (Rs. /ha)	Projected net income with the value of carbon sequestered by Poplar-based agroforestry system (Rs. /ha)	
	Rice	Wheat	Total	Poplar+Wheat	Value of carbon sequestered/ha @Rs.333/t $CO_{2\,e}$	Total Income
2008-09	17074	18195	35269	-16392	0	-16392
2009-10	20966	11831	32797	-202	0	-202
2010-11	24134	20613	44747	2308	40197	42505
2011-12	8779	25165	33945	4053	51268	55321
2012-13	26581	26581	53163	-800	62716	61916
2013-14	56084	20648	76732	6800	69298	76098
2014-15	41030	10021	51050	599045	80247	679292
Total	194648	133054	327703	594811	303726	898537

Source: Singh, M. et al. (2020)

An initiative taken by WIMCO; a West India matches manufacturing company in the terai plains of western Uttar Pradesh to promote poplar cultivation. WIMCO has played a critical role in enabling farmers to profit from poplar-based agroforestry. The study is based on seven years of data, from 2004 to 2011. According to the study, poplar-based agroforestry yielded Rs. 1,00,065 per acre per year, whereas sugarcane crop yielded Rs. 27,000 per acre per year, and paddy-wheat rotation yielded Rs. 24,500 per acre per year. For the same timeframe, the net present value of returns for poplar-based agroforestry with

intercrop was 4.07 times higher than wheat-paddy rotation and 3.71 times higher than sugarcane crop farming (Chaudhary, N. P., & Chaudhary, G. 2012.

Poplar as a tool for economic development and job creation in rural areas

The expansion of poplar activities, from nursery production to wood processing, offers significant employment opportunities for trained, semi-skilled, and unskilled workers within the poplar-producing region and beyond. Each harvested tree generates five man-days of work: one man-day during nursery growth and plantation maintenance, one during harvesting and log handling, and three during wood processing in industrial units. Estimates suggest one crore trees yield one crore man-days in nursery and plantation production, another crore in wood harvesting and handling, and three crores in wood processing, totaling five crore man-days.

An additional one crore man-days are estimated in supporting sectors like machinery, tools, chemicals, and fertilizers in poplar nursery and plantation production. Since these activities occur in rural areas, they often provide self-employment opportunities as producers handle many tasks themselves. While some timber is exported to other States, this may shift job creation elsewhere. Poplar trees also meet the majority of firewood needs previously sourced from government forests, with each tree yielding around 35 kg of roots and 20 kg of firewood from lops and tops. This development significantly impacts rural employment, particularly for women involved in local nursery and plantation work. While estimates for nursery production, plantation management, and wood harvest are realistic, those for wood processing are approximate.

Role in ecological Amelioration and Poplar-based Agroforestry farms as carbon sinks

Poplar has a lot of potential for sequestering atmospheric carbon in tree components, locking it up in wood products for a long time, and offsetting carbon emissions to the atmosphere by displacing fossil fuels. Ethanol from the biomass of poplar wood can become a substitute for fossil fuel.

Agroforestry helps in solving not only poverty, hunger, malnutrition, and other issues, but also the environment's degradation. Poplars and other fast-growing trees, play an essential role in absorbing atmospheric carbon dioxide and reducing pollution. The emerging carbon market could offer landowners a new viable option if carbon prices are high enough to make planting trees a better investment than other land uses, and procedures for trading carbon sequestered in trees on small farms in fragmented holdings are simplified for easy documentation and trade.

Conclusion

The study underscores poplar-based agroforestry's economic and environmental advantages over traditional wheat-rice crops. With its fast growth, short rotation period, and ability to accommodate intercropping, poplar significantly boosts farmer income. Its versatile wood finds use in matchbox production, furniture, papermaking, construction, and bio-energy, transforming its status from a weed tree to an economic asset. Poplar cultivation creates employment across various stages, from seedling development to wood processing. However, challenges like price fluctuations, insurance issues, and lack of financial support persist. To ensure the sustainability of poplar cultivation and promote its adoption, a robust policy framework is essential.

Limitations of the Study

The study is based on secondary data. No personal interview has been taken with the farmers to know about their economic upliftment after adopting poplar-based agroforestry.

Prospectus for Future Research

A constant stream of research is required to support the rising commercial poplar farming to improve cultivation methods and create new, quickly developing clones. To make poplar cultivation competitive and cost-effective compared to other land-use systems, concentrated efforts are required. Researchers should pay close attention to the current state of popular culture because of its limited genetic foundation in India. There is a lack of information available about the authority which settles the market price. Policies related to the fixation of the prices of poplar wood should be made by the Government so that farmers are not discouraged from poplar farming due to price fluctuations. During the recent decade, from 2005-06 to 2015-16, the price instability of poplar wood deterred farmers from starting new plants.

The increasing number of net imports of wood and wood-based products was an example of agroforestry policy failure. Overall, it was shown that a policy framework that has a substantial impact on the growth of agroforestry is required.

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