Economic Analysis of Black Pepper Production in Kolli Hills: A Study of Costs and Returns

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Abstract
Black pepper (*Piper nigrum*) is an important spice crop in India, contributing significantly to farm income and rural livelihoods, particularly in hill ecosystems. However, region-specific evidence on its farm-level economics remains limited. This study analyses the cost of cultivation, returns, and profitability of black pepper production in Kolli Hills, Tamil Nadu. Primary data were collected from 60 farmers across four village clusters using a structured interview schedule. Economic analysis was carried out using descriptive statistics, cost–return analysis, per-hectare estimation, Benefit-Cost Ratio (BCR), and discounted cash flow techniques.
The results showed that the average cost of cultivation was ₹4.15 lakh per hectare, while gross and net returns were estimated at ₹7.80 lakh and ₹3.60 lakh per hectare, respectively, based on an average yield of 17 quintals per hectare and a price of ₹550 per kg. The undiscounted BCR indicated that black pepper cultivation is economically viable, with labour and input costs forming the major share of total expenditure.
Considering the perennial nature of the crop, a 15-year discounted cash flow analysis at a 12 percent discount rate was conducted, incorporating the initial establishment phase. The results revealed a positive Net Present Value (₹11,13,970 per hectare) and a discounted BCR of 1.57, confirming long-term financial viability. The study highlights that improving input efficiency, technology adoption, and market access can further enhance productivity and sustainability.

Keywords: Black pepper, Cost of cultivation, Profitability analysis, Plantation crops, Discounted cash flow, Kolli Hills

1. Introduction

Agriculture still remains a mainstay in developing countries, providing livelihoods, food security, and economic development. The industry has experienced massive change over the last few decades since the advent of globalization, technology and changing market forces. Contract farming and other institutional mechanisms have become a significant instrument in enhancing access of farmers to the market, and welfare, although their effects differ in different settings (Bellemare and Bloem 2018). Simultaneously, agronomic technologies like seed priming have proven to enhance crop productivity, especially in less-favoured settings (Carrillo-Reche, Vallejo-Marín, and Quilliam 2018). These changes underscore the importance of combined strategies to boost agricultural productivity and agricultural income.
The competitiveness in trade and export performance has gained relevance in the global agricultural system especially to the high-value crops (Castellani, Damijan, and Kostevc 2020). Agriculture in India is being confronted with two issues of maintaining a growth in productivity and structural problems of fragmented landholdings and lack of resources (Chand 2019). Agroecological solutions are becoming popular as sustainable measures to enhance environmental performance and nutritional security (Deaconu et al. 2021). Besides, the alignment of agricultural systems to the mitigation and adaptation objectives of climate change has become a global priority. (Doelman et al. 2019).
Climate variability and extreme weather conditions are some of the environmental stressors that have a major impact on agricultural productivity. It has been demonstrated that geographical and climatic aspects are crucial in establishing resilience and vulnerability of crops (Dorado-Liñán et al. 2019). Smallholder farmers face these issues especially, as they are a significant percentage of agricultural producers in developing nations and are the key to food and nutrition security (Fan and Rue 2020). The size of farms, the endowment of resources and management practices also influence productivity and efficiency, and the question of the optimal farm size and mechanization continues to be controversial in the modern world of agriculture (Foster and Rosenzweig 2022). Moreover, biodiversity and crop-specific attributes are also a source of economic and ecological value in the agricultural systems (Gaurav et al. 2023).

New technologies in agricultural inputs and technologies such as biochar use and climate-resilient production methods have also helped in enhancing productivity and sustainability (Layek et al. 2022; Li et al. 2022). The practice of efficient soil and water management is necessary as well to alleviate the environmental stresses like waterlogging and to maintain crop production (Manik et al. 2019). In the meantime, biopesticides and other environmentally-friendly options are becoming increasingly popular in sustainable agriculture (Hamrouni et al. 2025). In spite of these developments, agricultural systems in most of the developing countries still experience limitations in terms of access to inputs, technology and markets which constrain productivity and profitability (Massrie 2025).

The black pepper (Piper nigrum), which in the Indian context is popularly referred to as the King of Spices, is a vital economic crop in the country, both as a local and export crop (Nair 2020). Plantation crops like black pepper are adding to the farm income and rural employment of the regions, mostly hill and tribal areas (Nair 2021). The profitability of growing black pepper is however based on various factors such as cost of cultivation, variation in yield, fluctuation in prices and market conditions. The problem of food commodity contamination (Pandey et al. 2023) General issues of sustainability also contribute to the importance of economic analysis of the agricultural production system in detail.

Although black pepper is economically significant, limited empirical data on cost structures and profitability of farms at a specific location e.g. Kolli Hills are available. Current literature is characterized by interest in major producing states, and it does not pay much attention to regional differences in the agro-climatic conditions, patterns of costs, and levels of productivity. Moreover, conventional profitability analyses tend to take the same annual returns, which is not necessarily the case with the biological and economic properties of perennial plantation crops.

Black pepper is a perennial plant whose life cycle includes a specific time of establishment, then a time of growing productivity, maximum yield and a decline. The initial years of cultivation entail a lot of investment with minimal or no returns, hence the need to include time-based financial analysis. Thus, long-term investment appraisal methods like Net Present Value (NPV) and Benefit-Cost Ratio (BCR) are better to determine profitability and see a more realistic picture of economic feasibility.

It is on this basis that the present research seeks to examine the cost of cultivating black pepper, yield, returns and profitability of black pepper cultivation in Kolli Hills, based on an average yield of 17 quintals per hectare, and a market price of ₹550 per kg. The long-term economic viability of a 15-year period with a discount rate of 12 percent has also been carried out in the study; the establishment years and lifecycle behaviour of the crop have been taken into explicit consideration. The combination of farm-level data with discounted cash flow analysis enables the study to give an insight into the sustainability and income-generating potential of black pepper cultivation in the hill ecosystems.

2. Review of Literature

The economics of spice crops in India has drawn great focus over the past years, especially considering that they play a role in diversification of agriculture, earning of foreign exchange, and income to farmers (Shandilya, Gulia, and Arora 2022). It has been noted that spice crops including black pepper, cardamom and ginger are of much importance to the farm profitability due to their high market values and potential for export. Another issue that research has raised concerns with is the need to enhance productivity and efficiency in the production of spices to be competitive in the global market particularly in the light of changes in prices and variable trade dynamics (Sivaraman, Thankamani, and Srinivasan 2024).

There has been a large literature on the price of growing black pepper especially in biggest producing states like Kerala and Karnataka (Hema, Kumar, and Singh 2007). The same studies have shown that the production of black pepper is a labour-intensive product with labour expenditure the highest proportion of the total production expenses followed by the input expenses of fertilisers, manure, and plant protection chemicals (Entebang, Wong, and Mercer 2020). Imputation of costs which include family labour and rent value of the land has been discovered to substantially affect the overall cost estimates and profitability calculations (Khan et al. 2024). Although the majority of the studies report the positive returns on the black pepper crop, they also point to different cost structures in the regions, as a result of the differences in the size of farms, management strategies, and inputs.

A study of returns and profitability of plantation crops has also indicated that crops like black pepper, tea, coffee, and rubber are usually profitable when the agro-climatic and market conditions are favourable (Lady Aqnes Kurniawati et al. 2021). The indicators usually used to measure profitability include net returns, benefit-cost ratio (BCR), and when the value exceeds one, the economy is considered to be viable (Kumar et al. 2023). Research has revealed that increased production, resource use and enhanced access to the market are some of the reasons why the profitability is enhanced (Shah et al. 2025). Market price volatility and increased input costs may however impact income stability although this is more so for the smallholder farmers.

Comparative studies carried out in various areas have been able to show substantial differences in structure of costs and yield levels. Such differences can generally be explained by the following factors: the soil fertility, climatic conditions, irrigation availability and the use of better technologies (Mishra et al. 2025). As an example, the farm that has better access to inputs and technical knowledge is more likely to have higher productivity and unit costs which enhances overall profitability. On the other hand, the lack of resources and the unavailability of extension services may lead to decreased yield and increased cost of production.

Various studies have also been done to determine the factors affecting profitability in spice cultivation (Shah et al. 2025). The determinants are farm size, efficiency of inputs, availability of labour, pests and diseases and access to the markets (Boros et al. 2024). Moreover, the climate variability, support of policies, and price changes are external factors, that are significant in determining economic performance (Rashid 2024). Implementation of better cultivation systems like

integrated nutrient management and climate-resistant technologies have been noted as an important aspect of improving productivity and lowering costs.

Even though the economics of spice crops is widely documented, there is still a substantial gap in the literature that includes the micro level, region-specific studies, especially in those regions that are less well studied like the Kolli Hills. The majority of the available research is at state-level or oriented to large producing areas and, thus, ignores local discrepancies in the cost structure, yield performance, and profitability. As Kolli Hills has its distinct agro-climatic conditions and agro-ecosystems, there is a necessity of conducting specific farm-level analysis to produce context-specific outputs. The current research paper is trying to address this gap with a thorough economic study on the cultivation of black pepper in Kolli Hills in terms of cost, returns and profitability.

3. Materials and Methods

3.1 Study Area

The current research took place on the Kolli Hills area of Tamil Nadu, India which is a leading hill agro-ecosystem with spice and plantation crop production. The region also has good agro-climatic conditions to produce black pepper such as moderate temperatures, sufficient rainfall, suitable elevation and fertile soil. Agriculture in the area is mainly done by small and marginal farmers and black pepper is a significant source of income crops either as single or mixed crop. Kolli Hills has been chosen as the study area because of its importance as a pepper producing area and no region-specific economic analysis of black pepper production is available.

3.2 Data Source and Sampling Procedure

It was founded on primary data that was gathered on black pepper growers in Kolli Hills with the help of a field survey using a pre-tested and structured interview schedule. The sampling was made in such a way as to reflect the current system of farming and variability of the farming practices in the area. Personal interviews with farmers were used to collect data, which included a lot of information about area under cultivation, input utilization, production, cost and returns.

The data gathered allowed economic analysis on a farm level and the data were further standardized in terms of hectares to allow comparison of farms of various sizes.

3.3 Variables Considered

The variables used to make the analysis were production, cost, and the variables of the returns.

- Variables of production were area under cultivation, yield per hectare and total output. The average yield of black pepper was considered as 17 quintals per hectare.
- Price variable: The average market price of black pepper was assumed to be ₹550 per kg.
- Cost variables were based on: labour, fertilisers, manure, plant protection and other operational costs that added up to the overall cost of cultivation. The average cultivation cost was estimated to be ₹4.15 lakh per hectare in the productive period (annual average).
- Return variables were gross returns and net returns. The gross and net returns were estimated to be 7.80 lakh and 3.60 lakh per hectare on average, respectively.

These variables were chosen because they are the most important variables to measure economic performance and profitability of black pepper cultivation.

3.4 Analytical Techniques

Descriptive statistics like mean, averages, and percentages were used to analyse the data and summarised farm characteristics, costs, and returns. The following measures were used to assess economic performance:

- Gross Return (GR): GR = yield x market price.
- Net Return (NR): Net Return = gross return less total cost of cultivation.
- Benefit-Cost Ratio (BCR): The gross return is divided by the total cost of cultivation giving a ratio. A BCR of more than one will be a sign of economic viability.

To be able to compare all the economic indicators meaningfully, they were all estimated per hectare.

3.5 Discounted Cash Flow Analysis

A discounted cash flow analysis was conducted on a 15-year basis to determine the economic viability of the crop in the long term, as the commercial life of the crop was 15 years. Black pepper being a perennial crop, the first three years were considered as establishment years, during which costs are incurred but returns are minimal or negative. The establishment costs were estimated at ₹3,70,000 per hectare. The production patterns were realistically modelled by the annual costs, yields and returns, with the yields growing slowly at the beginning of the establishment phase and reaching a peak and declining in the later years. To consider the time value of money, a discount rate of 12 percent was used. The discount factor was calculated using the formula:

$$DF_t = \frac{1}{(1+r)^t}$$

where:

- r= discount rate (12%)
- t= time period (year)

The present value (PV) of net returns was calculated as:

$$PV = \text{Net Return} \times \text{Discount Factor}$$

The economic indicators obtained were as follows:

- Net Present Value (NPV): Difference between total discounted returns and total discounted costs. NpV in this study was calculated to be 11,13,970 per hectare, which represents good long-term profitability.
- Benefit-Cost Ratio (BCR): Ratio of the sum of discounted returns to the sum of discounted costs.
- The discounted BCR was calculated to be 1.57, which validated the economic viability.
- Amortisation of Establishment Cost: The total establishment cost was amortised over the crop life by using the standard amortisation formula. The amortised fixed cost was estimated to be 54,390 in rupees per hectare in a year.

3.6 Per Hectare Economic Analysis

All economic indicators were standardised on a per-hectare basis since the size of the farms differed among respondents. This strategy reduced the impact of variations in the size of farm and enabled the correct comparison of productivity and profitability across farms. The per-hectare analysis entailed cost of cultivation, yield, gross returns and net returns which gave a better explanation of the economic efficiency in the cultivation of black pepper.

3.7 Scope of the Methodology

The approach taken in this paper offers an extensive farm-based economic assessment of the production of black pepper in Kolli Hills. The study combines the cost analysis, the return estimation and the discounted cash flow techniques to ensure that both the short-term profitability and the financial viability are captured. Establishment years and production analysis based on lifecycle make the study especially realistic and thus especially applicable to perennial plantation crops. The results provide place-based information, which is applicable in policy making, decision making on a farm level, sustainable agricultural development within hill ecosystems.

4. Results

4.1 Socio-economic and farm-size profile of black pepper growers

It involved 60 farmers of black pepper who were chosen in four village clusters of Kolli Hills, which include Vaalavanthi Nadu (20 farmers; 33.33%), Devanoor Nadu (15 farmers; 25.00%), Ariyur Nadu (15 farmers; 25.00%) and Thinnanur Nadu (10 farmers; 16. The mean size of the black pepper crop was 7.15 acres, and the size of the farm was 4-12 acres. The sample of the distribution of holdings indicated that medium-sized farms predominated, and the sample of farmers concentrated around the 7-8 acre range. This suggests that in the study area, the production of black pepper was largely concentrated among the medium-scale farmers.

Table 1 shows the village-wise distribution and the mean pepper area. The mean area under black pepper was highest in Thinnanur Nadu (8.20 acres), Ariyur Nadu (7.47 acres) and Vaalavanthi Nadu (7.25 acres) and lowest in Devanoor Nadu (6.00 acres) which was selected. The sample farmer distribution based on area under black pepper is shown in Figure 1 where a concentration is evident in the medium farm-size groups.

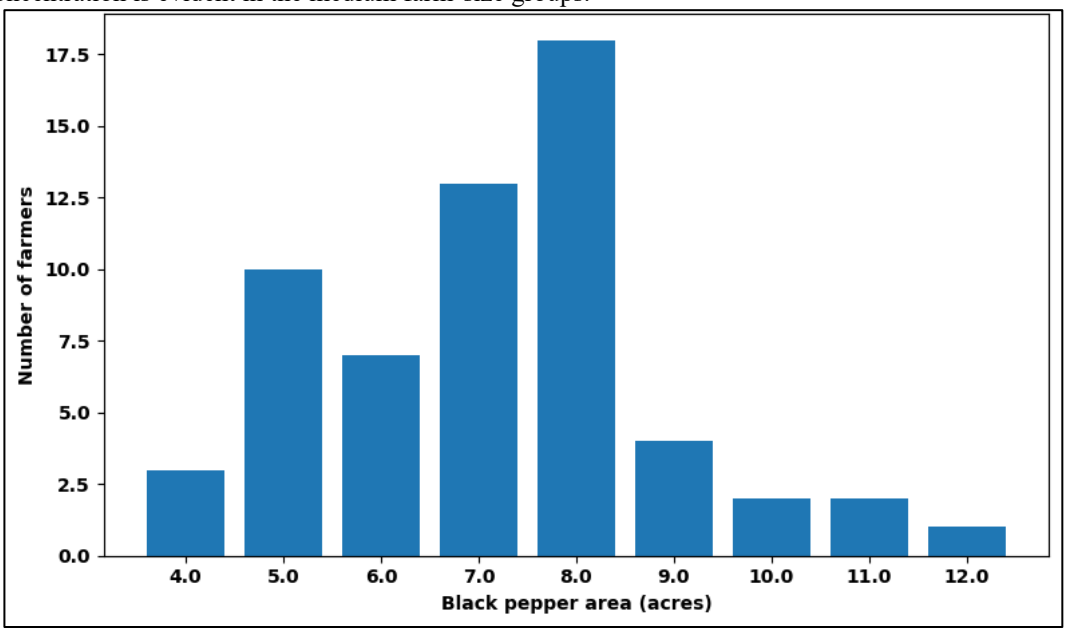

Figure 1. Distribution of sample farmers by black pepper area

Table 1. Village-wise distribution and farm-size characteristics of black pepper growers in Kolli Hills

Village	Number of farmers	Percentage (%)	Mean pepper area (acres)
Vaalavanthi Nadu	20	33.33	7.25
Devanoor Nadu	15	25.00	6.00

Ariyur Nadu	15	25.00	7.47
Thinnanur Nadu	10	16.67	8.20
Overall	**60**	**100.00**	**7.15**

Table 1 data show that the variation in the area under cultivation can affect the overall production and income at the farm level. The subsequent economic indicators however, to eliminate the impact of farm size variation, were all standardized and talked about per hectare basis.

4.2 Cost of cultivation of black pepper

The economic analysis showed that the average annual cost of cultivation of black pepper was ₹4.15 lakh per hectare . As not all respondents had the same-sized farms, the cost analysis was standardised based on the hectares to allow valid comparison. The cost structure showed that human labour had the highest percentage of total cost of cultivation, then the value of the rental of the owned land, fertiliser, imputed value of family labour and manure. This attests to the fact that the production of black pepper in Kolli Hills has been labour-intensive and input-intensive.

Table 2 shows the average cost structure whereas Figure 2 provides a diagrammatic representation of the significance of the significant cost elements. The contribution of labour to the total cultivation cost was 21.69 percent which shows that availability of labour and wage rates is crucial in determining how profitable it is. The rental value of owned land comprised 18.00 percent, followed by fertiliser and imputed family labour, which had a contribution of 13.01 percent and 12.27 percent, respectively. The cost of manure (10.84 percent) and plant protection (8.68 percent) were also significant parts of the total cost.

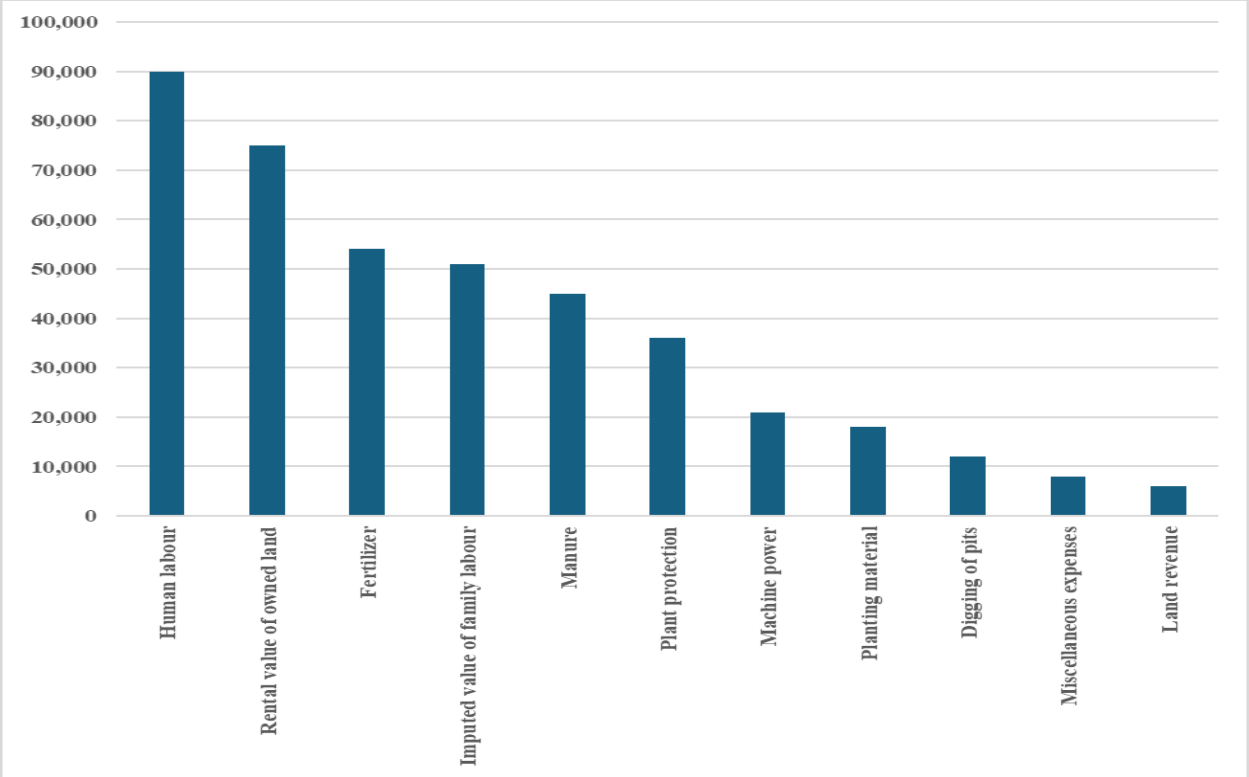

Figure 2. Average cost structure of black pepper cultivation on a per hectare basis

Table 2. Average cost structure of black pepper cultivation in Kolli Hills (per hectare basis)

Cost component	Mean cost per hectare (₹)	Share of total cost (%)
Digging of pits	12,004	2.89
Planting material	17,998	4.34
Manure	44,999	10.84
Fertilizer	53,998	13.01
Human labour	89,999	21.69
Machine power	21,001	5.06
Plant protection	36,002	8.68
Land revenue	5,998	1.45
Miscellaneous expenses	7,405	1.78
Rental value of owned land	74,680	18.00
Imputed value of family labour	50,920	12.27
Total cost	**4,15,000**	**100.00**

Black pepper production as illustrated in Table 2 and Figure 2 requires a lot of labour and purchased inputs. Thus, enhanced labour productivity and optimisation of input utilisation would be important in increasing the profitability of the farms.

4.3 Yield, returns, and profitability of black pepper cultivation

The per hectare analysis revealed that the average yield of black pepper was 17 quintals per hectare (1,700 kg/ha) with an average selling price of ₹550 per kg . According to this yield and price level the gross return was projected as 7.80 lakh per hectare and the net return was projected as 3.60 lakh per hectare. These results clearly show that black pepper cultivation generated a positive economic surplus over the cost of cultivation.

Table 3 gives a summary of the profitability indicators. The Benefit-Cost Ratio (BCR) without discounting was calculated to be 1.88, which means that every rupee spent on growing black pepper earned ₹1.88 as gross returns. This validates the fact that black pepper production is a viable economic activity under the current production and price factors in Kolli Hills.

Figure 3 shows the relative size of cost, gross, and net returns. The figure indicates clearly that the gross returns were significantly more than the cultivation cost making the net return per hectare to be positive and significant.

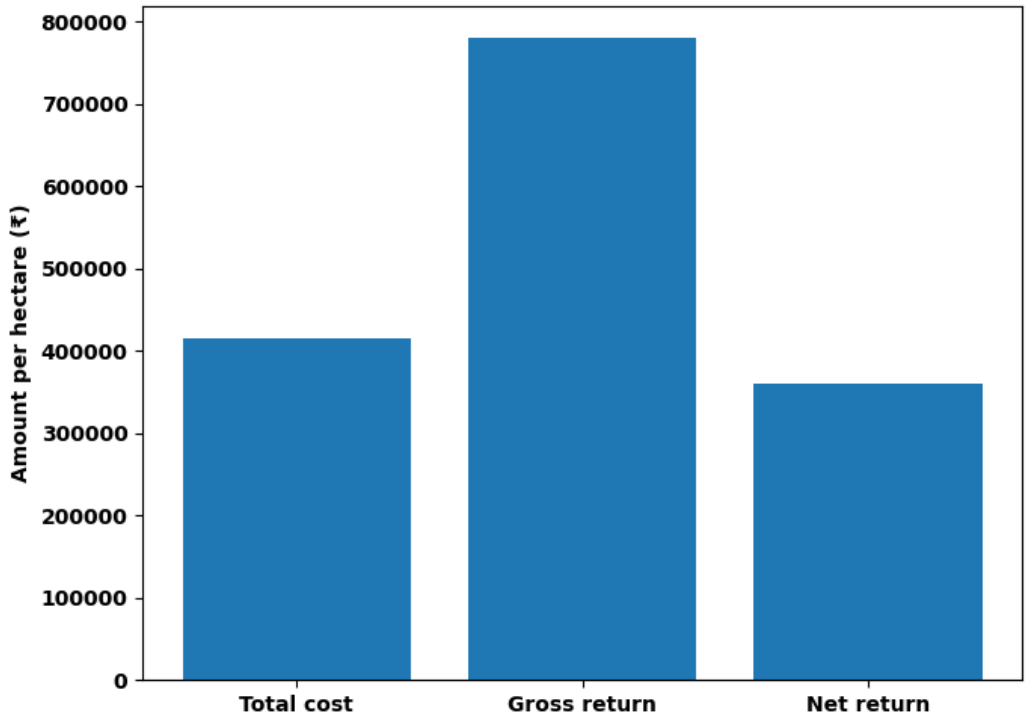

Figure 3. Cost, gross return, and net return of black pepper cultivation on a per hectare basis

Table 3. Yield, returns, and profitability of black pepper cultivation (per hectare basis)

Particulars	Value
Yield (quintals/ha)	17.00
Yield (kg/ha)	1,700
Price (₹/kg)	550
Gross return (₹/ha)	7,80,000
Net return (₹/ha)	3,60,000
Total cost (₹/ha)	4,15,000
Benefit-Cost Ratio	1.88

The figures in Table 3 and Figure 3 indicate that the cultivation of black pepper is profitable per hectare. Despite the high investment in cultivation, the crop has good returns and adds value to the farm income in the hill production system.

4.4 Discounted economic analysis of black pepper cultivation (15-year period)

In order to determine the economic sustainability of black pepper farming in the long run, a discounted cash flow analysis was performed with a 12 percent discount rate over 15 years of a commercial life cycle. The new analysis, compared to the previous constant-return one, also took into account the biological and economic behaviour of black pepper as a perennial crop. The initial three years were taken as establishment years and there was no return or minimal returns on cultivation expenses.

Table 4 shows the yearly trend of the cost, yield, gross return and net return. The farmers made no returns and only made costs in the first two years. Since the third year onward the crop began to generate income and returns were increasing

steadily. The net returns were highest at the mid years of the crop cycle and slowly decreased to the later years. The trend depicts the stage of formation, high yielding phase, and the subsequent deterioration with time.

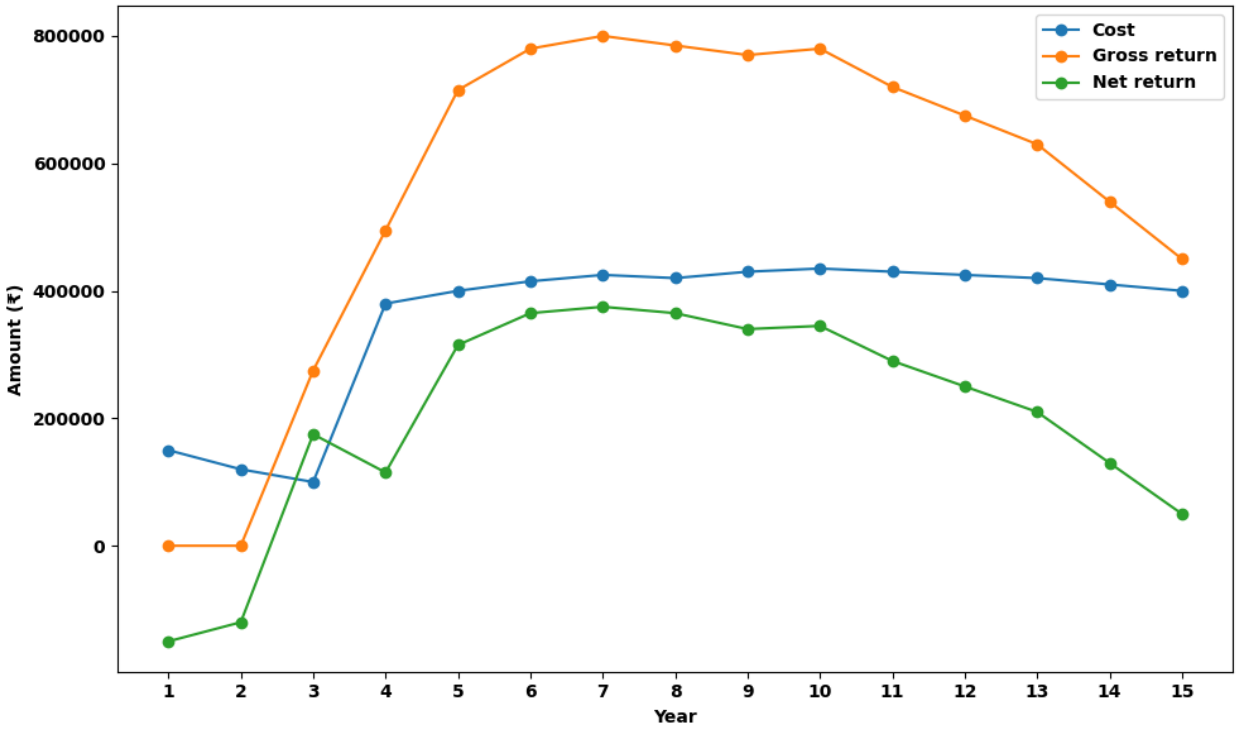

Figure 4. Year-wise cost, gross return, and net return of black pepper cultivation over a 15-year period

Table 4. Year-wise cost, yield, gross return, and net return of black pepper cultivation (15 years, per hectare basis)

Year	Cost (₹)	Yield (kg)	Gross Return (₹)	Net Return (₹)
1	1,50,000	0	0	-1,50,000
2	1,20,000	0	0	-1,20,000
3	1,00,000	500	2,75,000	1,75,000
4	3,80,000	900	4,95,000	1,15,000
5	4,00,000	1,300	7,15,000	3,15,000
6	4,15,000	1,700	7,80,000	3,65,000
7	4,25,000	1,750	8,00,000	3,75,000
8	4,20,000	1,720	7,85,000	3,65,000
9	4,30,000	1,680	7,70,000	3,40,000
10	4,35,000	1,700	7,80,000	3,45,000
11	4,30,000	1,600	7,20,000	2,90,000
12	4,25,000	1,500	6,75,000	2,50,000
13	4,20,000	1,400	6,30,000	2,10,000
14	4,10,000	1,200	5,40,000	1,30,000
15	4,00,000	1,000	4,50,000	50,000

Time value of money was calculated by considering discount factor per year and the present value of net returns was calculated. Table 5 shows the results. Discount factors decreased with time, and thus, present value of subsequent year returns was lower. Despite this, the majority of the productive years produced high positive present values counterbalancing the negative values in the establishment period.

Table 5. Discount factor and present value of net returns of black pepper cultivation

Year	Net Return (₹)	Discount Factor (12%)	Present Value (₹)
1	-1,50,000	0.893	-1,33,950
2	-1,20,000	0.797	-95,640
3	1,75,000	0.712	1,24,600
4	1,15,000	0.636	73,140
5	3,15,000	0.567	1,78,605
6	3,65,000	0.507	1,85,055
7	3,75,000	0.452	1,69,500
8	3,65,000	0.404	1,47,460
9	3,40,000	0.361	1,22,740

10	3,45,000	0.322	1,11,090
11	2,90,000	0.287	83,230
12	2,50,000	0.257	64,250
13	2,10,000	0.229	48,090
14	1,30,000	0.205	26,650
15	50,000	0.183	9,150

The discounted analysis revealed that the Net Present Value (NPV) is 11,13,970 per hectare, which meant that the black pepper farming is economically viable in the long run. The benefit-cost ratio with a discounted value (BCR) was estimated at 1.57 which also shows that the enterprise is economically viable even with consideration of time value of money. The establishment cost incurred in the first three years amounted to 3,70,000 per hectare and the amortized fixed cost was estimated to be 54,390 per hectare/year.

5. Discussion

The findings of the current research indicate that black pepper farming in Kolli Hills is a viable economic activity, based on a per-hectare basis with an average net income of approximately 3.60 lakh per hectare and a cultivation expenditure of 4.15 lakh per hectare. The gross return of 7.80 lakh per hectare is estimated and the Benefit-Cost Ratio, not discounted, exceeds unity which indicates that the crop gives a positive economic surplus given the current conditions of production and price. These results can be related to previous research which has pointed out the importance of diversified and traditional agricultural systems to enhance productivity, resilience, and sustainability (Pandey et al. 2022). Such diversification also helps to achieve an efficient use of resources and ecological equilibrium in hill ecosystems, including black pepper cultivated in mixed or agroforestry, like in the Kolli Hills.

The yields realized in the research of 17 quintals per hectare are similar to those found in other black pepper major areas of India. Regional differences in yield and production have been explained by differences in agro-climatic conditions, farm management and access to markets The moderate-to-high productivity in Kolli Hills has been attributed to the fact that the region has favourable ecological conditions that support the cultivation of black pepper, yet there is still room to improve this through improved input management and the adoption of technology.

The effects of environmental and climate related factors are very critical factors in defining long term agricultural productivity. Adaptive strategies to reduce the risks of climate and increase the resilience of spice crops like black pepper and ginger are reinforced by studies (Praveen Kumar et al. 2025). Such environmental factors could be one of the reasons why the yield and returns of the farms were different across the farms in this study. It has proposed sustainable intensification methods such as better input management and ecological farming methods as effective measures to balance between productivity and environmental sustainability (Pretty et al. 2018).

The cost structure analysis showed that input costs and labour costs are the largest portion of the total cultivation costs. This observation goes hand in hand with other studies which affirm the significance of effective input utilization and management methods in identifying profitability in the black pepper production (Sapkal et al. 2024). Since labour only constitutes a considerable share of total cost, a better labour productivity and the implementation of labour-saving technologies can lead to a significant increase in farm income. Policy interventions, such as subsidies on input and better access to quality inputs can also be critical in enhancing economic performance and environmental sustainability (Sapkota and Bijay-Singh 2025).

In a broader view, the issue of food security and environmental sustainability is a worldwide challenge. Transformative food systems focus on effective use of resources, less impact on the environment and better livelihoods of farmers (Searchinger et al. 2019). The findings of this research suggest that black pepper as high-value crop can play an important role in these goals as long as it is effectively managed.

The technological innovations have tremendous potentials to improve agricultural productivity and profitability. Nano-fertilizers and other innovations have demonstrated to enhance the efficiency of nutrient use and crop performance (Mahmoud F. Seleiman 2020). Likewise, competitiveness and realization of price of the export crops like black pepper can be improved through value chain additions, such as improved market linkages, grading, and value addition (Shandilya et al. 2022). Within the Kolli Hills setting, market access and value addition should be enhanced to further boost the income of farmers.

Agriculture is also important in the overall economic development. Research has established that there is a correlation between agricultural value addition, foreign direct investment and economic growth (Sharmiladevi 2023). The large returns of black pepper that is produced in the area of study brings out its potential in rural development and growth of the region economy.

Remote sensing and precision agriculture are emerging technologies that can be used to increase efficiency in farms and overcome limitations affecting smallholder farmers (Singh et al. 2024). These technologies have the potential to facilitate the use of inputs optimally, increased productivity, and minimized production risks. Moreover, diversification plans have been found to enhance farm earnings and minimize exposure to shocks (Thapa et al. 2018), recommending that economic benefits can be further improved by adding black pepper to other crops.

The performance of spices in India is not just a production activity but also a trade and export activity. Research about the spice trade underlines their significance in earning foreign exchange and developing the economy (Yazhini and Malaisamy 2024). The economic feasibility of the black pepper production witnessed in this research supports its significance as a high-value commodity with a high market potential. Notably, the current research emphasizes that the growth of black pepper takes a specific lifecycle pattern, which is an establishment phase, a phase of increasing returns,

peak productivity, and decline. The initial three years are characterized by heavy investment with little or negative returns hence the need to plan on long term financial planning to the farmers. The discounted cash flow analysis (DCF) analysis that has been done on a 15-year-period presents a more realistic view of the profitability than the traditional annual analysis.

The positive Net Present Value (11,13,970 per hectare) and discounted Benefit-Cost Ratio (1.57) indicate that it is financially feasible to cultivate black pepper in the long-run, despite taking into consideration the time value of money. The first few years may be characterized by financial limitations as a result of the costs of establishing it but the years following it will yield high returns that will offset the losses incurred during the first few years. This estimated amortized cost of establishing also shows that the investment is effectively spread over the productive life of the crop, so that there is stable annual returns.

On the whole, the discussion indicates that although the black pepper farming in Kolli Hills is economically feasible, much can be done to improve productivity and profitability by managing resources better, adopting technologies, and implementing proactive policy changes. The inclusion of lifecycle-based analysis and discounted analysis empowers the interpretation of black pepper farming as a sustainable and long-term income generating venture.

6. Policy Implications and Recommendations

The findings of the current research reveal that the black pepper farming in the Kolli Hills is profit-making, but specific policy responses will be needed to increase the productivity and profitability. Considering the high proportion of labour in the overall cultivation cost, there is a necessity to introduce labour-saving technologies and small-scale mechanisation that can be implemented in hilly soils as well as the training programmes to enhance labour efficiency. The cost of inputs especially fertilisers, manure and plant protection can be streamlined by following the application of integrated nutrient and pest management methods such as use of bio-fertilisers and environmentally friendly inputs in case of sustainability. It is important to strengthen agricultural extension services in order to spread better cultivation, disease management practises and post-harvest handling practises that would bring about less yield variations across farms. Ensuring further market access by better infrastructure, empowering farmer producer organisations (FPOs) and promoting value addition including grading and packaging and branding can greatly improve the price realisation and the income of farmers. Since plantation crops are susceptible to climate change, there is need to promote climatic resistant practises, such as water conservation, mulching, and availability of crop insurance and weather advisory systems.

Moreover, institutional credit, which is cheap, should be made available and technology adoption subsidies should be offered to the small and marginal farmers to make investment easy. Increased investment in research and development to come up with high yielding and disease resistant varieties as well as region specific use of cultivation will additionally help in increasing productivity. In general, the economic potential of black pepper cultivation in Kolli Hills needs a holistic, location-specific policy that unites technological, institutional, and market-based interventions in order to support the sustainability and improvement of the same.

7. Conclusion

The current research offers a full farm-level economic evaluation of the black pepper farming in the Kolli Hills, its cost structure, yield, returns and long-term profitability. The results show that black pepper farming is a profitable business when considered per hectare, with an average price of 4.15 lakh per hectare of costs incurred, grossing 7.80 lakh per hectare and netting 3.60 lakh per hectare. All this means that, even though the cost of cultivation is fairly high, the crop has a positive economic surplus and will provide a significant part of farm earnings. Another aspect the study lays emphasis on is that profitability depends on the change in yield, input management, farm size, and agro-climatic conditions. The average yield of 17 quintals per hectare recorded and a market price of 550 per kg illustrate the high income-generation capacity of black pepper under a favourable production environment. Nevertheless, the findings indicate that productivity and returns can be further improved with the help of input-use efficiency and better management practices. An important addition to this research is the inclusion of a discounted perennial economic evaluation based on a lifecycle, which offers a more realistic evaluation of profitability of a perennial crop such as black pepper. The findings indicate that the initial three years are an establishment period where farmers incur a lot of expenses with negative or low returns. However, after the years after the initial ones, the crop yields return which increase up to the maximum in the mid-years of its commercial life. The long-term financial viability of black pepper cultivation is confirmed with the discounted cash flow analysis over 15 years. The positive Net Present Value and a discounted Benefit-Cost Ratio of 1.57 points support the fact that the investment is economically viable even taking into consideration the time value of money.

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