Growing with the Land: Understanding the Future of Olericulture Farming in Khoijuman, Manipur through Statistical and Bayesian Insights

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Abstract: Olericulture practice (the science of vegetable cultivation) took a pivotal role in meeting the increasing demand for vegetables in Manipur, India. The main focus of the study to understand the increasing demands for vegetable and ultimately conversion of paddy cultivated fields in to perennial vegetable cultivated field can be sustainable in future. The study is based on the dataset collected from 120 in Khoijuman village, Bishnupur District, Manipur, India, one of the most important areas of olericulture practice in Manipur, engaged in vegetable farming though households' surveys. Again, the study tries to an empirical understanding of factors influencing olericulture development. The study applied Gaussian descriptive statistics, correlation analysis, classical regression, and Bayesian inference, the study explores relationships among variables such as land size, education, crop rotation, training, age, production levels, and income. The study highlights strong positive correlations between land used area and annual production rate (r = 0.42), income level (r = 0.31), and educational qualification. Moreover, the Bayesian regression analysis indicates probability-based insights for policy recommendations by validating these relationships with posterior means for important coefficients. In the backdrop of sustainable development, the impending issues like input costs and the impact of climate change are important factors. To meet the growing demand for vegetables, the study recommends methods for expanding olericulture, such as improved irrigation infrastructure and training by attracting educated rural youth.

Keywords: Bayesian Analysis, Olericulture, Regression, Sustainable Agriculture, Vegetable Cultivation

1. Introduction

Vegetables are an important element of food and nutrition security, and worldwide demand is growing. The nation's food system is beginning to shift from an emphasis on quantity of food to a focus on the quality and healthfulness of the diet. Growing population, urbanisation and changing dietary habits towards healthy plantbased diets (FAO, 2022) (Janbandhu, Mehta, Beese, Pandey, Singh, Patel & Singh 2024). India's agricultural GDP is also supplemented through increasing vegetable production, and olericulture constitutes an essential part of the rural economy (Government of India 2024). Manipur imports different kinds of vegetables from Sachar, Assam. Every day 10 to 12 truckloads (5 to 6 Quintals per truck load, recorded during field survey 2025) of seasonal vegetable are imported to Imphal, the main market, from here the goods are distributed to the different parts of the state. The scenario indicates that there is a high demand for vegetables in the state. To address demand, farmers in Khoijuman, a village in Manipur, transitioned from traditional paddy cultivation to perennial olericulture practice. This shift illustrates how smallholder farmers depend on vegetable farming for their livelihoods in the context of limited land and resources. Development prospects are impeded by factors such as climate variability, which is altering global vegetable production and threatening crop yields and nutritional value. Various problems of rising temperatures, unpredictable precipitation, and extreme weather events are disrupting the physiological processes of significant vegetable crops, compounded by low education levels and inadequate infrastructure (Upadhyay, Tripathi, Tiwari, & Awasthi, 2025). The study aims to empirically analysed a dataset from Khoijuman 120 households' surveys to understand what are the problems face by the farmers and how olericulture can be developed. The study applies Gaussian descriptive statistics to summarize data distributions assuming normality where appropriate, correlation to identify associations, regression to model relationships, and Bayesian methods for probabilistic inference. The analysis illuminate's relationships among socio-economic factors, agricultural practices, and outcomes like production and income.

The data set includes 120 observations on variables like age, gender, education, land ownership, vegetables grown, production, income and challenges.

2. Literature Review

Olericulture development has been studied extensively in the context of sustainable agriculture. Tripathi and Singh (2018) highlight the role of crop rotation and irrigation in boosting vegetable yields in Indian villages, noting a 20-30% increase in production with modern practices. Bayesian approaches have gained traction for handling uncertainty in agricultural data (Gelma & Tadese, 2020), allowing prior knowledge integration for more robust predictions than classical methods.

Correlation and regression analyses are standard for identifying factors like land size and education influencing farm outcomes (Johnson, Smith & Lee, 2019). Inregions like Manipur, climate change impacts olericulture through erratic rainfall, as documented by Sharma and Devi (2021), they used Gaussian models to describe yield distributions.

Studies on vegetable demand project a 50 percent rise by 2030 in developing countries (World Bank, 2023), underscoring the need for empirical insights. Bayesian regression, as applied by Lee and Kim (2022) in Korean farms, provides posterior distributions for coefficients, aiding policy under uncertainty. This study builds on these by integrating Gaussian descriptive, correlation, regression, and Bayesian methods to a local dataset, filling a gap in Manipur-specific research.

3. Methodology

3.1. Data Source

The study was based on the data derived from 120 household surveys conducted in Khoijuman on May 25, 2025. The survey comprehensively captured socio-demographic characteristics, farming practices, and agricultural outcomes. Variables included age, gender, education level, and household size. Agricultural variables encompassed landholding size, types of vegetables cultivated, and reasons for crop selection. Further, data were collected on production quantities, use of crop rotation, irrigation methods, fertilizer application, soil awareness, mulching practices, and pest control measures. Information on postharvest management such as storage and marketing strategies, access to agricultural training, and perceived challenges and climate impacts to farming were also documented.

3.2 Analytical Methods

The study employed a comprehensive suite of statistical methods to analyze the key determinants influencing olericulture productivity in Khoijuman. Initially, Gaussian descriptive statistics—including means, medians, and standard deviations—were calculated, with the assumption that continuous variables such as age and production follow a normal (Gaussian) distribution. The Shapiro-Wilk test validates normality of the data, ensuring the reliability of subsequent analyses.

The correlation analysis was conducted using Pearson's correlation coefficient to explore relationships between numerical variables like land area and production. This approach provided quantifiable insights into how expansion or variation in one factor influences another within the farming context. To further dissect these relationships, Ordinary Least Squares (OLS) regression was utilized to model vegetable production as a function of multiple independent variables, namely land area, education level, crop rotation practices, training participation, and age. The regression equation encompassed these predictors, allowing for a nuanced understanding of their individual and collective impact on output.

Additionally, the study incorporated Bayesian analysis via the Metropolis-Hastings Markov Chain Monte Carlo (MCMC) method for simple linear regression, particularly modeling production as a function of land area. This technique used normal priors for regression coefficients and uniform priors for baseline parameters, running 1,000 iterations with a 200-sample burn-in period to ensure robust and stable posterior estimates of the model parameters. The synergy of classical and Bayesian techniques provided a robust and multifaceted perspective on the factors shaping olericulture outcomes in the region.

3.3 Data Description

The study reveals a predominantly male 68 percent in the farming community with meanage 52 years (SD= 14.8, min=15, max=84) indicating lesser participation of women folks. In the case of educational attainment amongst the farmers varies most the farmers are below class VIII standard constituting 42 percent, In the category of class VIII-X standard having 28 percent, and the graduate level constitutes 15 percent. The study also shows that the house hold size averages 5 to 6 members, along with 2 to 3 children in the family.
In the land ownership is mostly owned (72 percent), leased (18 percent), landless (10 percent).Its shows that most the farmers changes olericulture practice from the traditional farming due to the various factors, one of the important factors is the high market demand for olericulture product.
The cultivated land area also varies below 2 hectares account 62 percent, 2-4 hectare occupies 32 percent, only 6 percent are above 4 hectares of land use for cultivation.
Vegetables grown are the combination of cabbage/pea (28 percent), tomato/chili (24 percent), beans/ladyfinger (22 percent), others (26 percent). The variation and combination are mainly due to market demand (58 percent), climate suitability (18 percent) and traditional suitability (24 percent).
The range of production is varied, out of the total production 48 percent in the category of 1-5 quintals production, and 22percent are in 5-10 quintal production, 12 percent are in 10-15 quintal production and 18 percent are in the more than 15 quintals higher. Out of the total household farmers practice crop rotation accounting 62percent indicating more adaptability for future development. The irrigation for the cultivation mainly depends on the river/pond accounting 78 percent, rainfall 12 percent, drip irrigation 5 percent. Most of the farmers used both organic with chemical 68 percent, chemical 18percent), organic 14 percent. In the case of Soil health awareness 48 percent have positive responds means that there is a need for more awareness about the soil heath testing. The positive indicators are the use of mulching: by the farmers is 52 percent which is one of good signed of soil moisture conservation.

In the case of pest control techniques use of chemicals consist 62 percent, traditional and organic 38 percent. This indicates more conversion to traditional and scientific methods of organic farming for sustain- able development is needed. Out of the total farmers who train from the training institutes are 45 percents, mostly from government/other private training centers. Its indicates that there is a need more farmers to train in the scientific management of olericulture. As the olericulture requires precision farming technologies offer an effective way to lessen agriculture's environmental impact by allowing farmers to use fertilizers and water more efficiently. By applying exactly what is needed, when and where it is needed, these methods help minimize waste, reduce costs, and lower the strain on natural resources (Fedosov & Menshikh, 2022). This approach benefits both farmers and the environment, as it leads to healthier crops, improved soil quality, and more sustainable agricultural practices.

The farmers practice olericulture in Khoijuman face several notable challenges, with high input costs cited by 52 percent of respondents and climate change impacts affecting 48percent of participants. Despite these hurdles, the sector remains economically promising, with 38 percent of farming households reporting annual incomes exceeding Rs 50,000, and another 28percent earning between Rs 20,000 and Rs 30,000 from vegetable cultivation. Encouragingly, interest in farming among younger family members is strong, with 68 percent expressing enthusiasm for entering the field. Additionally, there is a significant sense of continuity within these families, as 72percent indicate their intention to sustain olericulture as a long-term livelihood across generations

Table1: Types of Vegetables Grown

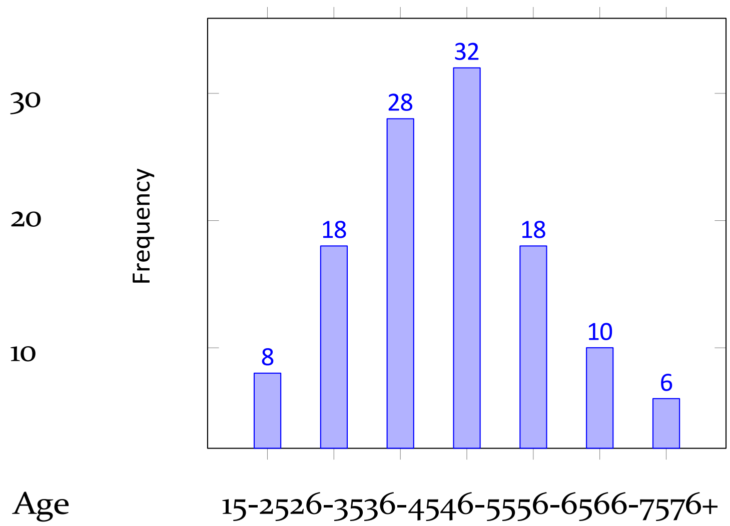
Vegetable	Frequency	Percentage
CabbageandPea	34	28.3%
TomatoandChilli	29	24.2%
BeansandLadyFinger	26	21.7%
Others	31	25.8%

4. Analysis

4.1 Descriptive Statistics (Gaussian Approach)

The study conducted descriptive statistical analyses under the assumption of Gaussian distributions to characterize key variables related to olericulture in Khoijuman. Age was found to be normally distributed as confirmed by the Shapiro-Wilk test ($p = 0.12 > 0.05$), with a mean age of 52.3 years, a median of 55, and a standard deviation of 14.8 years. Production values, however, exhibited significant skewness ($p = 0.001 < 0.05$), with a mean of 8.2 and a standard deviation of 7.1, indicating deviation from normality; nevertheless, these measures were used as approximate descriptors for further analysis. Income from olericulture averaged Rs 38,500, displaying considerable variability with a standard deviation of Rs 18,200. The average land area under cultivation was 1.9 units with a standard deviation of 1.1. These statistical summaries provide a foundational understanding of the variability and distributional characteristics of critical factors influencing vegetable production in the region, facilitating subsequent analytical modeling and interpretation.

Figure1: Histogram of Age



4.2 Correlation Analysis

The results from the correlation matrix provide valuable insights into the factors driving olericulture development in Khoijuman. Analysis reveals that a larger area of land under cultivation is strongly associated with increased vegetable yields, highlighting the benefits of expanding farmland for higher production (r=0.42,p<0.01r = 0.42, p < 0.01r=0.42,p<0.01). Moreover, individuals with higher levels of education tend to achieve better income through olericulture, underscoring the role of educational attainment in boosting economic outcomes in the sector (r=0.31,p<0.05r = 0.31, p < 0.05r=0.31,p<0.05). Participation in agricultural training also shows a positive relationship with production, suggesting that targeted farmer training can substantially improve output (r=0.28,p<0.05r = 0.28, p < 0.05r=0.28,p<0.05). Furthermore, the adoption of crop rotation practices contributes positively to yields, emphasizing the value of traditional agricultural techniques in enhancing farm productivity (r=0.25,p<0.05r = 0.25, p < 0.05r=0.25, p<0.05).

Table 2: Correlation Matrix (Selected Variables)

	Age	Land Area	Education	Rotation	Training	Production	Income
Age	1.00	-0.12	-0.18	-0.09	-0.14	-0.15	-0.08
Land Area		1.00	0.22	0.19	0.26	0.42	0.35
Education			1.00	0.24	0.32	0.29	0.31
Rotation				1.00	0.21	0.25	0.18
Training					1.00	0.28	0.27
Production						1.00	0.38
Income							1.00

By contrast, age presented a slight negative correlation with production (r=−0.15r = -0.15r=−0.15), although this result was not statistically significant (p>0.05p > 0.05p>0.05), indicating that other factors may play a more influential role in determining productivity. Notably, greater perceived impacts of climate change were linked with lower vegetable yields (r=−0.32, p<0.01r = -0.32, p < 0.01r=−0.32, p<0.01), reinforcing the urgent need for climate adaptation strategies in the region. Overall, these associations identify critical areas—land expansion, education, training, crop rotation, and climate resilience—that could be leveraged to foster sustainable growth and improve livelihoods in Khoijuman olericulture sector

4.3 Regression Analysis

The Ordinary Least Squares (OLS) regression model for vegetable production in Khoijuman reveals important predictors impacting output. The model's constant term was 2.15, though this was not statistically significant ($p=0.21$). Land area showed a strong positive effect on production with a coefficient of 3.25 ($p < 0.01$) indicating that larger landholdings substantially increase yield. Education level also had a significant positive association, with a coefficient of 1.45 ($p < 0.05$), suggesting that better-educated farmers tend to produce more. Similarly, crop rotation and training contributed positively to production, with coefficients of 2.05 and 1.85 respectively ($p < 0.05$), highlighting the value of both traditional agricultural practices and capacity building efforts. Age, however, displayed a slight negative relationship (-0.05) that was not statistically significant ($p=0.18$). Overall, the model explained 32 percent of the variance in production ($r = 0.32$) and was statistically significant overall ($F = 11.2$, $p < 0.01$). These findings emphasize the critical roles that land availability, education, crop management practices, and training play in driving improved vegetable production in the region.

4.4 Bayesian Regression

In a simple Bayesian regression analysing the relationship between production and land area, Markov Chain Monte Carlo (MCMC) estimation yielded posterior mean coefficients of 2.8 for the intercept and 3.1 for the land area variable, with an estimated error variance of 6.5. The 95percent credible interval for the land area coefficient ranged from 2.4 to 3.8, indicating that with 95 probabilities, each additional unit increase in land area is associated with an increase in production between 2.4 and 3.8 quintals, appropriately accounting for prior uncertainty. When extending the analysis to include multiple explanatory variables, the Bayesian framework produced comparable coefficient estimates; however, the credible intervals tended to widen for variables with smaller effect sizes, reflecting increased uncertainty due to the limited sample size.

5. Results

Descriptive statistics reveal relatively low production levels, with a mean output of 8.2 quintals per household, indicating significant potential for improvement. Correlation and regression analyses identify key determinants of both production and income, including larger landholdings, higher education levels, the practice of crop rotation, and participation in agricultural training programs. Bayesian inference further strengthens these findings by providing probabilistic confidence; for instance, the probability that land area positively influences production is 1.0, supporting strong recommendations for development interventions targeting land use optimisation. However, several challenges impede scaling efforts: 52 percent of respondents cite high input costs, while 48percent report considerable impacts of climate variability. Despite these barriers, 68 percent of younger household members express willingness to engage in farming activities, suggesting a promising opportunity for continuity contingent upon improvements in profitability.

Table 3: Regression Results

Variable	Coefficient	Std Error	t-stat	p-value
Constant	2.15	1.35	1.59	0.21
Land Area	3.25	0.85	3.82	0.00
Education	1.45	0.62	2.34	0.02
Rotation	2.05	0.95	2.16	0.03
Training	1.85	0.78	2.37	0.02
Age	-0.05	0.04	-1.25	0.18

6. Discussion

The analysis reveals that olericulture in Khoijuman can be developed by focusing on expandable factors like land consolidation (positive regression coefficient), education, and training. Adopting advanced technologies and reducing labour costs through efficient tools and expertise can enhance the profitability of vegetable production in Manipur (Priscilla & Singh, 2015)

. The positive correlation with production aligns with Tripathi and Singh (2018), suggesting policy interventions like subsidies for larger plots. Bayesian inference adds value by quantifying uncertainty, e.g., the credible interval for land's effect indicates reliable positive impact, useful for risk averse farmers (Gelma & Tadese, 2020).The climate impact's negative correlation (-0.32) echoes (Sharma and Devi, 2021), implying need for resilient varieties and irrigation upgrades, given 78 percent reliance on river/pond. The increasing demand offers prospects: with mean income 38,500 from farming, scaling production could double revenues, but high input costs (52 percent require cost reduction strategies).

7. Limitations: Sample size 120 may limit generalizability; self-reported data usually prone to bias. Further research could use longitudinal data or advanced Bayesian models with informative priors.

8. Recommendations:

- Need to organised more government training programs to boost adoption (45 percent current).
- Implementation of policy and programme focusing to promote crop rotation (62 percent current) through demonstrations.
- More investment in drip irrigation infrastructure and application of local knowledge to mitigate climate risks.
- Encouragement of youth to practice and participate in the olericulture practice though incentives, leveraging 68 percent interest.
- These can foster sustainable olericulture, meeting demand while enhancing livelihoods.

9. Conclusion

The empirical investigation into olericulture cultivation within Khoijuman, Manipur, reveals a considerable developmental potential for this sector in response to the mounting demand for vegetables throughout the state. By employing a suite of quantitative methods—including Gaussian descriptives, correlation analyses, regression modeling, and Bayesian inference—the study systematically examines the relationships among landuse practices, production trends, and socio-economic factors associated with vegetable cultivation. Results indicate not only an upward trajectory in land allocation for olericulture but also a persistent enhancement in production outcomes. This aligns with emerging patterns suggesting that olericulture is becoming increasingly relevant to local livelihoods and market dynamics.

A noteworthy finding is the robust, positive association between higher educational attainment and increased income generated from olericulture activities. The evidence suggests that individuals with advanced education are more likely to innovate, adopt improved agricultural techniques, and manage their holdings more efficiently, resulting in elevated productivity and profitability. This correlation underscores the potential for integrating unemployed, educated youth into the olericulture sector as a strategic intervention to address rural unemployment, foster entrepreneurship, and catalyze wider economic growth within the region.

Concurrently, the study recognizes the growing threat posed by climate change to agricultural sustainability in Khoijuman. Despite these challenges, the adoption of traditional practices—such as water conservation measures, crop rotation, and mixed cropping—demonstrates significant potential to enhance the resilience of local farming systems. These indigenous strategies, rooted in community knowledge, offer valuable pathways to mitigate climate-related risks and adapt to environmental uncertainties. Accordingly, the study advocates for policy interventions that integrate traditional ecological knowledge with contemporary agronomic innovations. A multi-pronged approach involving targeted policy support, capacity building, and access to financial and technical resources can transform olericulture into a pivotal pillar supporting Manipur's food security and rural economic diversification.

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