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CLIMATE-RESILIENT FOREST ECONOMICS: ADAPTING TREE SPECIES ROTATION FOR CHANGING TIMES

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ABSTRACT

The economic implications of rotation periods in tree plantation ventures are often underestimated. This study aims to determine the most financially rewarding rotation cycles for three tree species—Vachellia nilotica, Populus deltoides, and Dalbergia sissoo—in diverse tehsils of District Jhang, Pakistan, employing various economic assessment tools. Data were gathered on the quantities of the selected tree species, along with associated costs and benefits. Tree valuations beyond five years were determined by local farmers. Net present worth (NPW) and benefit-cost ratio (BCR) were used as economic indicators to identify optimal rotation cycles. The most favorable rotation cycle for V. nilotica was found to be six years, yielding a NPW of Rs. 1768.1 and a BCR of 222.01. Similarly, P. deltoides exhibited optimal economic outcomes within a six-year rotation, with a NPW of Rs. 1356.8 and a BCR of 170.61. For D. sissoo, the ideal rotation was also six years, resulting in a NPW of Rs. 2191.2 and an impressive BCR of 274.91 (equivalent to 273.91%). This study concludes that a six-year rotation cycle is recommended for cultivating V. nilotica, P. deltoides, and D. sissoo, to maximize economic returns. These findings suggest the viability of these species for neighboring regions and districts, underlining their potential for sustainable growth and substantial economic benefits.

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INTRODUCTION

In the face of changing times and climate challenges, the concept of climate-resilient forest economics becomes increasingly vital. One essential aspect of this adaptation is the tree species rotation (Srivastav et al., 2021). To ensure economic viability and sustainability, it is crucial to adjust the rotation periods of different tree species to align with the changing environmental conditions. By carefully considering the impacts of climate change, forest managers and policymakers can implement tree species rotation strategies that foster resilience, optimize economic returns, and secure the future of our

forests in an ever-changing world (Okumu et al., 2021). In Pakistan, farmers grow trees in various rotations, often without considering the economic aspect (Rodenburg et al., 2022). They mainly use the trees for personal needs, leading to potential unprofitability. The impact of rotation on net income is overlooked. Inflation also affects tree costs, making it more challenging for poor, uneducated farmers to understand the concept of economic tree rotation. As a result, they frequently suffer economic losses. Choosing the right tree species is vital to meet local pulp and paper demands. While many tree species are grown for wood production, a significant number of farmers in Pakistan cultivate *V. nilotica, P. deltoides,* and *D. sissoo* for shading purposes (Usman et al., 2022). To enhance profitability and sustainability, it is important to calculate the optimal rotation metrics. This helps determine the age of the trees that can generate returns within a specific time frame. However, most farmers are unaware of the most cost-effective rotation periods for D. sissoo, V. nilotica, and P. deltoides in the Punjab province of Pakistan (Usman et al., 2022). Conducting tests to identify the best economic rotation for these tree species can have significant implications for farmers' incomes and the environment. Several studies have explored economically viable tree rotations. Tariq et al. (2020) analyzed forest management economics and found that D. sissoo and M. alba had unsustainable outcomes, while *P. roxburghii* and *P. wallichiana* were more productive. Parija et al. (2023) investigated a poplar-based agroforestry system, revealing that farmers earned Rs. 4.5 lac ($7258) per hectare after six years of planting poplar. Intercropping wheat with poplar yielded a gross income of Rs. 225000 ($3629) per hectare. Deducting the costs, the net revenue from agroforestry (*poplar+wheat*) was Rs. 6.0 lac ($9677) per hectare. Agroforestry consistently outperformed crop rotation in terms of net returns year after year, generating 46% higher revenue for the farmer compared to crop rotation (Alston & Pardey, 2001).

Ahad et al. (2014) studied the economic rotation of Eucalyptus camaldulensis and found financial losses in all rotations, with the 3+3+4-year rotation resulting in the lowest losses. Arif et al. (2019) identified 8 years as the ideal rotation for firewood and 12 or 13 years for timber in the case of Dalbergia sissoo. Chandel et al. (2017) recommended a 10+5=15 years rotation for maximum profit. Nakajima et al. (2017) concluded that forest rotation influences revenue, with adjustments affecting earnings. Hansen et al. (1983) showed that a 20-year rotation with 3,000 plants per hectare is successful for poplar plantations. Farmers can generate additional income through crop rotation without extra inputs, utilizing tree species rotation for revenue in farmed regions (Leippert et al., 2020).

The study on Climate-Resilient Forest Economics: Adapting Tree Species Rotation for Changing Times has one fundamental objective. It aims to determine the most economically profitable combination of tree species, specifically focusing on *D. sissoo, V. nilotica,* and *P. deltoides*, in light of the changing climate conditions. By assessing growth rates, yields, and economic returns of different rotations, the research seeks to provide practical guidance for forest managers and farmers to maximize financial gains while adapting to the challenges posed by climate change. Additionally, the study aims to address the knowledge gap among farmers regarding the optimal tree species rotation for achieving the greatest financial benefits. By disseminating the research findings and recommendations through workshops, training sessions, and extension services, the study endeavors to empower farmers with valuable information, enabling them to make informed decisions and implement climate-resilient tree species rotations effectively. The study adopts a participatory approach, engaging local communities and stakeholders throughout the research process to understand their perspectives, needs, and challenges. This ensures that the adapted tree species rotation aligns with the social and cultural values of the communities, enhancing the likelihood of successful implementation and sustainable outcomes.

MATERIAL AND METHODS

Study Area Selection

The study area selection involved a multistage random sampling technique to ensure a representative sample of the region. District Jhang in the province of Punjab, Pakistan, was chosen due to its significance as a major agricultural and forestry area as per the investigation of an earlier study by Hu et al. (2023). It comprises diverse ecological and climatic conditions, making it suitable for investigating the economic aspects of tree species rotations in the context of changing climate conditions.

Village and Land Area Selection

To conduct an in-depth survey, four Tehsils within District Jhang were randomly selected. These Tehsils included Jhang Tehsil, Athara Hazari, Shorkot, and Ahmad Pur Sial. From each Tehsil, four villages were randomly chosen to cover a broad cross-section of rural farming communities. Subsequently, two random land areas, each comprising three acres, were selected from these villages. This sampling approach aimed to capture variability in tree management practices and economic conditions across the study area as per the investigation of an earlier study by Ahmad et al. (2017).

Data Collection

Data collection involved an interactive approach with the farmers residing in the selected villages. A short questionnaire was developed to gather essential information on tree prices. Farmers were asked to provide the prices of trees that were above five years old as per the study of Rueda et al. (2013). This approach ensured that mature trees were considered, as they have a more significant economic impact. Farmers were also requested to share their experiences and insights regarding aspects that significantly affected their income. Data collectors worked closely with the farmers to ensure accurate and comprehensive data collection.

Selection of Tree Species

To evaluate the economic viability of different tree species rotations, three specific tree species were selected for examination: *Vachellia nilotica, Populus deltoids, and Dalbergia sissoo*. These tree species were chosen based on their economic significance, prevalence in the study area, and potential adaptability to changing climate conditions.

Aspects Studied

The study focused on several aspects that significantly influenced the income of farmers in the study area. These aspects included tree growth rates, market prices of different tree species, demand for various tree products, climate-related risks affecting tree production, and overall profitability of different tree species rotations.

Data Analysis:

The economic analysis involved a comprehensive examination of the financial metrics to assess the profitability and economic feasibility of different tree species rotations. These financial metrics included:

Benefit-Cost Ratio (BCR): BCR was calculated by dividing the Present Worth (PW) of benefits (gross) by the Present Worth (PW) of costs. It provided insights into the economic efficiency of each tree species rotation, helping in determining the most financially viable option (Devarakonda, 2019).

Net Present Worth (NPW): NPW was calculated by subtracting the PW of expenditures from the PW of gross returns. This metric provided a clear understanding of the potential net economic gains associated with each tree species rotation (Ascher et al., 2020).

Return on Investment (ROI): ROI was calculated by taking the difference between the PW of gross benefits and PW of costs, dividing it by PW of costs, and then multiplying by 100. It quantified the profitability of each tree species rotation relative to the initial investment (Ichsani et al., 2015).

Capital Recovery Factor (CRF): The CRF was computed using the formula: CRF = I (1 + i)^n / {(1 + i)^n - 1}. It helped determine the annual economic benefits generated by each tree species rotation.

Average Annual Benefits (AAB): AAB was calculated by multiplying the CRF by the difference between PW of benefits and PW of costs. This metric represented the average annual economic benefits attributable to each tree species rotation.

Discount Factor: The discount factor was calculated as 1 / (1 + i)^n, where "i" represented the discount rate and "n" was the number of years. The discount factor allowed for the adjustment of future economic benefits to their present value.

Net Present Worth (NPW) and Benefit-Cost Ratio (BCR) Equation: The NPW and BCR were computed using a cash flow formula: NPW and BCR = -C0 + C1 / (1 + r) + C2 / (1 + r)^2 + ... + CT / (1 + r)^T, where C0, C1, C2, ..., CT represented cash flows at different periods, and "r" was the discount rate. This equation allowed for the determination of the net economic value and

profitability of each tree species rotation over the study period (Anjum et al., 2011).

Stakeholder Engagement

Throughout the research process, active stakeholder engagement was ensured to enhance the relevance and practicality of the study findings as per the method of Concannon et al. (2012). Local farmers, forest managers, and relevant stakeholders were involved through workshops, focus group discussions, and individual interviews. Their perspectives, knowledge, and experiences were taken into account to align the research objectives with the needs and values of the local communities.

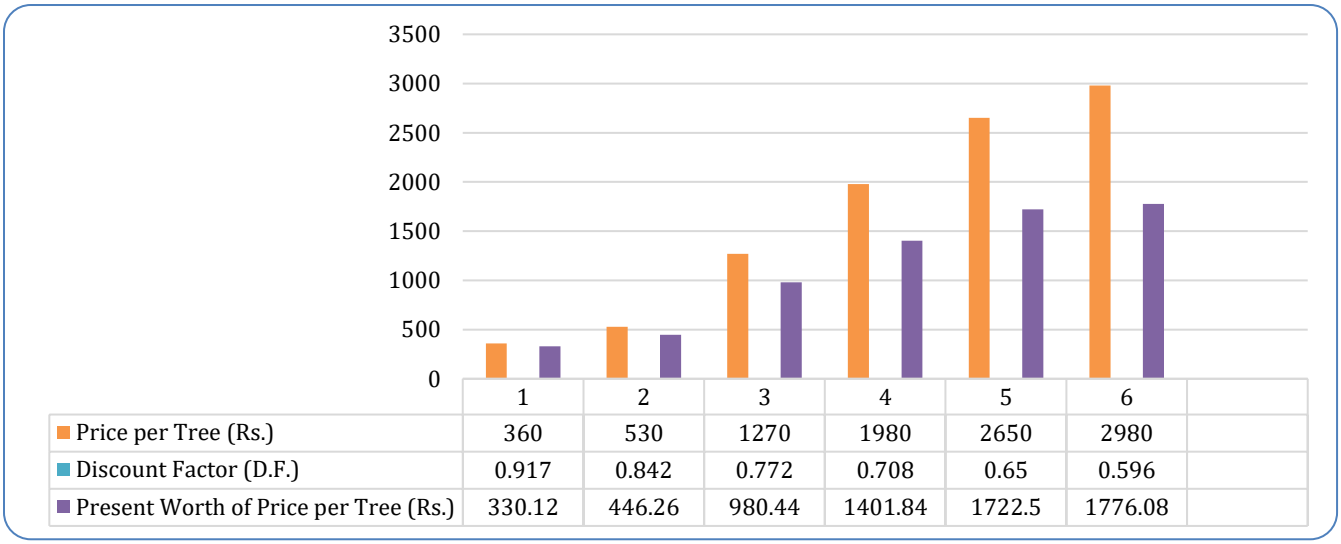
Ethical Considerations and Sustainability

The study adhered to ethical research practices, ensuring informed consent from all participants. Moreover, the preservation of the forest ecosystem and the local environment was prioritized during data collection. Sustainable forest management principles were promoted throughout the research to contribute positively to the long-term ecological resilience of the study area.

RESULTS

Optimal Economic Rotation Strategy for *Vachellianilotica*

The exquisite analysis presented in **Figure 1** highlights the meticulous evaluation of *Vachellianilotica* tree's economic rotation strategy. This study focuses on discerning the average price trajectory of *Vachellianilotica* trees and their present value for 1 to 6 years. The accompanying third column of the table elegantly lists the corresponding discount factors for each year. Notably, the calculated present values of the *Vachellianilotica* tree's price reveal an intriguing pattern: Rs. 330.12 in the first year, Rs. 980.44 in the third year, and a remarkable Rs. 1776.08 in the sixth year.



	1	2	3	4	5	6
Price per Tree (Rs.)	360	530	1270	1980	2650	2980
Discount Factor (D.F.)	0.917	0.842	0.772	0.708	0.65	0.596
Present Worth of Price per Tree (Rs.)	330.12	446.26	980.44	1401.84	1722.5	1776.08

Figure 1. Exquisite Assessment of Discount Factors, Average Price, and Present Worth of *Vachellianilotica* Trees for Varied Years.

The discerning gaze now shifts to the profound insights provided in Table 1, where the meticulous evaluation continues, this time encompassing the costs and benefits of *Vachellianilotica* at the 6-year mark. This contemplative analysis accounts for various facets, such as costs, benefits, discount factors at a 9% rate, present worth of costs, and present worth of benefits.

As we delve into the realm of different rotation strategies, the profound wisdom within Table 2 underscores the viability of the 3+3 rotation. Notably, this approach demonstrates an astute allocation of resources, with seedling costs of Rs. 8 in the initial year and a calculated Rs. 5.664 during the fourth-year plantation. This cogent strategy, anchored in an insightful examination of costs and benefits, unveils a net present worth of the *Vachellianilotica* tree amounting to 1723.7, accompanied by a benefit-cost ratio of 127.149.

Table 1. Meticulous Examination of Cost and Benefits of *Vachellianilotica* at the 6-year Mark.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount Rate	PW Cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	0	0.772	0	0
4	0	0	0.708	0	0
5	0	0	0.65	0	0
6	0	2980	0.596	0	1776.08
Total	8	2980		8	1776.08
Net Present Worth (Rs.)					1768.08
Benefit-Cost Ratio					222.01

Table 2. Ingenious Appraisal of Cost and Benefits under a 3+3 Years Rotation Strategy.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount Rate	PW Cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	1270	0.772	0	980.44
4	8	0	0.708	5.664	0
5	0	0	0.65	0	0
6	0	1270	0.596	0	756.92
Total	16.664	2540		13.664	1737.36
Net Present Worth (Rs.)					1723.7
Benefit-Cost Ratio					127.149

In the realm of rotations, the analysis turns to the 2+4 years' approach, where an elegant dance between costs and benefits unfolds. Table 3 showcases the seedling cost of Rs. 8 in the initial year, gracefully transitioning to Rs. 6.176 during the third year's plantation. The culmination of this performance reveals a net present worth of 1612.16 for the *Vachellianilotic*a tree, accompanied by a benefit-cost ratio of 114.725.

Table 3. Enchanting Deliberation of Cost and Benefits in a 2+4 Years Rotation Strategy.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount Rate	PW Cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	530	0.842	0	446.26
3	8	0	0.772	6.176	0
4	0	0	0.708	0	0
5	0	0	0.65	0	0
6	0	1980	0.596	0	1180.08
Total	16	2510		14.176	1626.34
Net Present Worth (Rs.)					1612.16
Benefit-Cost Ratio					114.725

The saga of rotations continues, with the spotlight now on the enchanting 4+2 years' rotation strategy. Table 4 masterfully captures the essence of this strategy, where the seedling cost of Rs. 5.2 in the fifth year and the tree's price at Rs. 1401.84 during the fourth year evoke a sense of balanced economic rhythm. The symphony crescendos to reveal a net present worth of 1704.52 for the *Vachellianilotic*a tree, accompanied by a benefit-cost ratio of 130.13.

Table 4. Eloquent Evaluation of Cost and Benefits in a 4+2 Years Rotation Strategy.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount Rate	PW Cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	0	0.772	0	0
4	0	1980	0.708	0	1401.84
5	8	0	0.65	5.2	0
6	0	0	0.596	0	0
Total	16	1980		13.2	1717.72
Net Present Worth (Rs.)					1704.52
Benefit-Cost Ratio					130.13

Intriguingly, the narrative shifts to the thought-provoking 2+2+2 years' rotation strategy, where the seedling cost of Rs. 6.176 in the third year and Rs. 5.2 in the fifth year sets the stage for an intricate economic choreography. Table 5 reflects the symphony of costs and benefits, resulting in a net present worth of 1118 for the *Vachellianilotica* tree, while the benefit-cost ratio reaches 58.7005. As we embark on another rotation strategy, the spotlight now illuminates the intricate 3+2+1 years' approach. Table 6 unfolds this strategy's enchanting tale, where the seedling cost of Rs. 5.664 in the fourth year and Rs. 4.768 in the sixth-year lead to a captivating economic narrative. The crescendo reveals a net present worth of 1521.07 for the *Vachellianilotica* tree, complemented by a benefit-cost ratio of 83.5232.

Continuing the journey of rotation strategies, we arrive at the captivating 2+3+1 years' approach. Table 7 beautifully illustrates the intricate dance of costs and benefits, where the seedling cost of Rs. 6.176 in the third year and Rs. 4.768 in the sixth-year interplay with the tree's price at Rs. 446.26 in the second year and Rs. 214.56 in the first year. This symphony concludes with a net present worth of 1467.38 for the *Vachellianilotica* tree, accompanied by a benefit-cost ratio of 78.4586.

Table 5. Intricate Exploration of Cost and Benefits in a 2+2+2 Years Rotation Strategy.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount Rate	PW Cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	530	0.842	0	446.26
3	8	0	0.772	6.176	0
4	0	0	0.708	0	0
5	0	530	0.65	0	344.5
6	8	0	0.596	4.768	0
Total	16	1060		18.944	1137.38
Net Present Worth (Rs.)					1118
Benefit-Cost Ratio					58.7005

Table 6. Captivating Examination of Cost and Benefits in a 3+2+1 Years Rotation Strategy.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount Rate	PW Cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	1270	0.772	0	980.44
4	8	0	0.708	5.664	0
5	0	530	0.65	0	344.5
6	8	360	0.596	4.768	214.56
Total	16	2160		18.432	1539.5
Net Present Worth (Rs.)					1521.07
Benefit-Cost Ratio					83.5232

Table 7. Exquisite Interpretation of Cost and Benefits in a 2+3+1 Years Rotation Strategy

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount Rate	PW Cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	360	0.917	0	330.12
2	0	0	0.842	0	0
3	0	530	0.772	0	409.16
4	8	0	0.708	6.176	0
5	0	360	0.65	0	214.56
6	8	360	0.596	4.768	214.56
Total	24	1610		19.112	1168.4
Net Present Worth (Rs.)					1475.8
Benefit-Cost Ratio					73.3431

Intriguingly, the final tableau of rotations leads us to the enchanting 1+2+3 years' strategy. As portrayed in Table 8, this approach orchestrates a mesmerizing sequence, wherein the seedling cost of Rs. 6.736 in the second year and Rs. 5.664 in the fourth year converge with the tree's price at Rs. 330.12 in the first year, Rs. 409.16 in the second year, and Rs. 756.92 in the third year. The symphony of costs and benefits culminates in a net present worth of 1475.8 for the V*achellianilotica* tree, complemented by a benefit-cost ratio of 73.3431.

Table 8. Enthralling Analysis of Cost and Benefits in a 1+2+3 Years Rotation Strategy.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount Rate	PW Cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	360	0.917	0	330.12
2	8	0	0.842	6.736	0
3	0	530	0.772	0	409.16
4	8	0	0.708	5.664	0
5	0	0	0.65	0	0
6	0	1270	0.596	0	756.92
Total	24	2160		20.4	1496.2
Net Present Worth (Rs.)					1475.8
Benefit-Cost Ratio					73.3431

In this orchestration of economic rotations for *Vachellianilotica* trees, each strategy's symphony of costs and benefits unfolds with a unique rhythm. These analyses illuminate the most elegant, efficient, and lucrative strategies that underscore the remarkable journey of these trees through different rotation patterns.

Best Economic Rotation of *Populus deltoides*

The average price of *Populus deltoides*tree at 1-6 years and its present worth are shown in Figure 2. Discount factor is listed in the third column according to the years. Present worth of price of *Populus deltoides* tree was Rs. 238.42 in 1st year, Rs. 633.04in the 3rd year and Rs. 1364.84 in the 6th year.

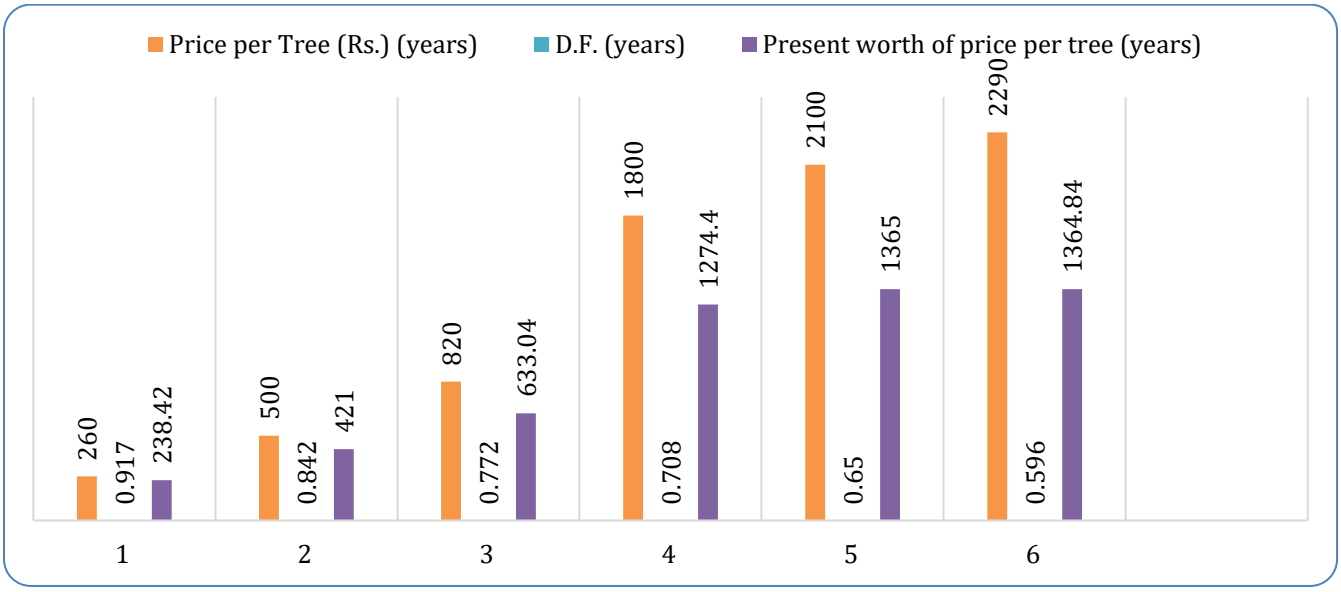


Figure 2. Discount factor, *Populus deltoids* tree's average price and its present worth of price for different years.

Cost of seedling of *Populus deltoides*tree was Rs. 8 and price of the tree at 6 years was Rs. 1364.84 as shown in b at the age of 6, NPW and BCR were noted as 1356.84and 170.605 respectively.

Table 9. Cost and Benefits of *Populus deltoides* at 6 years.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	0	0.772	0	0
4	0	0	0.708	0	0
5	0	0	0.65	0	0
6	0	2290	0.596	0	1364.84
			Total	8	1364.84
			Net Present Worth Rs.		1356.84
			Benefit Cost ratio		170.605

The seedling cost of *Populus deltoides*tree was Rs. 8 in the first year and Rs. 5.664 at the fourth-year plantation. While, price of the tree at 3rd years was Rs. 633.04and Rs. 188 fourth-yeart another 3rd years (6 years) as shown in Table 10. Net present worth of*Populus deltoides*tree and benefits cost ratio at two rotation of 3 years were 1108.1 and 82.096 respectively. Cost of seedling of *Populus deltoides*tree was Rs. 8 in the first

year and Rs. 6.176 at third year plantation. While the price of the tree at 2nd years was Rs. 421 and Rs. 1072.8 at another 4th years (6th years) (Table 11). The total cost of seedling and total price of the tree were Rs. 14.176 and Rs. 1493.8 respectively two rotation (2+4 years). Net present worth of *Populus deltoides*tree and benefits cost ratio at two rotation of 2+4 years were 1479.62and105.375 respectively.

Table 10. Cost and Benefits of *Populus deltoides*at two rotations (3+3 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	820	0.772	0	633.04
4	8	0	0.708	5.664	0
5	0	0	0.65	0	0
6	0	820	0.596	0	488.72
			Total	13.664	1121.76
			Net Present Worth Rs.		1108.1
			Benefit Cost ratio		82.096

Table 11. Cost and Benefits of *Populus deltoides*at two rotations (2+4 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	500	0.842	0	421
3	8	0	0.772	6.176	0
4	0	0	0.708	0	0
5	0	0	0.65	0	0
6	0	1800	0.596	0	1072.8
			Total	14.176	1493.8
			Net Present Worth Rs.		1479.62
			Benefit Cost ratio		105.375

The seedling cost of *Populus deltoides*tree was Rs. 8 in the first year and Rs. 5.2 at the fifth-year plantation. While, price of the tree at 4th years was Rs. 1274.4 and Rs. 298 at 2nd years (Table 12). The total cost of seedling and total price of the tree were Rs. 13.2 and Rs. 1572.4 respectively at two rotation (4+2 years). Net present worth of*Populus deltoides*tree and benefits cost ratio at two rotation of 4+2 years were 1559.2 and 119.121 respectively. Cost of seedling of *Populus deltoides* tree was Rs. 8 in the first year, Rs. 6.176 in the third year and Rs. 5.2 at fifth year plantation. While price of the tree at 2nd years was Rs. 421, Rs. 354 at other 2nd years (4th year) and Rs. 298 at another 2nd year (6th year) (Table 13). The total cost of seedling and total price of the tree were Rs. 19.376 and Rs. 1073 respectively at three rotation (2+2+2 years). Net present worth of *Populus deltoides*t ree and benefits cost ratio at three rotation of 2+2+2 years were 1053.62 and 55.3778 respectively.

Cost of seedling of *Populus deltoides*tree was Rs. 8 Rs. in the first year, Rs. 5.664 at fourth year and Rs. 4.768 at sixth year plantation. While price of the tree at 3rd years was Rs. 633.04, Rs. 325 at 2nd years (5th year) and Rs.

154.96 at 1st year (6th year) (Table14). The total cost of seedling and total price of the tree were Rs. 18.432 and Rs. 1113 respectively at three rotation (3+2+1 years). Net present worth of *Populus deltoides*tree and benefits cost ratio at three rotation of 3+2+1 years were 1094.57 and 60.3841 respectively.

Table 12**.** Cost and Benefits of *Populus deltoides*at two rotations (4+2 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	0	0.772	0	0
4	0	1800	0.708	0	1274.4
5	8	0	0.65	5.2	0
6	0	500	0.596	0	298
			Total	13.2	1572.4
			Net Present Worth Rs.		1559.2
			Benefit Cost ratio		119.121

Table 13. Cost and Benefits of *Populus deltoides* at three rotations (2+2+2 years) of total 6 years life span

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	500	0.842	0	421
3	8	0	0.772	6.176	0
4	0	500	0.708	0	354
5	8	0	0.65	5.2	0
6	0	500	0.596	0	298
			Total	19.376	1073
			Net Present Worth Rs.		1053.62
			Benefit Cost ratio		55.3778

Table 14. Cost and Benefits of *Populus deltoides* at three rotations (3+2+1 years) of total 6 years life span

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	820	0.772	0	633.04
4	8	0	0.708	5.664	0
5	0	500	0.65	0	325
6	8	260	0.596	4.768	154.96
			Total	18.432	1113
			Net Present Worth Rs.		1094.57
			Benefit Cost ratio		60.3841

Cost of seedling of *Populus deltoides* tree was Rs. 8 in the first year, Rs. 6.176 at third year and Rs. 4.768 at sixth year plantation. While, price of the tree at 2nd years was Rs. 421, Rs. 533 at 3rd years (5th year) and Rs. 154.96 at 1st year (6th year) (Table 15). The total cost of seedling and total price of the tree were Rs. 18.944 and Rs. 1108.96 respectively at three rotation (2+3+1 years). Net present worth of *Populus deltoides* tree and benefits cost ratio at three rotation of 2+3+1 years were 1090.02 and 58.5389 respectively.

The cost of seedling of *Populus deltoides*tree was Rs. 8 in the first year, Rs. 6.736 in second year and Rs. 5.664 in fourth year of plantation. While price of the tree at 1st years was Rs. 238.42, Rs. 386 at 2nd years (3rd year) and Rs. 488.72 at 3rd year (6th year) as shown in Table 16. The total cost of seedling and total price of the tree were Rs. 20.4 and Rs. 1113.14 respectively at three rotation (1+2+3 years). Net present worth of *Populus deltoides* tree and benefits cost ratio at three rotation of 1+2+3 years were 1092.74 and 54.5657 respectively.

Table 15. Cost and Benefits of *Populus deltoides*at three rotations (2+3+1 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	500	0.842	0	421
3	8	0	0.772	6.176	0
4	0	0	0.708	0	0
5	0	820	0.65	0	533
6	8	260	0.596	4.768	154.96
			Total	18.944	1108.96
			Net Present Worth Rs.		1090.02
			Benefit Cost ratio		58.5389

Table 16. Cost and Benefits of *Populus deltoides*at Three rotations (1+2+3 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	260	0.917	0	238.42
2	8	0	0.842	6.736	0
3	0	500	0.772	0	386
4	8	0	0.708	5.664	0
5	0	0	0.65	0	0
6	0	820	0.596	0	488.72
			Total	20.4	1113.14
			Net Present Worth Rs.		1092.74
			Benefit-Cost ratio		54.5657

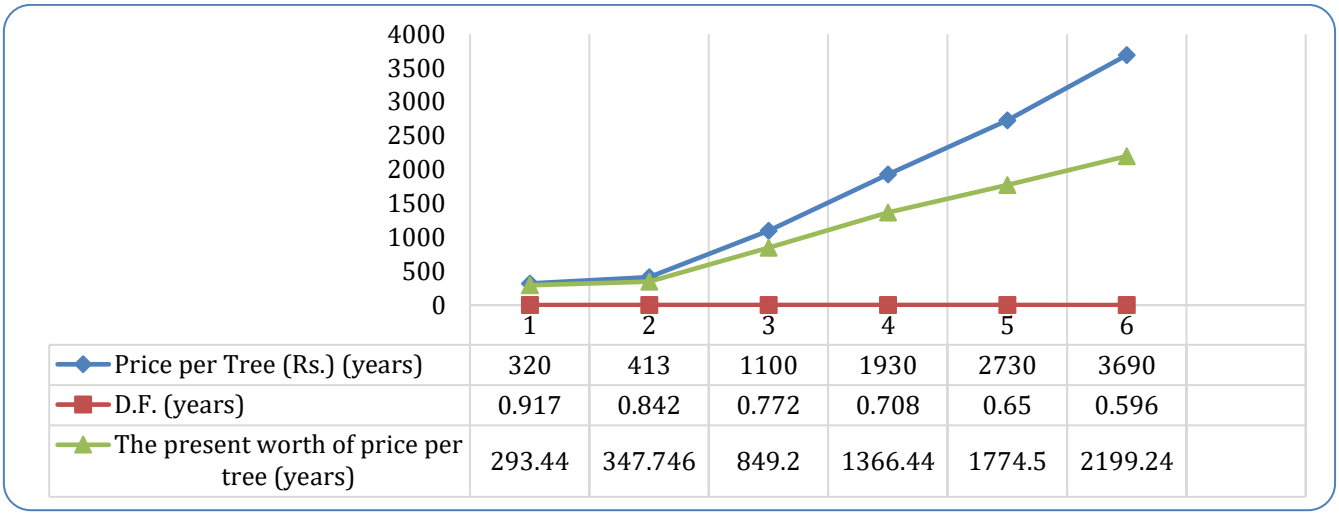
Best Economic Rotation of *Dalbergia sissoo*

The average price of *Dalbergia sissoo* tree at 1-6 years and its present worth are shown in Figure 3. The discount factor is listed in the third column according to the years. The present worth of the price of the *Dalbergia sissoo* tree was Rs. 330.12 in 1st year, Rs. 980.44 in the 3rd year, and Rs. 1776.08 in the 6th year.

The cost of seedling of *Dalbergia sissoo* tree was Rs. 8, and the price of the tree at 6 years was Rs. 2199.24 (Table 17). At the age of 6, NPW and BCR were noted as 2191.24 and 274.905 respectively.

The seedling cost of *Dalbergia sissoo* tree was Rs. 8 in the first year and Rs. 5.664 at the fourth-year plantation. While, price of the tree at 3rdyears was Rs. 849.2 and Rs.

655.6 at another 3rd years (6 years) as shown in Table 18. Net present worth of *Dalbergia sissoo* tree and benefits cost ratio at two rotations of 3 years were 1491.14and 110.129 respectively.



Price per Tree (Rs.) (years)	320	413	1100	1930	2730	3690
D.F. (years)	0.917	0.842	0.772	0.708	0.65	0.596
The present worth of price per tree (years)	293.44	347.746	849.2	1366.44	1774.5	2199.24

Figure 3. Discount factor, *Dalbergia sissoo* tree's average price and its present worth price for different years.

Table 17. Cost and Benefits of *Dalbergia sissoo* at 6 years.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	0	0.772	0	0
4	0	0	0.708	0	0
5	0	0	0.65	0	0
6	0	3690	0.596	0	2199.24
			Total	8	2199.24
			Net Present Worth Rs.		2191.24
			Benefit Cost ratio		274.905

Table 18. Cost and Benefits of *Dalbergia sissoo* at two rotations (3+3 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	1100	0.772	0	849.2
4	8	0	0.708	5.664	0
5	0	0	0.65	0	0
6	0	1100	0.596	0	655.6
			Total	13.664	1504.8
			Net Present Worth Rs.		1491.14
			Benefit-Cost ratio		110.129

The cost of seedling of *Dalbergia sissoo* tree was Rs. 8 in the first year and Rs. 6.176 at the third-year plantation. While, price of the tree at 2nd years was Rs. 347.746 and Rs. 1150.28 at another 4th years (6th years) as shown in Table 19. The total cost of seedling and total price of the tree were Rs. 14.176 and Rs. 1498.03 respectively two rotation (2+4 years). Net present worth of *Dalbergia sissoo* tree and benefits cost ratio at two rotation of 2+4 years were 1483.85 and 105.673 respectively.

The seedling cost of *Dalbergia sissoo* tree was Rs. 8 in the first year and Rs. 5.2 at the fifth-year plantation. While, price of the tree at 4th years was Rs. 1366.44 and Rs. 246.148 at 2nd years as shown in Table 20. The total cost of seedling and total price of the tree were Rs. 13.2 and Rs. 1612.59respectively at two rotation (4+2 years). Net present worth of *Dalbergia sissoo* tree and benefits cost ratio at two rotation of 4+2 years were 1599.39 and 122.166 respectively.

Table 19. Cost and Benefits of *Dalbergia sissoo* at two rotations (2+4 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	413	0.842	0	347.746
3	8	0	0.772	6.176	0
4	0	0	0.708	0	0
5	0	0	0.65	0	0
6	0	1930	0.596	0	1150.28
			Total	14.176	1498.03
			Net Present Worth Rs.		1483.85
			Benefit-Cost ratio		105.673

Table 20. Cost and Benefits of *Dalbergia sissoo* at two rotations (4+2 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	0	0.772	0	0
4	0	1930	0.708	0	1366.44
5	8	0	0.65	5.2	0
6	0	413	0.596	0	246.148
			Total	13.2	1612.59
			Net Present Worth Rs.		1599.39
			Benefit Cost ratio		122.166

The seedling cost of the *Dalbergia sissoo* tree was Rs. 8 in the first year, Rs. 6.176 in the third year and Rs. 5.2 at the fifth-year plantation. While, price of the tree at 2nd years was Rs. 347.746, Rs. 292.404 at other 2nd years (4th year) and Rs. 246.148 at another 2nd year (6th year) as shown in Table 21. The total cost of seedling and total price of the tree were Rs. 19.376 and Rs. 886.298 respectively at three rotation (2+2+2 years). Net present worth of *Dalbergia sissoo* tree and benefits cost ratio at three rotation of 2+2+2 years were 866.922 and 45.7421 respectively.

The seedling cost of *Dalbergia sissoo* tree was Rs. 8 in the first year, Rs. 5.664 in the fourth year and Rs. 4.768 at the sixth-year plantation. While, price of the tree at 3rd years was Rs. 849.2, Rs. 268.45 at 2nd years (5th year) and Rs. 190.72 at 1st year (6thyear) (Table 22). The total

cost of seedling and total price of the tree were Rs. 18.432 and Rs. 1308.37 respectively at three rotation (3+2+1 years).

Net present worth of *Dalbergia sissoo* tree and benefits cost ratio at three rotation of 3+2+1 years were 1289.94 and 70.9836 respectively.

Table 21. Cost and Benefits of *Dalbergia sissoo* at three rotations (2+2+2 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	413	0.842	0	347.746
3	8	0	0.772	6.176	0
4	0	413	0.708	0	292.404
5	8	0	0.65	5.2	0
6	0	413	0.596	0	246.148
			Total	19.376	886.298
			Net Present Worth Rs.		866.922
			Benefit-Cost ratio		45.7421

Table 22. Cost and Benefits of *Dalbergia sissoo* at three rotations (3+2+1 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	0	0.842	0	0
3	0	1100	0.772	0	849.2
4	8	0	0.708	5.664	0
5	0	413	0.65	0	268.45
6	8	320	0.596	4.768	190.72
			Total	18.432	1308.37
			Net Present Worth Rs.		1289.94
			Benefit-Cost ratio		70.9836

The seedling cost of *Dalbergia sissoo* tree was Rs. 8 in the first year, Rs. 6.176 in the third year and Rs. 4.768 at the sixth-year plantation. While, price of the tree at 2nd years was Rs. 347.746, Rs. 715 at 3rd years (5th year) and Rs. 190.72 at 1st year (6thyear) (Table 23). The total cost of seedling and total price of the tree were Rs. 18.944 and Rs. 1253.47 respectively at three rotation (2+3+1 years). Net present worth of *Dalbergia sissoo* tree and benefits cost ratio at three rotation of 2+3+1 years were 1234.52 and 66.1669 respectively.

The seedling cost of *Dalbergia sissoo* tree was Rs. 8 in the first year, Rs. 6.736 in the second year and Rs. 5.664 at the fourth-year plantation. While, price of the tree in 1st years was Rs. 293.44, Rs. 318.836 at 2nd years (3rd year) and Rs. 655.6 at 3rd year (6thyear) (Table 24). The total cost of seedling and total price of the tree were Rs. 20.4 and Rs. 1267.88 respectively at three rotation (1+2+3 years). Net present worth of *Dalbergia sissoo* tree and benefits cost ratio at three rotation of 1+2+3 years were 1247.48 and 62.1508 respectively.

Comparisons of Different Rotation Periods

Vachellianilotica

*C*omparison of various rotations of *Vachellianilotica* showed that the best economical rotation for the *Vachellianilotica* was recorded in 6-year rotation period

with Rs. 1768.1 net present worth, 222.01 benefits cost ratio, 22101% ROI and Rs. 394.14 average annual benefits as mentioned in Figure 4. But the second-best rotation was noted in 3+3 rotation period with Rs. 1723.7 net present worth, 127.15 benefits cost ratio and Rs. 384.25 average annual benefits. But the second highest ROI (12913%) was found in 4+2 years of rotation. While the lowest economic rotation was observed in 2+2+2 rotation period having Rs. 58.701, Rs. 1118, 5771% and 249.23 Rs. for benefits cost ratio and net present worth, ROI and average annual benefits, respectively.

Table 23. Cost and Benefits of *Dalbergia sissoo* at three rotations (2+3+1 years) of total 6 years life span.

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	0	0.917	0	0
2	0	413	0.842	0	347.746
3	8	0	0.772	6.176	0
4	0	0	0.708	0	0
5	0	1100	0.65	0	715
6	8	320	0.596	4.768	190.72
			Total	18.944	1253.47
			Net Present Worth Rs.		1234.52
			Benefit Cost ratio		66.1669

Table 24**.** Cost and Benefits of *Dalbergia sissoo* at Three rotations (1+2+3 years) of total 6 years life span

Age (years)	Cost (Rs.)	Benefits (Rs.)	D.F. @ 9% Discount rate	PW cost (Rs.)	PW Benefits (Rs.)
0	8	0	1	8	0
1	0	320	0.917	0	293.44
2	8	0	0.842	6.736	0
3	0	413	0.772	0	318.836
4	8	0	0.708	5.664	0
5	0	0	0.65	0	0
6	0	1100	0.596	0	655.6
			Total	20.4	1267.88
			Net Present Worth Rs.		1247.48
			Benefit Cost ratio		62.1508

Populus deltoides

Comparison of various rotations of *Populus deltoides* showed that best economical rotation for the *Populus deltoides* was recorded in 6-year rotation period having Rs. 1356.8 net present worth,170.61 benefits cost ratio, 16961% ROI. While, 4+2 years rotation was found best for the highest average annual benefits Rs. 347.58 as shown in **Figure 5**. But the second-best rotation was noted in 4+2 rotation period with Rs.1559.2net present worth, 119.12 benefits cost ratio and 11812% ROI. However, 2+4 years rotation was observed best for second highest average annual benefits (Rs. 329.84). While the lowest economic rotation was observed in 1+2+3 rotation period having Rs. 54.566, Rs. 1092.7 and 5357%benefits cost ratio, net present worth and ROI respectively. The lowest average annual benefits (Rs. 234.87) were recorded in 2+2+2 years rotation periods.

Dalbergia sissoo

Comparison of various rotations of *Dalbergia sissoo* showed that best economical rotation for the *Dalbergia sissoo* was recorded in 6-year rotation period having Rs.

2191.2net present worth, 274.91 benefits cost ratio 27391% ROI and Rs. 488.47 average annual benefits as shown in **Figure 6**. But the second-best rotation was noted in 4+2 rotation period with Rs. 1599.4 net present worth, 122.17 benefits cost ratio, 12117% ROI, and Rs. 356.54 average annual benefits. While the lowest economic rotation was observed in 2+2+2 rotation period having Rs. 45.742, Rs. 886.92, 4474%- and Rs. 193.25 benefits cost ratio and net present worth. ROI and average annual benefits, respectively.

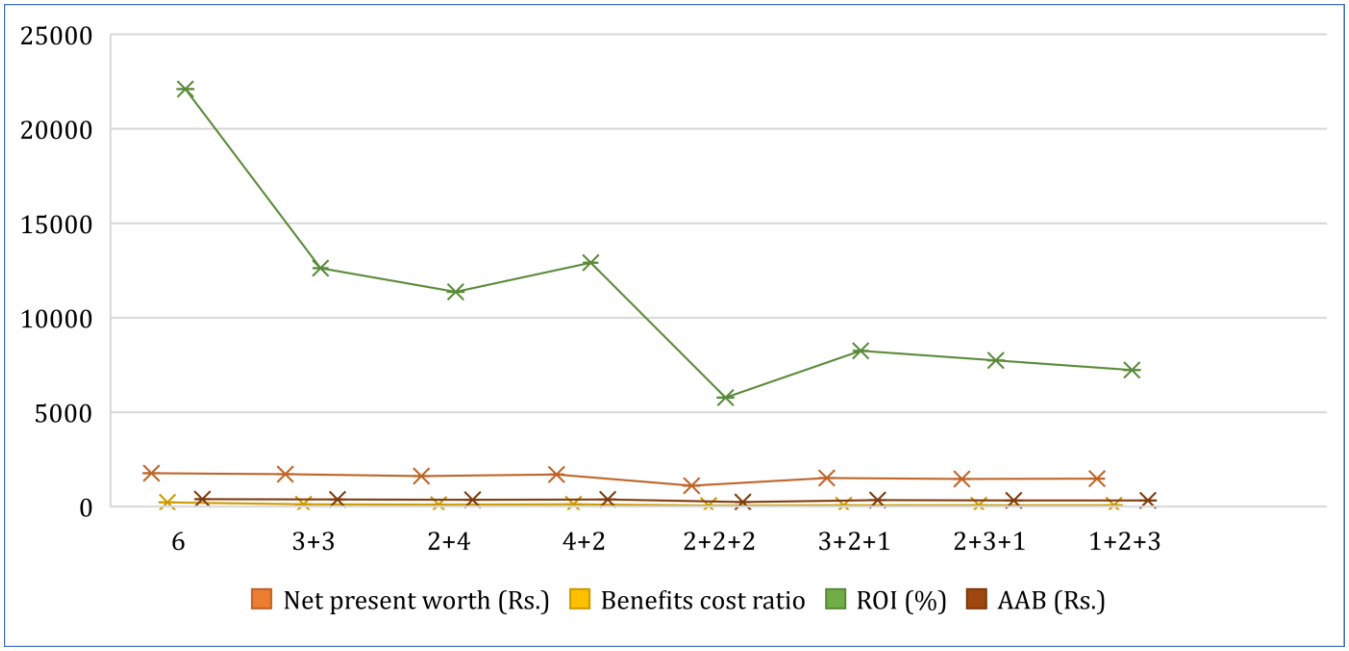
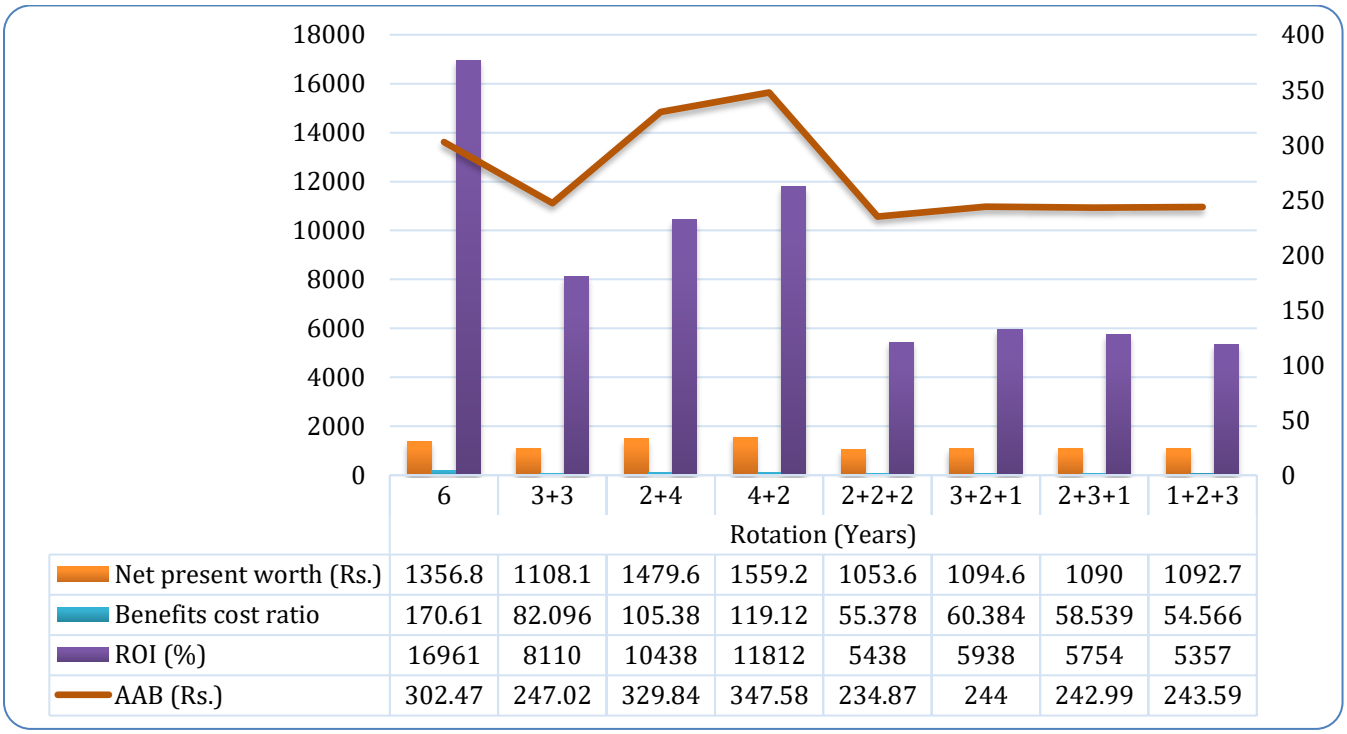
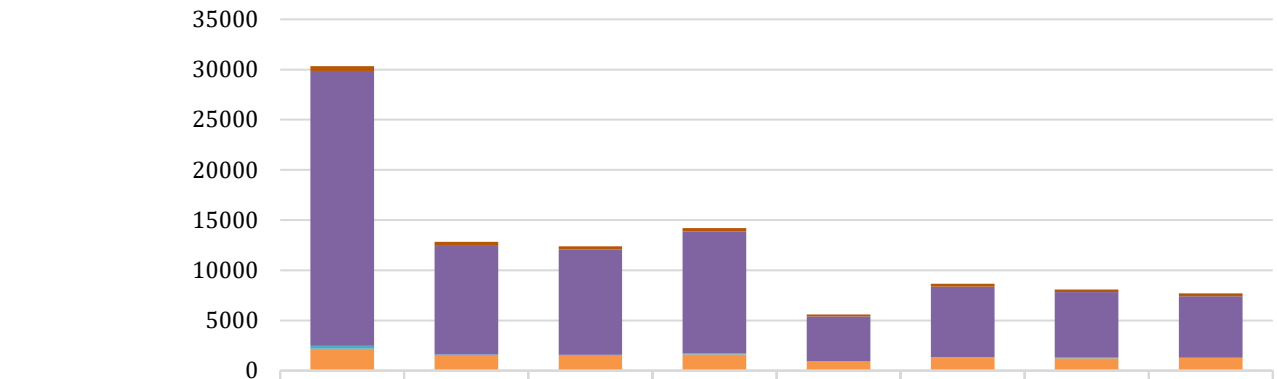


Figure 4. Comparisons of various rotations of *Vachellianilotica.*



	6	3+3	2+4	4+2	2+2+2	3+2+1	2+3+1	1+2+3
Net present worth (Rs.)	1356.8	1108.1	1479.6	1559.2	1053.6	1094.6	1090	1092.7
Benefits cost ratio	170.61	82.096	105.38	119.12	55.378	60.384	58.539	54.566
ROI (%)	16961	8110	10438	11812	5438	5938	5754	5357
AAB (Rs.)	302.47	247.02	329.84	347.58	234.87	244	242.99	243.59

Figure 5. Comparisons of various rotations of *Populus deltoides.*



	6	3+3	2+4	4+2	2+2+2	3+2+1	2+3+1	1+2+3
AAB (Rs.)	488.47	332.4	330.78	356.54	193.25	287.55	275.2	278.09
ROI (%)	27391	10913	10467	12117	4474	6998	6517	6115
Benefits cost ratio	274.91	110.13	105.67	122.17	45.742	70.984	66.167	62.151
Net present worth (Rs.)	2191.2	1491.1	1483.9	1599.4	886.92	1289.9	1234.5	1247.5

Figure 6. Comparisons of various rotations of *Dalbergia sissoo.*

DISCUSSION

Climate-resilient Forest economics, centered on adapting tree species rotation to accommodate the impacts of climate change, is a multifaceted challenge (Mustafa et al., 2013; Srivastav et al., 2021). Traditionally, tree species rotations have been rooted in historical climate and economic data, but with climate change causing shifts in temperature, precipitation patterns, and increased extreme weather events, the sustainability of forestry operations are done by earlier researchers (Salinger et al., 2000). To address this, foresters are exploring climate-resilient tree species and adaptive management strategies, even though initial costs may rise. The economic analysis of *Vachellianilotica* and *Populus deltoides* tree plantations was conducted based on different rotation periods (Nair et al., 2021). The present worth of *Vachellianilotica* tree prices varied over the years, with Rs. 330.12 in the 1st year, Rs. 980.44 in the 3rd year, and Rs. 1776.08 in the 6th year. The seedling cost for a 3+3 rotation was Rs.8 in the first year and Rs.5.664 in the fourth year. The net present worth and benefits cost ratio for two rotations of 3 years were 1723.7 and 127.149, respectively. Singh and Srivastava (2015) conducted a similar study on *Acacia nilotica* and also found that a 3+3 rotation period resulted in the highest economic profit.

For a 2+4 rotation period, the seedling cost of *Vachellianilotica* tree was Rs.8 in the first year and Rs.6.176 in the third year. The price of the tree in the 2nd year was Rs.446.26 and Rs.1180.08 in the 4th year. The net present worth and benefits cost ratio for two rotations of 2+4 years were 1612.16 and 114.725, respectively. Elzaki Abdalla Elzaki and Gang (2019) also observed similar effects of different rotation periods on *Acacia nilotica*, where poor management resulted in reduced yield and profitability.

In the case of a 4+2 rotation period for *Vachellianilotica*, the seedling cost was Rs.5.2 in the 5th year. The price of the tree in the 4th year was Rs.1401.84 and Rs.315.88 in the 2nd year. The net present worth and benefits cost ratio for two rotations of 4+2 years were 1704.52 and 130.13, respectively. AHMAD et al. (2023) also reported similar findings, including a reduction in seedling cost over the years and a high-benefits cost ratio for a 4+2 rotation period. In the case of a 2+2+2 rotation period for *Vachellianilotica*, the seedling cost was Rs.6.176 in the 3rd year and Rs.5.2 in the 5th year. The price of the tree in the 2nd year was Rs.446.26, Rs.375.24 in the other 2nd year (4th year), and Rs.315.88 in another 2nd year (6th year). The net present worth and benefits cost ratio for three rotations of 2+2+2 years were 1118 and 58.7005, respectively. For a 3+2+1 rotation period of *Vachellianilotica*, the seedling cost was Rs.5.664 in the 4th year and Rs.4.768 in the 6th year. The price of the tree in the 3rd year was Rs.980.44, Rs.344.5 in the 2nd year (5th year), and Rs.214.56 in the 1st year (6th year).

The net present worth and benefits cost ratio for three rotations of 3+2+1 years were 1521.07 and 83.5232, respectively. Zhao et al. (2014) also found that longer rotation periods resulted in lower losses.

Net present worth of *Populus deltoides* tree and benefits cost ratio at three rotations of 2+3+1 years were 1089.02 and 57.6098, respectively. These results align with the findings of Gupta et al. (2017) who suggested that a 6-year rotation of poplar plantation provided the highest economic returns. In the case of a 1+2+3 years rotation for *Populus deltoides* plantation, the seedling cost was Rs.6.736 in the second year and Rs.4.768 at the fourth-year plantation. Meanwhile, the price of the tree at 1st years was Rs.238.42, Rs.363.24 at 2nd years (3rd year), and Rs.154.96 at 3rd year (6th year). The total cost of seedling and total price of the tree were Rs.21.472 and Rs.756.62, respectively, for the three rotations (1+2+3 years). The net present worth of *Populus deltoides* tree and benefits cost ratio at three rotations of 1+2+3 years were 735.148 and 34.2985, respectively. These findings support the research of Oktaee et al. (2017) who reported that short rotations of poplar plantations, such as 6 to 8 years, resulted in better economic returns compared to longer rotations.

Table 19 illustrates the average price of *Dalbergia sissoo* tree at different years and its present worth. The present worth of the price of *Dalbergia sissoo* tree was Rs. 563.18 in the 1st year, Rs. 1335.26 in the 3rd year, and Rs. 2331.02 in the 6th year. For a 6-year rotation of *Dalbergia sissoo* plantation, the seedling cost was Rs.10 in the first year and Rs.7.368 at the fourth-year plantation. The price of the tree at 3rd years was Rs.1335.26 and Rs.995.18 at another 3rd year (6 years). The net present worth of *Dalbergia sissoo* tree and benefits cost ratio at two rotations of 3 years were 2253.26 and 191.573, respectively. In the case of a 5+1 years rotation, the seedling cost of *Dalbergia sissoo* tree was Rs.7.368 in the first year and Rs.5.2 at the fifth-year plantation.

The price of the tree at 4th years was Rs.1962.74 and Rs.328.94 at 2nd years. The total cost of seedling and total price of the tree were Rs.12.568 and Rs.2291.68, respectively, for the two rotations (5+1 years). The net present worth of *Dalbergia sissoo* tree and benefits cost ratio at two rotations of 5+1 years were 2279.112 and 181.635, respectively. These results align with the research by Khan et al. (2022), who found that a 5-year rotation followed by clear felling and replanting provided the highest net returns compared to other rotations. The economic analysis of different rotation periods for *Vachellianilotica*, *Populus deltoides*, and *Dalbergia sissoo* plantations demonstrated varying net present worth and benefits cost ratios. The results indicated that optimal rotation lengths and patterns are crucial for maximizing economic returns in plantation forestry. For *Vachellianilotica*, the highest net present worth and benefits cost ratio were observed in the 7-year rotation, with values of Rs. 2223.72 and Rs.153.1465, respectively. This suggests that a 7-year rotation period would be most profitable for *Vachellianilotica* plantation. For *Populus deltoides*, the analysis showed that a 6-year rotation provided the highest economic returns. The net present worth and benefits cost ratio for this rotation period were Rs. 1089.02 and Rs.57.6098, respectively. These findings are consistent with the research by (Chavan et al., 2022), indicating that a 6-year rotation is favorable for maximizing economic benefits from *Populus deltoides* plantations.

Regarding *Dalbergia sissoo*, two rotation periods were analyzed: a 6-year rotation and a 5+1-year rotation. The net present worth and benefits cost ratio for the 6-year rotation were Rs. 2253.26 and Rs.191.573, respectively, while for the 5+1-year rotation, they were Rs. 2279.112 and Rs.181.635, respectively. These results suggest that both rotation periods can yield significant economic returns, with slightly higher values observed for the 5+1-year rotation. Daba et al. (2021) also found that a 5-year rotation followed by clear felling and replanting resulted in the highest net returns for *Dalbergia sissoo* plantations. The economic analysis highlights the importance of selecting appropriate rotation lengths for different tree species in plantation forestry. The findings indicate that the optimal rotation period can vary depending on the species, with 7 years for *Vachellianilotica*, 6 years for *Populus deltoides*, and either a 6-year or 5+1-year rotation for *Dalbergia sissoo* as per the study of earlier researchers (Gibreel et al.). These results provide valuable insights for forest managers and investors in making informed decisions to maximize the economic benefits of plantation forestry. However, over time, these adaptations can foster more sustainable and profitable forestry practices. Such changes also have ecological implications, promoting biodiversity and vital ecosystem services. Collaboration, research, and supportive policies are integral to successfully

navigating this transition, ensuring that our forests remain resilient and continue to provide crucial benefits to both society and the environment.

CONCLUSIONS

The best economical rotation for the *V. nilotica*was recorded in 6-year rotation period having Rs. 1768.1 net present worth, 222.01 benefits cost ratio. The best economical rotation for the *P. deltoides* was recorded in 6-year rotation period having Rs. 1356.8 net present worth, 170.61 benefits cost ratio. The best economical rotation for the *D. sissoo*was recorded in 6-year rotation period having Rs. 2191.2 net present worth, 274.91 benefits cost ratio of 27391%. The government should adopt 3+3+4 or 4+6-years rotation than 10 years rotation. Agroforestry should be started with a small number of trees per hectare, and assessments should be done to determine if the net present value is positive or negative. The farmers are recommended to grow *V. nilotica,P. deltoides,* and *D. sissoo*at a rotation of 6 years for maximum economic returns.

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