

Geographical Analysis of Litchi Cultivation, Spatial Distribution, And Production in Muzaffarpur District

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ABSTRACT: An analysis of spatial pattern and distribution of litchi production in Muzaffarpur District, one of the prominent litchi-producing states in India, is attempted in the paper. Overall, the objective of the present study is to understand region-wide disparities and determinants influencing litchi cultivation. The secondary data approach utilizes two main objectives targeting the district's distribution of litchi production and the factors affecting production outcomes, such as soil quality, agro-climatic conditions, and access to irrigation. Data is analyzed from various regions in the district. The study results show that the fertility of alluvial soils and favourable agro-climatic conditions are essential for achieving high production levels. There is a significant need for advanced irrigation systems and training in high-tech farming to maintain these production levels. Additionally, providing subsidies for high-yielding litchi varieties is necessary to increase productivity in the long term. The study proposes that spatial analysis be carried out to identify areas which require immediate intervention so targeted agricultural planning should be done. The study throws light upon factors driving the cultivation of litchi in Muzaffarpur, thus acting as a premise for sustainable agricultural practices in similar regions.

KEYWORDS: Agro-climatic conditions, Litchi Cultivation, Litchi Production, Muzaffarpur District, Spatial distribution, Sustainable agriculture.

I. INTRODUCTION

Litchi, or *Litchi chinensis* Sonn., is a fruit plant that grows in tropical and subtropical regions. Originating from the southern region of China, it is renowned for its flavour, health values, and economic importance. Cultivation is not restricted to China; rather, it has received extensive attention globally, especially in India, through its significant contribution to the agricultural economy. In regions like Muzaffarpur District, Bihar, India, litchi cultivation has been of prime importance with their contribution greatly to the economies of the local and national levels.

The major states for litchi cultivation in India are Bihar, West Bengal, Assam, and some parts of Uttar Pradesh. Bihar alone contributes to about 70% of the total production of litchi produced in the country (Ray, et. al., 2019). Muzaffarpur District is famous as the "Litchi Kingdom" of India, known for producing the Shahi Litchi, which is a variety of high demand due to its excellent quality and taste. The litchi cultivated at Muzaffarpur not only forms an important source of livelihood for thousands of farmers but also helps play a key role in the socio-economic development of the region.

Litchi growing is a rather specialized undertaking since it thrives under some specific agro-climatic conditions hardly available anywhere in the world. This limits it as a rather niche crop with specific geographical needs. The tree thrives in full rainfall with tropical climates and fertile, well-drained soils rich in organic nutrients. Its climatic and soil conditions have made Muzaffarpur District the best place for litchi cultivation and created its reputation as India's highest producer of litchi (Saraswat & Sharma, 2000).

Muzaffarpur is a historically rich place for litchi cultivation due to good climatic and soil conditions, hence an ideal location for litchi, allowing fruit cultivation for generations. For many years, litchi has very strongly been adapted to the agriculture in this region following the generations of farmers who always have passed the traditional knowledge and practices from one to another (Raj, 2023). The growth of litchi cultivation has been determined by the impacts of government policies. The policy measures included the provision of subsidies, training programs, and infrastructural support for boosting production (Kumar, 2009).

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Moreover, the implementation of modern farming practices and pest management techniques has also largely influenced the long-term sustainability and furthering of litchi cultivation in Muzaffarpur. As such, the current prospects for production trends and problems in this district are not intelligible without an understanding of this past and policy-oriented background.

Besides the economic importance, there is significant cultural and social importance attached to the cultivation of litchi in Muzaffarpur. People from all parts of the country celebrate the annual litchi season with fetes and fairs throughout the city. Export to overseas markets, such as the United States and Europe, underscores the importance of the fruit as a high-value horticultural crop of immense potential in foreign exchange generation (Belal, 2023).

The study of litchi cultivation in Muzaffarpur District requires an in-depth analysis of several key variables that influence its success and sustainability. These variables include spatial distribution, production, and agricultural practices, each playing a critical role in determining the overall productivity and economic viability of litchi farming in the region, which is as defined below:

Spatial distribution: The spread of litchi cultivation in various areas in Muzaffarpur District is related to the geographical spread. Awareness of spatial distribution is crucial for judging areas with the most spread of litchi farming and areas that may grow or decline. Several factors, like the quality of soil, available water supply, topography, and accessibility to markets, will decide the spread of litchi cultivation. Litchi orchards mainly dominate the areas of Muzaffarpur that have fertile alluvial soils so attractive towards the optimum supply of nutrients and easy drainage for healthy growth. Spatial analysis of the spread of litchi cultivation would also help us assess environmental factors like climate change, which might be affecting the suitability of places for litchi cultivation. For example, variations in temperature and amount of rainfall could also be known to affect the blooming and fruiting schedules of litchi plants, thus resulting in differences between the quality and quantity of the yield (Sajan et al., 2023). Understanding spatiality in litchi orchard distribution would provide valuable information about the most susceptible areas under environmental changes and therefore should require specific intervention to sustain production.

Production: The fruit production in Muzaffarpur District will be taken usually in the form of metric tons, which is equivalent to the quantity produced. Such factors have contributed towards the quantities produced of the litchi, including the situation and age of the trees, availability of water, nutrient resources, control measures for pests and diseases, and high technology among farmers (Kumar, 2012). Productivity levels are normally related to the condition of orchards and the care they receive. Orchards, therefore, that are properly cared for with the necessary amenities have high production. Conversely, factors of less good soil fertility, limited water, or improper pest control may result in low production. Litchi in Muzaffarpur has been seen to shift quite often through the years as fluctuations mainly led by weather conditions and the development of modern agricultural technology. In some regions, supported by developed irrigation systems, organic fertilizers, and IPM, production levels have improved. However, in some regions, it is still on conventional farming, not efficient or sustainable (Lakshmi et al., 2023). The knowledge of trends in litchi production is a good tool for identifying the significant factors that give higher yields and how best to implement strategies that can boost productivity in low-output areas.

Agricultural practices: All of the litchi farming techniques and methods practised in Muzaffarpur District can come under agriculture practices. Some of these agricultural practices include tilling the soil, planting, irrigation, fertilization, pest control, controlling diseases, pruning, and harvesting (Cronje et al., 2023). Generally, the farming practices chosen affect considerably the general health as well as productivity of litchi orchards and the final quality of the fruit yielded. The farming practices in Muzaffarpur are embedded with a lot of tradition, and successive generations of farmers have adopted tested techniques that have been found suitable to local conditions. However, the adoption of modern agricultural practices, which include high-yielding varieties of litchis, drip irrigation systems, and organic pest control practices, had salutary effects on productivity and sustainability (Nath et al., 2022). The implementation of these practices differs throughout the district, as certain farmers wholeheartedly embrace modern techniques, while others persist in relying on conventional methods.

Muzaffarpur is quite conveniently referred to as the litchi capital of India and litchi cultivation holds great economic importance here. This tropical fruit apart from direct sale revenues and export income earned by the local economy provides much support to livelihood for many small and marginal farmers. The dependence of the region on litchi production is one of the most important parts of its agricultural landscape, as it moulds local farming practices and the seasonal scope of employment. Thus, the geographical spread and pattern of litchi production in Muzaffarpur are vital for gaining insight into how these factors influence the district economy and how well the cultivation ecosystem is serving the cause of farm-people well-being, considering its economic importance.

The study focuses on analyzing the geographical distribution and production of litchi in Muzaffarpur District. The study aims to analyze the spatial distribution of litchi cultivation and determine the factors that play a significant role in shaping its growth patterns in the area. Gaining a deeper understanding of these patterns will shed light on the variations in production across different regions and offer valuable insights into the obstacles and possibilities that farmers encounter. This analysis aims to provide a comprehensive view of litchi farming in Muzaffarpur, contributing to better agricultural planning and policymaking.

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After introducing the study in Section 1, the rest of the study is divided into the following sections: Section 2 is a review of the existing literature regarding the development of litchi cultivation, spatial distribution, and production in Muzaffarpur District with a focus on the selective influence of these factors. Section 3 refers to the research objectives with particular attention to geographical aspects of litchi cultivation. Section 4 is a comprehensive outline of the research methodology focusing on reliance on secondary data sources for analysis. Section 5 presents results from the research tabulated and figured, thereafter, discussed thoughtfully. Section 6 summarises important findings with any implications thereof, acknowledges the limitations in the study, and postulates future research directions for further understanding of the subject matter under study. In this final section, a list of the references cited in the paper is provided.

II. REVIEW OF LITERATURE

The researcher has bifurcated the literature review into three heads- literature on the Evolution of Litchi Cultivation in Muzaffarpur and Intra-regional Disparities in Litchi Production.

Evolution of Litchi Cultivation in Muzaffarpur

The noted increase in litchi cultivation in the Muzaffarpur District of Bihar can be due to some specific cultivars adopted and the ideal conditions. Kumar (2020) mentioned the gradual progress in litchi production, which has also been found by Lakshmi et al. (2023), who concluded that most of the farmers involved in litchi cultivation in that region had only basic knowledge and experience about GMPs. However, the problems of low technological know-how and the inconsistent fruit setting persisted, and growth rates for several years between 2001 and 2016 were thus between -1.64% and 6.34% (Kumar et al., 2018).

'Early Large Red' is one of the superior litchi varieties due to its uniform fruiting, higher yields, and ability to tolerate recurrent issues such as fruit break (Chauhan, 2008). Micronutrients and plant growth regulators were believed to promote the growth, yield, and fruit quality of litchi, especially the 'Muzaffarpur' variety (Devaraja, 2019). Besides, integrated nutrient management is related to higher yield and quality of fruit (Raghavan et al., 2018), Compared to that, larger farms will be associated with NPV values of 6.21 lakh and reduced production costs (Kumari, 2023). All these developments were indicators of how the litchi farming practices of Muzaffarpur are changing, supporting the sustained growth of the area as an important hub of agriculture.

Intra-regional Disparities in Litchi Production

Although litchi production in Bihar, especially in Muzaffarpur, exhibits various critical factors that influence both yield and quality, most of the country's crops come from this state, contributing to as much as 40% of Indian production. The pollination practice significantly influences fruit set; therefore, as open-pollinated plants, specifically those that are honeybee pollinated, show much higher yields and quality, it is greatly beneficial to grow five to ten honeybee colonies per hectare (Srivastava et al., 2017; Kumar, 2014). Long-term sustainable agricultural practices in litchi orchards reduce soil pH and phosphorus, which lowers the activity of enzymes and even bacterial diversity. The use of chemical fertilizers may degrade the quality of the soil; hence, integrated soil management practices become more important (Chen et al., 2021).

Among the litchi farmers in Muzaffarpur, the implementation of GMPs seems rather equitable and effective; here, variables including farming experience and attitude towards GMPs, affect knowledge and adoption rates (Lakshmi et al., 2023). Improved production technology, especially in the field of pest control, has resulted in better-quality fruits and greater net returns (Kumar, 2012). The use of Azotobacter and vermicompost, integral approaches to integrated soil management, has increased the yield and quality of fruit obtained from better fruiting. Organic and inorganic mulching has contributed both to higher levels of soil health and litchi output (Kumar et al., 2018; Kumari & Khare, 2019). The net present value was found positive; hence, this is economically viable for litchi production in Muzaffarpur while better IRR exists for reinvestment (Kumari, 2023). These results indicated the necessity of technical assistance and improved fertilizer application in conserving and improving litchi production and export performance in the area (Kumar et al., 2018).

III. OBJECTIVES OF THE STUDY

- To evaluate the spatial distribution of litchi cultivation in Muzaffarpur District.
- To analyze the factors influencing production outcomes in different regions of the district.

IV. RESEARCH METHODOLOGY

The research methodology for this study involves utilizing secondary data sources to analyze the geographical distribution and production of litchi in Muzaffarpur District. The chosen research methods and design will primarily rely on secondary sources of information. These sources include agricultural reports, research articles, district-level surveys, and GIS databases. The analysis will quantify production trends, map spatial distribution, and examine factors affecting litchi cultivation using statistical tools such

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as GIS software for spatial mapping. Key variables include production volumes, spatial patterns, soil quality, and water availability. This approach aims to provide a comprehensive understanding of the spatial and production dynamics of litchi cultivation in Muzaffarpur, highlighting regional disparities and factors influencing production outcomes.

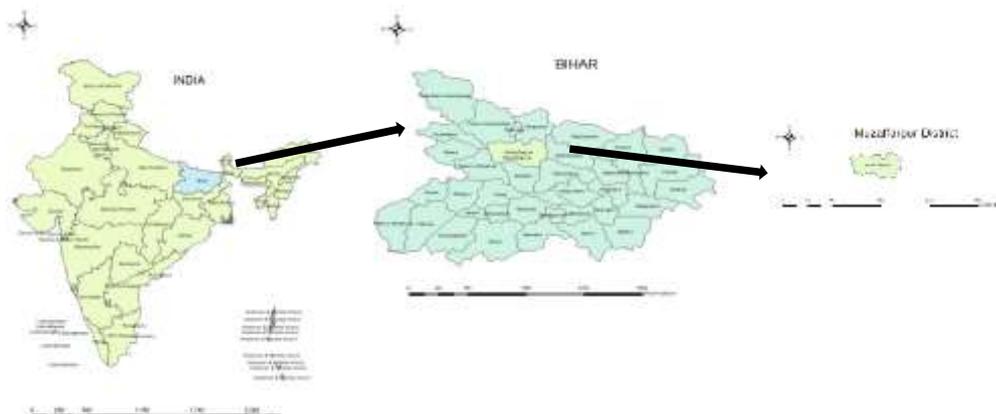


Figure 1. Study Area

Source: Self-prepared by author

V. RESULTS

• Current Status of Litchi Cultivation in India

Litchi is well-established in India's agricultural scene, ranking seventh by area and ninth by production in fruit crops. Bihar is the single largest producer by a huge margin, accounting for a massive 74% of national output. The area under Litchi has progressively risen since its initiation at 9,400 hectares in 1949-50 to the present enormous figure of 56,000 hectares in 1998-99. This significant growth is not due to cultivation alone but also partly because of the rising importance of the fruit in the economy of Bihar.

• Area and Production Data

Table 1 presents the area and production statistics for Litchi alongside other major fruit crops in India, illustrating the growth trajectory of Litchi over the years.

Table 1: Area and Production of Major Fruit Crops in India

Crops	Area (000 ha)	Production (000 tonnes)
	1991-92	1998-99
Litchi	49.00	56.00
Banana	384.00	464.00
Mango	1078.00	1401.00

Source: <https://doi.org/10.20546/ijcmas.2020.905.079>

The upward trend in productivity is indicative of advancements in agricultural techniques and improved orchard management.

• Export Trends of Litchi

Analyzing the export trends from Muzaffarpur would provide very valuable insights into the economic impact of Litchi cultivation. Table 2 gives the quantity exported as well as the value per kilogram from 2001-02 to 2015-16. The data shows fluctuations in the volumes of exports, reflecting the market dynamics and production levels.

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Table 2. Trend of Export of Litchi from Muzaffarpur and India (2001-02 to 2015-16)

Year	Quantity Exported (Tonnes)	Percent Share in Export	Value (Rs/kg)
2001-02	53	300	12
2002-03	42	347	20.46
2003-04	46	962	13.93
2004-05	25	544	13.03
2005-06	22	718	13.04
2006-07	30	1661	98.9
2007-08	40	1615	39.28
2008-09	50	1546.5	100.8
2009-10	21	545.4	163.01
2010-11	46	1186.11	135.85
2011-12	39	319.94	38.76
2012-13	24	794.86	118.13
2013-14	49	457.49	28.22
2014-15	45	961.43	215.18
2015-16	42	708.86	5.49
CGR	-1.64	6.34	17.55
CV % Change from Base Year	28.6	59.98	79.73
	20.75	70.88	54
2001-02			

Source: Kumar, (2022)

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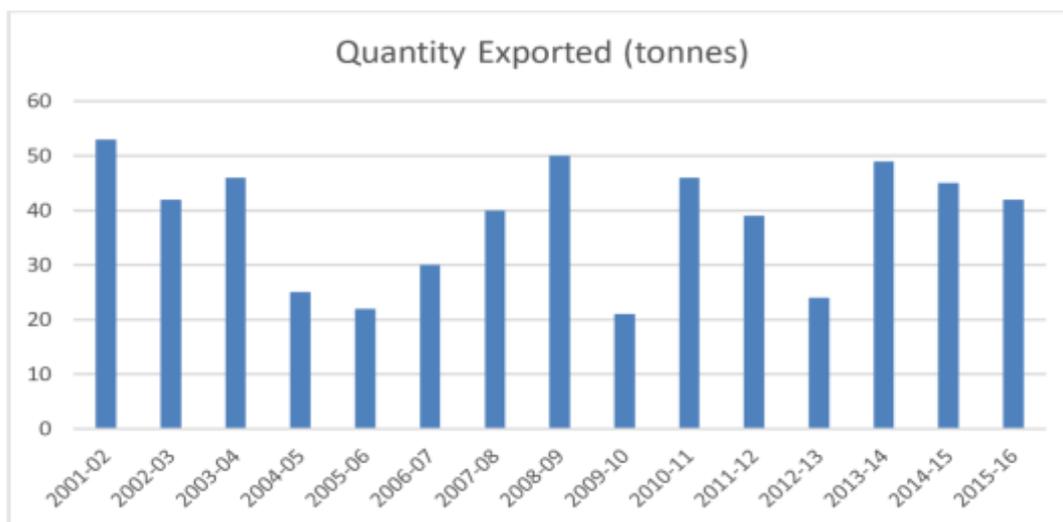


Figure 2: Trend of Export of Litchi from Muzaffarpur

Source: Self-prepared by author

The compound growth rates (CGR) and coefficients of variation (CV) indicate the overall performance and variability of exports during this period, with a significant percentage change from the base year highlighting the evolving market for Litchi.

- **Varietal Distribution and Characteristics**

Bihar has some important cultivars of Litchi, amongst which "Shahi" ranks in the top position due to its delectable flavour and flavour aroma. Other important varieties are "China," "Bedana," and "Ajhauli." Table 3 The physicochemical characteristics of these varieties have shown their adaptability to different climatic conditions.

Table 3. Physicochemical Characteristics of Important Litchi Cultivars

Varieties	Cracking (%)	Estimated Yield (Kg/plant)	Total Sugar (g/100g)
Shahi	12.25	100.3	12.97
China	0.33	95.33	10.95
Bedana	0.24	32.75	10.20

Source: <http://www.ijcmas.com>

- **Maturity and Harvest Patterns**

Litchi matures with marked differences in periods across regions. Bihar harvest typically spans from the third to fourth week of May. That is a critical date for farmers coinciding with climatic conditions favorable to ripening.

Table 4. Maturity Period of Litchi by Region

Region	Harvest Period
Tripura	1st week of May
West Bengal	2nd week of May
Bihar	3rd-4th week of May
Uttar Pradesh	2nd-3rd week of June

Source: <https://www.fao.org/4/ac684e/ac684e08.htm>

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- **Spatial Analysis Using GIS**

The spatial distribution of Litchi orchards using GIS technology showed a focus on fertile river basin areas. Figure 1 delineates the detailed distribution, with a delineation of areas that should be targeted using interventions in agriculture for increased productivity.

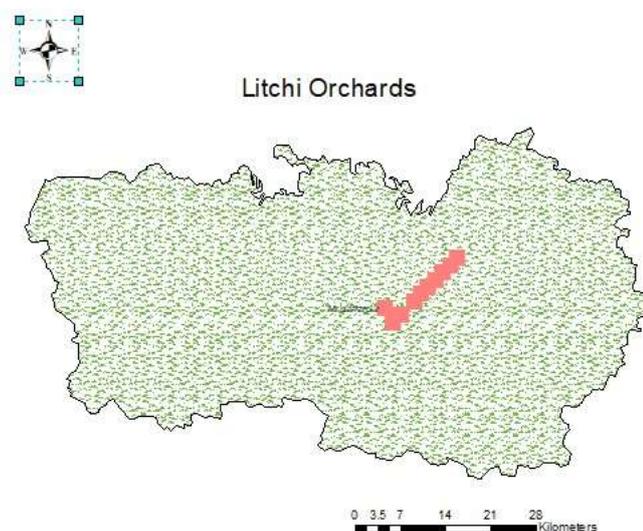


Figure 3: Geographic distribution of Litchi orchards in Muzaffarpur District.

Source: Self-prepared by author

The GIS analysis not only highlights the current state of Litchi cultivation but also serves as a vital tool for planning future agricultural development initiatives.

- **Economic Implications of Marketing Channels**

Understanding the channels through which Litchis are marketed would mean knowing the economic scenario relating to the farmers. Table 5 brings out the price spread and producer's share of the different marketing channels, one that explains the dynamics of marketing cost margins, efficiency of the chain, etc.

Table 5. Price Spread and Producer's Share in Consumer's Rupee Under Different Marketing Channels of Litchi

Particulars	Channel - I	Channel - II	Channel - III	Channel - IV
Total Marketing Cost	900	1500	1700	2000
Total Marketing Margin	115	250	450	750
Price Spread	900	1500	1900	2500
Producer's Share	83.64	72.72	65.45	54.54
Marketing Efficiency	5.11	2.66	1.89	1.02

Source: <https://www.fao.org/4/ac684e/ac684e08.htm>

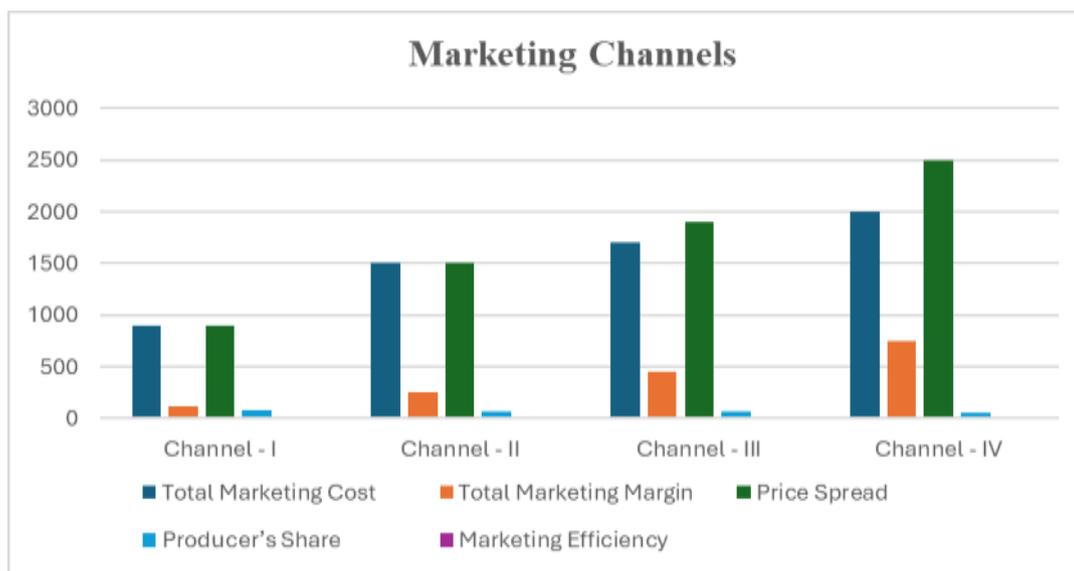


Figure 4: Marketing Channels of Litchi

Source: Self-prepared by author

These insights into marketing efficiency illustrate the importance of reducing marketing costs and increasing the producer's share for sustainable income in Litchi farming.

VI. DISCUSSION

This analysis of litchi cultivation in Muzaffarpur District proved to be very revelatory about the complexities of spatial distribution, production scales, and agricultural practices that characterize the success of this lucrative fruit. The study had two objectives: namely, spatial distribution analysis of litchi cultivation in Muzaffarpur District and the factors that influence production outcomes in different parts of the district. The ascertained facts point out that the quality of soil and distinctive agro-climatic conditions of Muzaffarpur contribute heavily to making it a major litchi-producing region in India. Bihar alone accounts for about 70% of national production (Kumari, 2017). This high level of production underscored the economic importance of litchi farming for the local farmers and the larger agricultural economy (Li, et. al., 2019).

Previous research has examined various facets of litchi cultivation, including its historical evolution, production techniques, and socioeconomic impacts. For example, Kumari, et. al., (2018) documented steady growth in litchi production, however, raised challenges in irregular fruit settings and limited technical know-how, which may even hinder the productivity of farmers. In a similar vein, Lakshmi et al. (2023) urged a necessity to take the GMPs into litchi cultivation. Even though moderate success is reported, many farmers still face hurdles in putting the advanced methods into operation. The studies herein highlighted the comprehension of specific factors that influence litchi production; yet they often omitted spatial distribution dynamics along with geographic factors influencing the variations in yield. Monitoring the impact of the environmental and agricultural policy changes directly influencing litchi production in the region is not without gaps (Kumar et al., 2018). The previously identified gaps are resolved by a high-resolution analysis of the geography of litchi cultivation at Muzaffarpur based on GIS-based methodologies to assess the spatial pattern distribution and time-series trends. District-level surveys, agricultural reports, and other sources synthesize the interplay between environmental factors and agricultural practices with their resultant economic implications at the scale of the farming of litchis. The findings align with the work of Urmi, et. al. (2022), who indicated by the following, nutrient-integrated management might greatly enhance the litchi yields and add more weight to the importance of adaptive farming techniques. Additionally, the study reinforces Kumar, (2012) assertion that improved pest management and advanced irrigation systems are crucial for litchi production improvement, hence bestowing actionable insights on policymakers as well as farmers.

The study's findings extend far beyond the immediate agricultural practices to the socio-economic well-being of local communities. Litchi is an economic activity in Muzaffarpur, but it also forms the cultural base; this entrenches community engagement, especially during harvest seasons with community-wide celebrations. This way, it better equips the stakeholders to strategize interventions not only for yield improvement but most importantly enhance livelihoods for farmers. The study has further added value to the knowledge of litchi cultivation in Muzaffarpur regarding the spatial distribution and issues in production by the farmer. Therefore, further study should be based on long-term climate impact analyses and evaluation of the efficiency of government policies designed to assist litchi farming. This would be crucial for sustaining the economics of this agricultural sector

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while improving its profitability since farmers are given ample room to respond to environmental impacts through changing economic returns.

VII. CONCLUSION

The study focused on litchi cultivation in Muzaffarpur District, providing an almost exhaustive geographical analysis in terms of spatial distribution and factors that led to the production. The results showed that agro-climatic conditions within the region were surprisingly fertile alluvial soils and easy irrigation critical in maintaining high levels of production. The integrated pest management and irrigation systems in modern farming were responsible for better yields, while other regions with traditional practices had lesser productivity. This would denote the imperative of adopting technology to improve the production outcome. A GIS-based spatial analysis of concentrations in orchards may account for maximal gains in the given regions in terms of productivity. Besides, it showed the non-uniform farming practices that existed within the district, indicating that targeted inputs could raise litchi production in the low-producing areas by quite substantial margins. The implications of the results are huge for both the policymakers and the farmers. Policymakers would need to focus on expanding agricultural support services, particularly in orchard-growth districts where orchards are not performing up to the mark. Access to more modern irrigation systems, training in high-tech farming techniques, and offering subsidies for sowing high-yielding litchi varieties are very important steps toward ensuring these sustainable agriculture practices. Most importantly, the involvement of spatial analysis in agricultural planning can help identify regions that need urgent attention due to critical changes in environmental conditions, primarily because of the increased concern regarding climate in crop productivity.

Although the study has contributed to this endeavour, it has its limitations, such as relying on secondary data sources which might have skipped up-to-date agricultural trends or localized challenges. The lack of availability of primary data at the field level helps restrict the socioeconomic factors more intricately influencing production. Market-related dynamics like price volatility and access to markets are not debated in detail, which are very important critical determinants affecting the choice of farmers and an overall profit from farming. Future studies should be done to collect primary data through field observations and farmer surveys to make the explanation more explicit about farming practices, socio-economic conditions, and market access. The long-term impacts of climate change on the litchi crops' yields would have to be carefully tracked for formulating adaptation strategies to preserve yield. Future studies may also investigate whether and in what way government policies, such as subsidies, and training on agribusiness, aim to enhance agricultural outputs. Further analyses into the value chain, specifically pricing mechanisms, would further contribute toward profitability for smallholder farmers in Muzaffarpur. Addressing the gaps in research and working with the basis of these findings will help to devise future interventions better in a way that Litchi cultivation should be sustainably grown and become important for the agricultural and economic development of this region.

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