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Environmental and Economic Benefits of Naturally Coloured Cotton: A Comparative Study with Conventional Cotton

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Abstract: ***Naturally coloured cotton has emerged as a sustainable alternative to conventional white cotton, addressing increasing environmental concerns associated with dyeing and textile processing. This study evaluates the economic feasibility and ecological advantages of naturally coloured cotton in comparison with conventional cotton production in India. Primary data were acquired from the University of Agricultural Sciences, Raichur (2022-23), while secondary data were sourced from the International Cotton Advisory Committee and pertinent literature. Percentage analysis, ratio analysis, and simulation approaches were applied to measure cost of cultivation, processing efficiency, energy usage, water consumption, and carbon emissions. Results found that although naturally coloured cotton yields were 35% lower than those of conventional cotton, its total cultivation cost was roughly 47.5% lower. The removal of dyeing and related chemical treatments resulted in a nearly 66% reduction in processing costs. During processing, naturally colored cotton used only one-third of the water, used 75% less energy, and produced much less carbon emissions. According to simulation studies, the environmental impact might be significantly reduced by substituting even 10% of traditional cotton production with naturally colored cotton by 2030. At a market price of USD 125.84 per quintal, naturally colored cotton reached its break-even threshold; higher prices provided growers with significant financial incentives. n conclusion, naturally colored cotton presents a viable path toward environmentally sustainable textile production, particularly in regions with limited resources. It also promotes low-impact value chains in the cotton industry with the support of policy assistance, increased consumer awareness, and research to address yield constraints.***

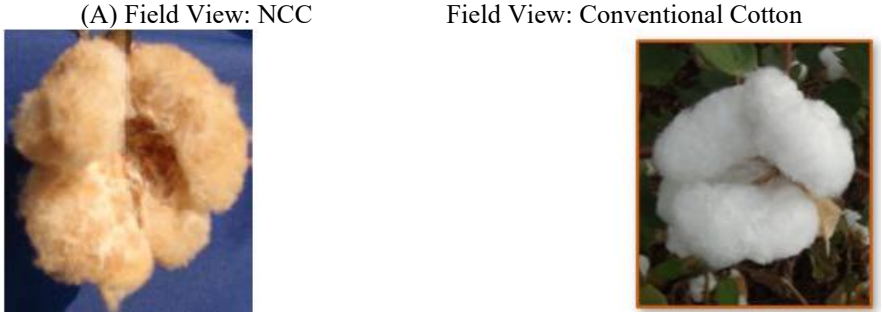
Keywords: Naturally Coloured Cotton; Economic benefits; Energy Utilization; Water Consumption; Emission reduction.

1. Introduction

Cotton is one of the most important natural fibres worldwide, serving as a primary raw material for the textile industry and supporting millions of livelihoods. India is the second-largest producer globally as of 2022–2023 (Ministry of Textiles, GOI). The crop forms the foundation of the textile industry, contributing nearly 70% of the nation's total fiber consumption, and a significant portion of the rural population still relies heavily on cotton cultivation for their income (Baghyalakshmi *et al*., 2024). Conventional white cotton, although widely cultivated and industrially optimized, requires extensive chemical processing particularly for dyeing and finishing to achieve the colour and functional properties demanded by modern consumers. This reliance on synthetic dyes, bleaching agents, and multiple wet-processing steps significantly increases water consumption, energy use, and environmental pollution from chemical effluents. The dyeing sector, in particular, is a major source of water and air pollution, contributing to soil fertility decline, increased salinity, and excessive energy and water usage. Dyed fabrics often contain toxic chemicals such as arsenic, lead, zinc, cobalt, and chromium, which can cause health problems, including skin irritation, especially in children (Sushila and Sarita Devi, 2022). According to the World Bank, dyeing activities alone account for nearly 20% of global water pollution, and at least 72 harmful chemicals have been detected in water bodies associated with textile effluent discharge.

Growing awareness of environmental sustainability, especially in developed nations like the United States and Europe, has increased the demand for eco-friendly textiles. Naturally coloured cotton has become a promising sustainable alternative because of its inherent pigmentation, which minimizes or removes the need for chemical dyeing (Naoumkina *et al*., 2024). The natural pigments in the fiber lumen give the lint its color, removing the need for chemical treatment. The cultivation and processing of naturally coloured cotton are increasingly recognized for their potential to lessen environmental impact, conserve resources, and improve economic efficiency throughout the textile value chain. Historically, naturally coloured cotton dates back to around 2500 B.C. in South America, where it was grown for local use (Keshamma, 2022). Today, several countries including China, Colombia, Egypt, Guatemala, India, Mexico, Peru, Russia, and the USA commercially cultivate coloured cotton. India mainly produces brown and green cotton in six shades (Fig 1), while countries like the USA and Russia cultivate additional colours such as black, blue, pink, and red. Regionally, dark brown cotton is grown in West Bengal and Karnataka, yellow-green in Meghalaya, and light pink in specific peninsular areas (CICR, Nagpur).

(A) Field View: NCC Field View: Conventional Cotton



(B) Single Boll : NCC Single Boll : NCC

Figure 1: A. Field view of NCC and Conventional cotton, B. Single boll of NCC and Conventional Cotton

However, despite these benefits, adoption remains limited, partly because of gaps in understanding the cost structures, resource utilization patterns, and comparative processing performance compared to conventional cotton. Moreover, scientific evaluations comparing its economic viability, environmental footprint, and resource requirements with those of conventional cotton are scarce. Although naturally colored cotton is widely seen as an eco-friendly alternative, empirical research quantifying its economic and environmental advantages remains limited. Evaluating these parameters is crucial for understanding the true ecological and economic advantages of naturally coloured cotton. Percentage analysis provides a systematic way to measure the share of costs, water use, and energy consumption at each processing stage, supporting an evidence-based evaluation of overall profitability and sustainability. This study therefore aims to compare naturally coloured cotton and conventional cotton in terms of processing cost, water and energy use, and electricity-related expenditure. By employing percentage analysis, the research provides insights into the extent to which naturally coloured cotton can contribute to more sustainable and cost-effective textile production.

2. Materials and Methods

Data collection

The Primary data on naturally coloured cotton in India has been collected from the University of Agricultural Sciences, Raichur, Karnataka, for the period 2022-2023. Similarly, data on the total cost of cultivation of conventional cotton during the same period are extracted from the International Cotton Advisory Committee (ICAC) to assess the differences and to compare the cost of production and cultivation between naturally coloured cotton and conventional cotton. Additional information on energy utilization and water consumption in the dyeing industry for the processing of naturally coloured cotton and conventional cotton, and carbon dioxide emission was extracted from past literature. The scenario analysis and simulation techniques were also applied to evaluate the economic feasibility and the environmental impact of adopting naturally coloured cotton over conventional cotton.

Methodology

The present study uses percentage analysis, ratio analysis, and simulation techniques to analyse the cost of cultivation and production of naturally coloured cotton and to assess the economic and environmental impact of naturally coloured cotton over conventional cotton.

Percentage analysis:

A percentage analysis was employed in this study to evaluate the costs incurred during the processing of naturally coloured cotton and conventional cotton, including energy consumption, water usage, and electricity-related expenses. By expressing these components as proportions of the total processing cost, this method enabled a systematic comparison of the economic viability and environmental efficiency of naturally coloured cotton relative to conventional cotton.

Percentage Contribution = (Total Value/Individual Parameter) ×100

Ratio analysis:

Ratio analysis was used as a methodology in this study to determine the cost of production and cultivation of naturally coloured cotton and to compare its cost and benefits with those of conventional cotton. This method aids in determining the economic feasibility and financial viability of naturally coloured cotton as a sustainable alternative to conventional cotton.

Simulation techniques:

The simulation technique involves the development of different scenarios to measure the economic and environmental advantages and benefits of naturally coloured cotton over conventional cotton. This method incorporates key parameters such as the area under conventional cotton cultivation from the 2022-23 time period, the cost of processing, electricity consumption, water and energy

utilisation, and carbon dioxide emission, and follows the same method used for naturally coloured cotton. Furthermore, different scenarios are measured for both conventional and naturally coloured cotton to assess the economic feasibility and environmental sustainability for large-scale commercialisation of naturally coloured cotton in India. These comprehensive methodologies provide a systematic evaluation of the economic and ecological viability of naturally coloured cotton for sustainable cotton production.

3. Results and Discussion

Economic analysis of the cost of cultivation

The economic analysis of conventional cotton and naturally coloured cotton highlighted the key differences in production cost and profitability. As shown in Table 1, the total variable cost and total fixed cost per hectare of naturally coloured cotton are lower than those of convention cotton. The variable cost incurred, i.e., the inputs requirements for cultivating naturally coloured cotton, is lower than conventional cotton. However, the yield of naturally coloured cotton was 12-14 quintals per hectare, which was approximately 35% lower than conventional cotton, which was 20-21 quintals per hectare. This difference in yield affected the cultivar's revenue potential. Additionally, the cost of cultivation, particularly for labour charges is lower than naturally coloured cotton due to its reduced farming operations in fertilizer and manure application, sowing operation, and other input applications

In terms of economic and market value, medium-staple-length conventional cotton had a price of $80.55 per quintal, and long-staple-length cotton had a price of $85.42 per quintal. In contrast, naturally coloured cotton provided a market value of $101.50 per quintal. When comparing both types of cotton, the break-even point was observed, if naturally coloured cotton was marketed at the price of $125.84 per quintal. This price point would have been financially equivalent to conventional cotton in terms of revenue. Furthermore, if naturally coloured cotton had been able to secure a premium price greater than or equivalent to $150.17 per quintal, it would have provided significant economic benefits for cultivars. In addition to its economic benefits, naturally coloured cotton offers additional environmental advantages.

Table 1: Naturally coloured cotton and conventional cotton costs of cultivation in India 2022-2023

S No	Particulars	NCC ($)	CC ($)
1	Human labour		
	Hired	140.33	552.31
	Family	17.41	257.88
2	Bullock labour	18.41	1.95
3	Machine labour	35.00	113.27
4	Input		
	Seeds	12.17	41.61
	Fertilizers and manures	104.18	158.44
	Insecticides	48.61	38.00
	Micronutrients and growth regulators	6.10	0.00
5	Others		
	Crop insurance	0.00	2.68
	Interest on working capital	69.83	29.79
	Miscellaneous	11.76	45.01
6	**Operating cost (Variable cost)**	**463.79**	**1240.93**
7	Rental value of owned land	185.46	240.60
8	Land and water tax	0.00	0.10
9	Depreciation	0.07	17.70
10	Interest on fixed capital	108.13	95.39
11	**Fixed cost**	**293.66**	**353.79**
12	**Total cost of cultivation**	**757.45**	**1594.72**
13	Yield (q/ha)	12-14	19-20

The cultivating cost incurred for producing naturally coloured cotton and conventional cotton is presented in Table 1. Notably, the cultivation cost of naturally coloured cotton was approximately 47.49 % lower than that of conventional cotton (Doddamani *et al.,* 2007).

Cost of processing comparison of naturally coloured cotton and conventional cotton

The analysis revealed that the processing cost of naturally coloured cotton was significantly lower than that of conventional Cotton (Muqaddim 2022). The primary reason for this cost difference was the high dyeing treatment cost for conventional cotton, which substantially increased the total expenditure, and those costs that were not incurred by naturally coloured cotton. Since naturally coloured cotton imparts its own colour to the fibre, it eliminates the need for chemical dyes, which leads to a cost reduction of approximately 78% compared with Conventional Cotton. As presented in Table 2, treatment in the dye machine costs for conventional cotton was $82.14 per qtl, whereas for naturally coloured cotton it was only $17.89 per qtl, indicating a cost difference of around 4.6 times. Other processing steps, such as batch preparation ($1.05 per qtl), cutting ($1.82 per qtl), drying ($2.22 per qtl), sanforising ($2.84 per qtl), and packaging ($3.68 per qtl), showed similar costs for both types of cotton. However, the absence of dyeing costs in naturally coloured cotton contributed to a 65.7% lower total processing cost ($33.46 per qtl) compared to conventional cotton ($97.67 per qtl). Using naturally coloured cotton provides a cleaner production alternative instead of using conventional cotton after dyeing. The dyeing process, which consumes the highest water, energy utilisation by the usage of naturally coloured cotton, which causes the highest wastewater load, was eliminated (Atav *et al*., 2022). As a result of the substantial reduction in processing cost, naturally coloured cotton represented a more sustainable and economically viable alternative to conventional cotton. Owing to its cost-saving ability during processing, it encouraged the adoption of naturally coloured cotton among textile manufacturers who were aiming for cost-effective and environmentally friendly production methods.

Table 2: Cost of processing of naturally coloured cotton and conventional cotton from 2022-2023

Treatment Steps	NCC Cost	CC Cost
	Cost in $/qtl	Cost in $/qtl
Batch Preparation	1.05	1.05
Treatments in the dye Machine	17.89	82.14
Cutting the tubular fabric	2.22	2.22
Drying in the stenter	5.79	5.79
Sanforising	2.84	2.84
Packaging	3.68	3.68
Total	33.46	97.67

The results indicated that naturally coloured cotton had lower processing costs and required fewer resources compared to

conventional cotton. This suggests that Naturally Coloured Cotton could be a cost-effective and eco-friendly alternative for the sustainable cotton industry.

Time consumption in the processing of conventional cotton and naturally coloured cotton

During the processing of naturally coloured cotton (NCC), 3 baths were used for chemical treatments: oil removal, washing, and softening, which require 20, 5, and 20 minutes respectively, with the remaining time attributed as a waiting period - totalling 1 hour and 46 minutes for processing. In contrast, conventional cotton (CC) used 10 baths during chemical treatment: H_2O_2 rinsing, 1st rinsing, 2nd rinsing, reactive dyeing, cold rinsing-neutralization, washing at 70^0C, washing at 95^0C, soaping at 95^0C, washing at 40^0C, and softening. These steps required 30, 5, 10, 150, 10, 10, 10, 20, 5, and 20 minutes, respectively, with the remaining time attributed as waiting periods – 7 hours and 22 minutes. As presented in Table 3. These findings indicate that conventional cotton consumed seven times more time than Naturally Coloured Cotton. The primary reason for this disparity was the extensive use of dyeing and its associated processes in conventional cotton. Additionally, naturally coloured cotton had a shorter processing time, which significantly reduced energy consumption, making it more sustainable and cost – effective for the textile industry.

Table 3: Time consumption in the processing of naturally coloured cotton and conventional cotton 2022-2023

Bath		Treatment steps		Process time (minutes)	
NCC	CC	NCC	CC	NCC	CC
1	1	Oil Removing	H2O2 Bleaching	20	30
2	2	Washing	1st Rinsing	5	5
3	3	Softening	2nd Rinsing	20	10
	4		Reactive Dyeing		150
	5		Cold Rinsing		10
	6		Washing at 700C		10
	7		Washing at 950C		10
	8		Soaping at 950C		20
	9		Washing at 400C		5
	10		Softening		20
Total				45	270

Energy utilization in the processing of conventional cotton and naturally coloured cotton

The analysis revealed that naturally coloured cotton utilized less energy than conventional cotton. Specifically, naturally coloured cotton consumed 75.43 kcal for the processing of 1 qtl of cotton, whereas conventional cotton utilizes 307.60 kcal as presented in Table 4. Compared to conventional cotton, naturally coloured cotton required less than one-fourth of the energy during processing. The primary disparity was due to the reactive dyeing process in conventional cotton, which consumes 31.5 kcal of energy, whereas these procedures that were absent in naturally coloured cotton. Additionally, conventional cotton undergoes multiple high-energy consumption treatments such as bleaching, high temperature washing, and soaping at 95^0 C. In contrast, naturally coloured cotton processing involved only three steps, namely, oil processing, washing, and softening, which significantly reduced energy consumption and promotes environmental stability. Furthermore, the cost of energy utilization also significantly differs between naturally coloured cotton and conventional cotton (T. Gülümser 2016). The total energy cost derived for naturally coloured cotton was $0.0067 per kcal, whereas for conventional cotton was $0.0273 per kcal. This indicated that the cost of energy utilization for naturally coloured cotton was approximately 75% lower than the conventional cotton. At the textile manufacturing stage, the energy and manufacturing technologies' impacts are greater. Increase in greenhouse gas emissions due to the utilization of carbon-intensive energy grids for conventional cotton during the dyeing process (Zhang et al. 2023). Hence, the use of alternative naturally coloured cotton fibre has the potential to reduce these environmental impacts. This substantial cost difference underscored the economic advantages of naturally coloured cotton processing, making it a more economically viable and eco-friendly alternative in the textile industry.

Table 4: Energy utilization and price during the processing of naturally coloured cotton from 2022-2023

Treatment Step		Energy utilized (kcal)		Price ($/kcal)	
NCC	CC	NCC	CC	NCC	CC
Oil Removing	H_2O_2 Bleaching	55.18	65.30	0.0049	0.0058
Washing	1st Rinsing	10.05	10.05	0.0009	0.0008
Softening	2nd Rinsing	10.20	10.10	0.0009	0.0009
	Reactive Dyeing		31.50		0.0028
	Cold Rinsing		0.00		0.0000
	Washing at 70^0C		40.10		0.0035
	Washing at 95^0C		65.10		0.0035
	Soaping at 95^0C		65.20		0.0058
	Washing at 40^0C		10.05		0.0009
	Softening		10.20		0.0009
Total		75.43	307.60	0..0067	0.0249

Note *The energy price per kW is considered to be ₹6.29 in India from 2022-2023*

The results in Table 4 highlighted that naturally coloured cotton required significantly lower energy consumption and cost compared to conventional cotton. The absence of dyeing and intensive washing in naturally coloured cotton reduce electricity usage, suggesting that it could be a cost-effective alternative for the textile industry.

Water utilization in the processing of naturally coloured cotton and conventional cotton

Water plays a crucial role in determining the sustainability of textile production. During processing, naturally coloured cotton consumed 30 cubic meters (m^3) whereas conventional cotton consumed 100 cubic meters (m^3) of water. These findings indicated that conventional cotton consumed 3.33 times more water than naturally coloured cotton (Muqaddim, 2022). Naturally coloured cotton utilize water for three-step processes: Oil removal, washing, and softening with each step requiring 1 cubic meter (m^3) of water. Similarly, conventional cotton involved 10 steps: H_2O_2 bleaching, 1st rinsing, 2nd rinsing, reactive dyeing, cold rinsing, washing at 70^0 C, washing at 95^0 C, soaping at 95^0 C, washing at 40^0 C, and softening. Each step utilized 1 cubic meter (m^3). An increase in the production of naturally coloured cotton may result in the reduction of water use and in the disposal of effluents into nature (Garcia, 2014). Owing to the presence of multiple steps in conventional cotton, processing led to it consuming three times more water over naturally coloured cotton. These findings highlighted the environmental advantages of natural coloured cotton, particularly in the context of water scarcity. The adoption of naturally coloured cotton over conventional cotton significantly reduced water consumption in the textile industry.

Carbon emissions in the processing of naturally coloured cotton and conventional cotton

The assessment showed a significant disparity between the naturally coloured cotton and conventional cotton concerning carbon dioxide emissions during processing. Naturally coloured cotton emitted 3.75 kg CO_2 /ton, and conventional cotton emitted 10.75 kgCO_2 /ton Compared to naturally coloured cotton, conventional cotton released considerably higher levels of CO_2. This substantial difference was attributed to the energy-intensive processes involved in the processing of conventional cotton, such as bleaching, dyeing, and multiple rinsing cycles, all of which contribute to increased CO_2 emissions. Dyeing of 1 ton of cotton fabric requires 3405.30kg oil eq of energy, $2.01*10^5$ PAF.m 3 .d of freshwater ecotoxicity and 15627.20kg CO2 eq of carbon (Li et al. 2024). The dyeing process in conventional cotton required high temperatures, a large amount of water, and electricity during processing, which significantly elevated carbon emissions. In contrast, naturally coloured cotton eliminates the need for chemical dyeing and intensive chemical treatments, which drastically reduces energy, water consumption, and CO_2 emissions. These findings emphasized the potential of naturally coloured cotton as a sustainable and eco-friendly alternative for reducing carbon footprints in textile production.

Simulation analysis

Simulation results indicate that a gradual shift from conventional cotton to naturally coloured cotton and the adoption of naturally coloured cotton as a new sustainable technology will significantly reduce the environmental and economic burdens of cotton processing, through the assumption that by 2030, a 10% replacement of conventional cotton with naturally coloured cotton will lead to considerable changes and benefits in terms of CO_2 emissions, energy consumption, and water usage as presented in Tables 6, 7, and 8.

Table 5: Simulation results for conventional cotton and naturally coloured cotton in terms of area from 2022-2023

Year	Base	Year 1	Year 2	Year 3	Year 4	Year 5	Year 2030
Conventional Cotton							
Scenario (%)	0	2.5	4.5	5.5	6.5	7.5	10.0
(Area in lakhs ha)	126.87	123.70	121.80	120.53	119.26	117.35	114.18
Processing cost ($/tons)	976.75	952.33	937.68	927.91	918.14	903.49	879.07
Electricity cost ($/tons)	273.95	267.10	262.99	260.25	257.51	253.41	246.56
Energy utilization (cal/ton)	3076000	2999100	2952960	2922200	2891440	2845300	2768400
Water consumption (L/ton)	30000	29250	28800	28500	28200	27750	27000
CO2 Emission (kg/ton)	10.75	10.43	10.32	10.21	10.11	9.94	9.67
Year	Base	Year 1	Year 2	Year 3	Year 4	Year 5	Year 2030
Naturally Colored Cotton							
Scenario (%)	0	2.5	4.0	5.0	6.0	7.5	10.0
(Area in ha)	0.00	3.17	5.07	6.34	7.61	9.51	12.68
Processing cost ($/tons)	334.55	342.91	347.93	351.28	354.62	359.64	368.01
Electricity cost ($/tons)	67.16	68.84	69.85	70.52	71.19	72.20	73.88
Energy utilization (cal/ton)	754300.0	773157.5	784472.0	792015.0	799558.0	810872.0	829730.0
Water consumption (L/ton)	30000	30750	31200	31500	31800	32250	33000
CO2 Emission (kg/ton)	3.75	3.84	3.90	3.93	3.97	4.03	4.12

A transition from conventional cotton to naturally coloured cotton reduced CO_2 from 10.75 kg/ton to 3.75 kg/ton. Similarly, energy consumption for conventional cotton processing was expected to decrease to 276840 cal/ton yet remained significantly higher than that of naturally coloured cotton, which inherently required much lower energy.

Table 6: Savings by new technology

Year	Base	Year 1	Year 2	Year 3	Year 4	Year 5	Year 2030
Scenario (%)	0	2.5	4.0	5.0	6.0	7.5	10.0
Reduction of CC (Area in lakh ha)	126.87	120.53	116.73	114.19	111.65	107.84	101.5
Processing cost ($/tons)	642.20	609.41	589.74	576.63	563.52	543.52	511.07
Electricity cost ($/tons)	206.79	198.26	193.14	189.73	186.32	181.20	172.68
Energy utilization (cal/ton)	2321700.0	2225942.5	2168488.0	2130185.0	2091882.0	2034427.5	1938670.0
Water consumption (L/ton)	70000	66750	64800	63500	62200	60250	57000
CO2 Emission (kg/ton)	7.00	6.59	6.42	6.28	6.13	5.91	5.55

By integrating the results of water use, energy demand, and cost analysis, naturally coloured cotton clearly demonstrates superior environmental and economic performance compared with conventional cotton. The reduction in resource-intensive chemical processes not only lowers operational costs but also minimizes pollution loads and conserves freshwater and energy resources. The findings reinforce the potential of naturally coloured cotton as a viable eco-friendly alternative to conventional dyed cotton. However, large-scale adoption may depend on improvements in fibre yield, colour range, and market acceptance. Nevertheless, the comparative analysis indicates that naturally coloured cotton offers a promising pathway toward more sustainable textile production systems. This study highlighted the significant environmental and economic benefits of transitioning from conventional cotton to naturally coloured cotton. The adoption of new technologies, such as naturally coloured cotton, would be an effective sustainable drive in the textile sector.

4. Conclusion

This study demonstrates that naturally coloured cotton offers significant environmental and economic advantages over conventional cotton during textile processing. In contrast, naturally coloured cotton contributes to balancing economic and environmental benefits because of its aesthetic value and unique features. Although its yield was lower than that of conventional cotton, its cost of cultivation was significantly lower, making it an economically viable option for resource-limited farmers. The percentage analysis of water use, energy consumption, and processing cost clearly shows that naturally coloured cotton requires substantially fewer resources due to the elimination of bleaching, dyeing, and other chemical-intensive steps. As a result, naturally coloured cotton not only reduces operational costs but also minimizes environmental impacts associated with chemical effluents, high energy demand, and excessive water usage. This alternative is well-suited for regions with limited access to chemical inputs and places with water scarcity. Naturally coloured cotton is not only a cost-effective choice over the long term, but also an environmentally friendly alternative. If naturally coloured cotton is paid at $125.91 per quintal, it would represent the break-even point for both types of cotton. Furthermore, a price of $150.26 per quintal would offset the cost reduction in fabric production achieved by eliminating the dyeing process, making naturally coloured cotton a financially attractive option. The value chain and value addition of naturally coloured cotton could be enhanced to cater to niche markets such as sportswear, apparel for people with sensitive skin, baby products, and environmentally conscious fashion. Overall, the findings underscore the importance of promoting and optimizing naturally coloured cotton as an eco-efficient alternative. Wider adoption of this fibre could contribute to reducing the textile sector's environmental footprint while supporting cost-effective manufacturing practices. Future research may focus on enhancing fibre quality, colour stability, and agronomic performance to further strengthen the commercial viability of naturally coloured cotton.

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Authors' contributions
Manasa CP wrote the initial draft of the manuscript, the first review was carried out by Shivakumar KM and the final formatting and review were done by Shivakumar KM and Baghyalakshmi K.

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