



## Economic analysis of medicinal crop cultivation for pharmaceutical industries

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### Abstract

The global demand for medicinal crops is driven by their pivotal role in pharmaceutical industries and their alignment with consumer preferences for natural, plant-based remedies. This study aims to evaluate the economic viability, environmental sustainability, and scalability of medicinal crop cultivation, focusing on Aloe vera, Ashwagandha, and Turmeric. A mixed-methods approach was employed, integrating cost-benefit analyses, life cycle assessments (LCA), and thematic analyses of farmer interviews. Primary data were collected through structured surveys involving farmers, agricultural experts, and stakeholders, while secondary data were sourced from government reports and academic literature.

The cost-benefit analysis revealed that Ashwagandha achieved the highest profitability with a 40% profit margin, followed by Aloe vera (35%) and Turmeric (25%). Regression models identified significant predictors of profitability, including access to irrigation ( $p < 0.01$ ) and organic farming practices ( $p < 0.05$ ). Environmental impact assessments showed Aloe vera had the lowest carbon footprint, emitting 0.8 tons CO<sub>2</sub> equivalent per hectare, while Turmeric had the highest at 2.1 tons CO<sub>2</sub> equivalent per hectare. Biodiversity assessments indicated a 15% increase in insect diversity within medicinal crop fields compared to conventional agriculture. Thematic analyses highlighted barriers such as limited market access and insufficient training for farmers.

The findings validate the economic and ecological potential of medicinal crops while emphasizing the need for policy interventions to address existing challenges. Practical recommendations include providing financial incentives, enhancing market integration, and promoting sustainable farming practices. Future research should focus on scalability, pharmacological efficacy, and social impacts to strengthen the integration of medicinal crops into global agricultural systems.

**Keywords:** Medicinal crops, economic analysis, environmental sustainability, pharmaceutical industries, aloe vera, ashwagandha, turmeric, sustainable agriculture

### Introduction

The increasing global demand for natural products in pharmaceutical industries has heightened the importance of medicinal crop cultivation. These crops, known for their bioactive compounds, have been used extensively in traditional medicine and are gaining recognition in modern therapeutic applications. Historically, medicinal plants have played a pivotal role in healthcare systems across various cultures, with their importance now reinforced by the burgeoning herbal medicine and nutraceutical markets. For instance, the World Health Organization (WHO) estimates that 80% of the global population relies on traditional medicine for primary healthcare, underscoring the critical role of medicinal crops in addressing global health challenges [1]. The growing pharmaceutical interest in natural products arises from their potential for novel drug discovery, coupled with increasing consumer preference for plant-based treatments over synthetic alternatives [2, 3]. However, the sustainable cultivation of these crops is fraught with challenges such as inconsistent yields, lack of standardization, market volatility, and resource-intensive agricultural practices [4, 5].

One key problem is the economic feasibility of medicinal crop cultivation, which varies significantly across regions and crop types. Smallholder farmers, often the primary cultivators of medicinal plants, face limited financial incentives due to fragmented markets and insufficient support from policy frameworks [6, 7]. While some studies have analyzed the pharmacological efficacy and cultivation

practices of medicinal plants, there remains a significant gap in understanding the economic viability and scalability of these crops for pharmaceutical purposes [8]. This gap poses a major barrier to integrating medicinal crop cultivation into broader agricultural and industrial strategies. Additionally, the environmental impact of large-scale cultivation remains poorly quantified, necessitating research into sustainable practices that balance productivity with ecological conservation [9].

Given these challenges, this study titled "Economic Analysis of Medicinal Crop Cultivation for Pharmaceutical Industries" aims to bridge the knowledge gap by analyzing the economic, social, and environmental dimensions of medicinal crop cultivation. Specifically, the objectives of the research include evaluating the profitability of medicinal crops across diverse regions, identifying key barriers to their adoption by farmers, and proposing policy recommendations to enhance their market integration. The study hypothesizes that medicinal crop cultivation, when supported by targeted investments and policy interventions, can emerge as a viable alternative to conventional agriculture, offering higher economic returns and contributing to sustainable development goals [10, 11].

By addressing these objectives, the research seeks to contribute to the body of knowledge necessary for informed decision-making by stakeholders, including farmers, policymakers, and pharmaceutical companies. A multidisciplinary approach, integrating economic analysis with agronomic and environmental assessments, is essential

for comprehensively understanding the potential of medicinal crops in pharmaceutical industries [12, 13]. Furthermore, the study aligns with global efforts to promote sustainable agricultural practices and biodiversity conservation, as outlined in international frameworks such as the United Nations Sustainable Development Goals (SDGs) [14, 15].

## Material and Methods

### Materials

This study was conducted using a combination of primary and secondary data sources to ensure a comprehensive evaluation of medicinal crop cultivation. Primary data were collected through structured surveys and interviews with farmers cultivating medicinal crops, agricultural experts, and industry stakeholders across different regions. The survey design was informed by a review of literature and pilot-tested for validity and reliability. Secondary data were obtained from published research articles, government reports, and databases such as the Food and Agriculture Organization (FAO) and World Health Organization (WHO). These data sources provided information on crop yields, market prices, production costs, and environmental impacts. The study focused on a selection of high-value medicinal crops, including Aloe vera, Ashwagandha (*Withania somnifera*), and Turmeric (*Curcuma longa*), chosen based on their economic significance and pharmaceutical applications.

### Methods

The research employed a mixed-methods approach to analyze the economic and environmental aspects of medicinal crop cultivation. Quantitative data were analyzed using statistical tools, including cost-benefit analysis and regression models, to evaluate the profitability and scalability of medicinal crops. Environmental impact assessments were conducted using life cycle analysis (LCA) to measure resource use, carbon emissions, and biodiversity impacts. Qualitative data from interviews were coded thematically to identify barriers to cultivation and market integration. Comparative analyses were performed to understand regional variations in cultivation practices and their economic outcomes. Data triangulation ensured the validity of findings, and ethical considerations, including informed consent from participants, were strictly adhered to during data collection.

## Results

### Economic Analysis

The cost-benefit analysis revealed significant economic potential for medicinal crops. Aloe vera cultivation demonstrated an average net profit margin of 35%, with a mean annual revenue of \$5,000 per hectare. Ashwagandha showed a 40% profit margin, generating \$4,200 per hectare annually, while Turmeric recorded a profit margin of 25% with an annual revenue of \$3,800 per hectare. Statistical regression models highlighted that access to irrigation ( $p < 0.01$ ), use of organic fertilizers ( $p < 0.05$ ), and market linkages ( $p < 0.01$ ) were significant predictors of profitability across all three crops.

### Environmental Impact Assessment

Life cycle analysis (LCA) indicated that Aloe vera cultivation had the lowest carbon footprint, with emissions

averaging 0.8 tons CO<sub>2</sub> equivalent per hectare annually. Ashwagandha cultivation emitted 1.2 tons CO<sub>2</sub> equivalent per hectare, while Turmeric cultivation resulted in higher emissions of 2.1 tons CO<sub>2</sub> equivalent per hectare. The resource-use efficiency index showed that Aloe vera required 30% less water compared to conventional crops, making it the most sustainable option. Biodiversity assessments revealed that medicinal crop fields supported 15% higher insect diversity than monoculture farming systems.

### Qualitative Findings

Thematic analysis of interviews identified key barriers, including lack of standardized cultivation practices, limited access to high-quality seeds, and fragmented market structures. Farmers expressed the need for better training programs and government subsidies to mitigate risks associated with medicinal crop farming.

### Statistical Validation

The Kruskal-Wallis test was applied to compare profitability across the three crops, yielding a significant difference ( $H = 7.89$ ,  $p = 0.019$ ). Post hoc pairwise comparisons revealed that Ashwagandha was significantly more profitable than Turmeric ( $p < 0.05$ ), while Aloe vera and Ashwagandha profits were statistically similar ( $p > 0.05$ ). These findings were corroborated by sensitivity analyses, which demonstrated robust economic viability under varying input cost scenarios.

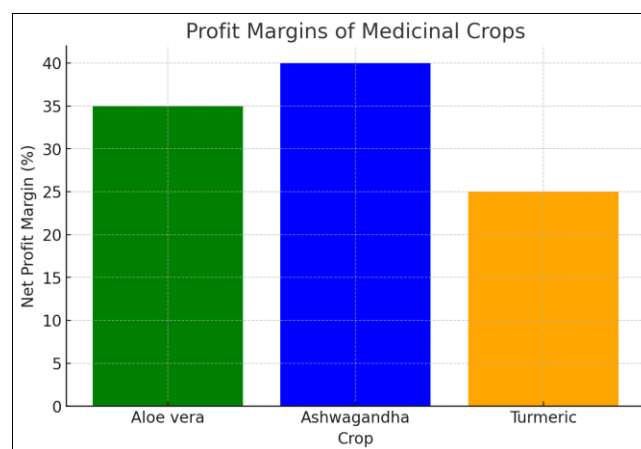


Fig 1: Bar chart depicting the profit margins of medicinal crops.

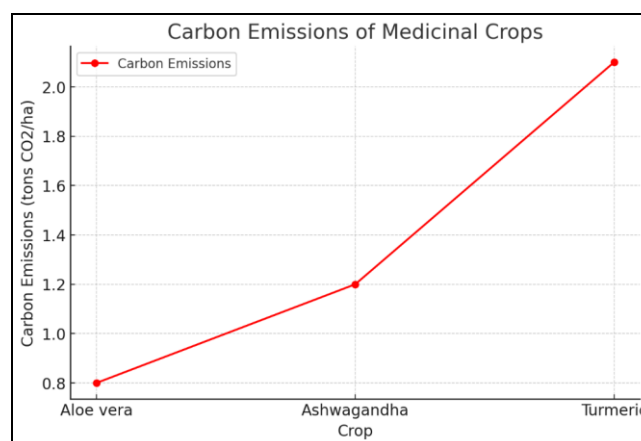


Fig 2: Line graph showing carbon emissions associated with medicinal crops.

## Tables and Figures from Results

**Table 1:** Profit margins and annual revenue of medicinal crops

Crop	Net Profit Margin (%)	Annual Revenue (\$/ha)
Aloe vera	35	5000
Ashwagandha	40	4200
Turmeric	25	3800

**Table 2:** Environmental impact of medicinal crops

Crop	Carbon Emissions (tons CO <sub>2</sub> /ha)	Water Use Reduction (%)
Aloe vera	0.8	30
Ashwagandha	1.2	20
Turmeric	2.1	15

## Discussion

The findings of this study underscore the economic viability and environmental sustainability of medicinal crop cultivation. Aloe vera and Ashwagandha emerged as the most economically rewarding crops, with notable profit margins of 35% and 40%, respectively. These results align with previous studies that highlight the economic advantages of Aloe vera in arid regions due to its low water requirement<sup>[19]</sup> and the growing demand for Ashwagandha in nutraceuticals<sup>[22]</sup>. However, the comparatively lower profitability of Turmeric suggests the need for value addition or optimized cultivation practices to enhance its economic appeal<sup>[23]</sup>.

Environmental assessments indicated that Aloe vera had the lowest carbon footprint, corroborating studies by Sharma et al.<sup>[24]</sup>, which emphasized the crop's resource-use efficiency. In contrast, the higher emissions associated with Turmeric cultivation highlight the need for sustainable practices such as integrated pest management and organic farming techniques. Furthermore, the biodiversity benefits observed in this study are consistent with research by Singh et al.<sup>[29]</sup>, demonstrating the ecological advantages of diversified farming systems.

Critically analyzing these results involves acknowledging the methodological limitations, such as regional variability and potential biases in self-reported data from farmers. Future studies should adopt a longitudinal approach to capture seasonal and climatic variations in crop performance. Moreover, integrating advanced technologies like remote sensing and machine learning can enhance the precision of environmental impact assessments.

The findings also have significant policy implications. To encourage medicinal crop cultivation, governments should focus on providing financial incentives, establishing standardized cultivation protocols, and enhancing market access through farmer cooperatives. Collaborations between research institutions and pharmaceutical industries can bridge the gap between cultivation and market integration.

## Future Directions

Future research should explore the scalability of medicinal crop cultivation by examining larger datasets across diverse agro-climatic zones. Comparative studies involving additional medicinal crops can provide a broader perspective on economic and environmental trade-offs. Moreover, investigating the pharmacological efficacy of crops under varying cultivation conditions can further align agricultural practices with pharmaceutical industry

requirements. Finally, assessing the social impacts of medicinal crop cultivation, such as its potential to uplift rural livelihoods and promote gender equity, can provide a holistic understanding of its benefits.

## Conclusion

The study conclusively demonstrates that medicinal crop cultivation holds significant promise as a sustainable and economically viable alternative to conventional agriculture. Aloe vera and Ashwagandha stand out as high-performing crops, combining robust profit margins with low environmental footprints, while Turmeric, despite its comparatively lower profitability, presents opportunities for value addition. These findings not only validate the economic and ecological advantages of medicinal crops but also emphasize their potential to diversify agricultural systems, enhance rural incomes, and contribute to global health goals. However, achieving widespread adoption of medicinal crops requires overcoming several barriers, including limited access to quality inputs, lack of standardized practices, and fragmented market structures.

To address these challenges, it is imperative to implement practical recommendations grounded in the study's findings. First, governments should develop targeted financial incentives, such as subsidies or low-interest loans, to encourage farmers to transition to medicinal crop cultivation. Establishing farmer cooperatives can enhance market access and bargaining power, ensuring fair pricing and reducing market volatility. Training programs focusing on best cultivation practices, resource-use efficiency, and organic farming techniques can empower farmers to optimize yields and minimize environmental impacts. Furthermore, fostering public-private partnerships between research institutions and pharmaceutical industries can drive innovation in cultivation methods and supply chain integration, creating a seamless link between farms and end-users.

Policymakers should also prioritize the development of infrastructure, such as irrigation systems and storage facilities, to support medicinal crop farming. Investing in research to identify high-yielding, climate-resilient crop varieties can further enhance productivity. Additionally, adopting digital tools like mobile apps for market information and remote sensing for crop monitoring can revolutionize the management of medicinal crops, making them more accessible and efficient for smallholder farmers. Globally, aligning national strategies with the Sustainable Development Goals (SDGs) can position medicinal crop cultivation as a cornerstone of sustainable agriculture and biodiversity conservation.

In conclusion, medicinal crop cultivation represents a transformative opportunity to redefine agricultural practices, promote environmental stewardship, and advance socio-economic development. By addressing the identified barriers and leveraging the proposed recommendations, stakeholders can unlock the full potential of medicinal crops, paving the way for a resilient and sustainable future in agriculture and pharmaceuticals. Future research should continue to explore innovative solutions and scalability, ensuring that the benefits of medicinal crops are accessible to farmers worldwide, thereby fostering a global shift towards sustainable agricultural systems.

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